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A Biological Investigation of the Fishes of Lake Chautauqua, Illinois

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DEPARTMENT OF REGISTRATION AND EDUCATION
NATURAL HISTORY SURVEY DIVISION
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This report is printed by authority of the State of Illinois, IRS Ch. 127, Par. 58.12. It is a contribution from the Section of Aquatic Biology of the Illinois Natural History Survey.

The fishing investigation reported in this paper was done as a cooperative project of the Illinois Natural History Survey, the Illinois Department of Conservation, and the U. S. Fish and Wildlife Service. Some funds from D-J Project F-14-R were used in preparing the manuscript. William C. Starrett, Aquatic Biologist with the Natural History Survey, was in charge of the investigation. Arnold W. Fritz, Fisheries Biologist with the Illinois Department of Conservation, was assigned to the Natural History Survey in 1956.

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A Biological Investigation of the Fishes of Lake Chautauqua, Illinois

WILLIAM C. STARRETT
ARNOLD W. FRITZ

THIS PAPER is based on a 10-year biological investigation of the fishes of Lake Chautauqua, a lateral-levee reservoir of approximately 3,500 acres located near Havana, in Mason County, Illinois. The reservoir, a floodplain lake adjacent to the Illinois River, is federal property managed by the U. S. Fish and Wildlife Service as a refuge for migratory waterfowl.

The biology of the Illinois River and its floodplain lakes was of considerable interest to early biologists working in Illinois (Bennett 1958:165–166). Some of their studies, and those reported by Thompson (1941:209–210), indicate that the floodplain lakes contained an abundance of fish foods and supported large standing crops of fish.

Drainage of Illinois River floodplain areas was begun before 1900. By 1929, about 200,000 acres of the floodplain had been drained and leveed off from the river for agricultural purposes (Mulvihill & Cornish 1929:36). Forbes & Richardson (1919:153) pointed out that the decline in the fishery of the Illinois River in 1908–1913 coincided with the increased drainage program of the period.

In 1947, the U. S. Fish and Wildlife Service recommended that the Corps of Engineers, U. S. Army, consider the possibility of acquiring five drainage and levee districts totaling 27,200 acres (formerly Illinois River floodplain lakes) for flood control reservoirs; the areas were to be used as public hunting and fishing grounds except in times of great floods (Jenkins & Walraven 1950: 29). This recommendation stimulated a renewed interest in floodplain lakes among conservationists in Illinois. As a result of this interest, representatives of the Illinois Natural History Survey, the Illinois Department of Conservation, and the U. S. Fish and Wildlife Service met in December, 1949, for the purpose of organizing a cooperative fishery research investigation at Lake Chautauqua. The objectives of the investigation, which was started in April, 1950 (Starrett & McNeil 1952:4), were "(1) to determine the values of the sport and commercial fisheries of an Illinois River bottomland lake; (2) to develop management practices that would increase the yield of sport and commercial fishes; (3) to study the biology of the fishes present; and (4) to estimate the dynamics of the fish population."

The economics of the fishery were discussed in an earlier paper (Starrett 1958). The calculated fishery value of the lake in 1954 was $103,294.28, or $29 per acre.

In 1950 and 1951, the Illinois Department of Conservation, through news releases and radio programs, informed anglers of the fishing possibilities at Lake Chautauqua. In 1952, a report was released on the sport fishery, based upon data from the previous 2 years of creel censusing (Starrett & McNeil 1952). This report stated that most anglers lacked knowledge on how to fish the lake and described successful methods of fishing, with the purpose of increasing the hook-and-line yield. Another effort to increase the hook-and-line yield was made in June, 1951, when a fishing "college" for anglers was conducted at the lake. Liberalized bass fishing regulations (continuous open

Frontispiece.—Aerial view showing part of Lake Chautauqua, a small section of the Illinois River, and a series of agricultural fields that were leveed off from the river in about 1920. Some of these fields were formerly covered by Thompson Lake, once a renowned fishing lake.

season and no size limits) were followed at Lake Chautauqua prior to their inclusion in the Illinois code. The liberalized regulations permitted anglers to remove more bass than was possible under the former restrictions "without measurably reducing the population of these fish" (Starrett 1955).

Crappies were taken in nets and seines by commercial fishermen and removed from the lake on an experimental basis in the period 1951–1954. This period was prior to enactment of the Illinois law that permitted the harvesting of crappies by commercial fishermen. Most of the crappies removed in the 1951–1954 period were taken in the 10 months beginning with September, 1951. The removal of crappies had no apparent effect upon the sport fishing (Starrett & Fritz 1957:14).

The yield of commercial fishes was greatly increased by permitting fishermen to use drag seines (beginning in 1951) and roundup fishing with wing nets (beginning in 1952). Formerly, fishermen had been allowed to set individual wing nets only.

In this paper, we are concerned largely with the various kinds of fishes and their relative abundance in Lake Chautauqua, their biology, the dynamics of their populations, and the effects of commerical fishing on them. We conducted some limnological investigations concurrently with the fishery research program. In 1950, engineers of the Illinois Water Survey made a sedimentation survey (Stall & Melsted 1951). Jackson (1954) collected a series of water samples for which dissolved oxygen determinations and water temperatures were recorded. Jackson & Starrett (1959) measured turbidities under various conditions. Paloumpis & Starrett (1960) made bottom fauna, chemical, and bacteriological studies.

We are indebted to a number of persons for their assistance during this investigation. The investigation was made possible through the efforts of Dr. George W. Bennett and Dr. Harlow B. Mills of the Illinois Natural History Survey and Mr. Sam A. Parr of the Illinois Department of Conservation. Dr. Bennett gave guidance and encouragement during the investigation and later made helpful suggestions in the preparation of the manuscript. Messrs. Leslie L. Layton and Larry Bohm, supported under the D-J Project F-14-R for Illinois, gave aid in preparing the manuscript, and Dr. Donald F. Hansen of the Illinois Natural History Survey made many helpful suggestions and criticisms. Messrs. Louis Ellebrecht (now deceased), Lyle Schoonover, Robert Abney, C. Arthur Hughlett, and K. Duane Norman of the U. S. Fish and Wildlife Service extended us excellent cooperation while they were serving as refuge managers of the Chautauqua National Wildlife Refuge. Messrs. William Nuess, Walter Hart, Robert Crompton, John Schilling, and Howard Crum, present or former employees of the Illinois Natural History Survey, were helpful with field work. Mr. Frank C. Bellrose of the Illinois Natural History Survey was very helpful in giving advice and information on problems relating to waterfowl, aquatic plants, and the history of Lake Chautauqua. The following boat livery operators cooperated helpfully: Messrs. James Bridgeman (now deceased), John Lane, Paul Riddle, and Burt Sperry. All of the commercial fishermen who participated in our program were fully cooperative, and without their efforts the program would have failed. Messrs. P. L. McNeil and William Bain gave assistance while assigned to the senior author by the Illinois Department of Conservation. Dr. Milton B. Trautman of Ohio State University and Dr. Reeve M. Bailey of the University of Michigan identified several species of fish. Mr. James S. Ayars of the Illinois Natural History Survey edited the manuscript. Mr. William E. Clark and Mr. Wilmer D. Zehr, as Survey staff members, made the photographs; Mrs. Anne R. Dreyfuss, Miss Marguerite M. Verley, and Miss Artha

Sue Loy made the graphs; Mrs. Blanche P. Young read the proof and dummied the pages. Miss Loy drew the maps (Fig. 4 and 5) from original maps prepared by the junior author.

Financial support of this study was given by the Illinois Natural History Survey and the Illinois Department of Conservation.

MATERIALS AND METHODS

The fishery program on which this study is based included 10 growing seasons at Lake Chautauqua. The field work was started on April 15, 1950, and was concluded on October 10, 1959.

Collection of Data

During the 10 years of field work, various types of fishery data were collected by our staff. Some of the data were collected from commercial fishermen, some from the owners of boat liveries, and some from the Illinois Department of Conservation. Most of the data were obtained through creel censusing by the staff or cooperators at boat liveries, through wing-net fishing and seining by commercial fishermen, and through minnow seining and test-netting by the staff.

Commercial fishing on Lake Chautauqua was done by local fishermen who used wing nets, trotlines, and drag seines. These fishing devices have been described by Starrett & Barnickol (1955).

Creel Censusing.—A creel census was conducted at all Lake Chautauqua boat liveries in 1950–1954 (Starrett 1958:41–43) in the manner described by Starrett & McNeil (1952:5–6). Burt Sperry has continued to make creel censuses at his boat livery. Sperry's catch data are considered to represent about one-half of the total sport yield for the lake; this figure was determined by dividing the catch data recorded by Sperry for 1953 and 1954 by the catch data for the entire lake in these years.

Trotline Fishing by Sportsmen.—Trotline fishing, limited to 50 hooks per person, was permitted at Lake Chautauqua after 1953. A complete record of trotline fishing by sportsmen at the lake was kept in 1954 (Starrett 1958:42, 44). Thereafter, a record of the trotline catch by sportsmen was maintained by Sperry at his boat livery.

Sperry's records of trotline fishing and his creel census data were extrapolated each year after 1954 to give estimates of the annual yield of the total sport fishery at Lake Chautauqua.

Commercial Wing-Net Fishing.—Commercial fishing with wing nets of legal mesh (1½-inch-square mesh or

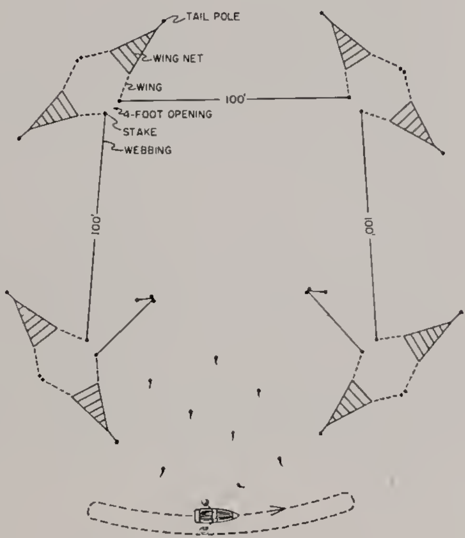


Fig. 1.—Diagram of a typical commercial roundup set with wing nets as used on Lake Chautauqua. The fishing crew consists of two men, who drive fish into the corral. When the fishermen believe sufficient numbers of fish are in the corral, they shut off the open end with lead netting and drive the fish into the wing nets set in the corners of the corral.

larger) was permitted on Lake Chautauqua in each year of field work from February or March through September. An effective method of commercial wing-net fishing (roundup) for bigmouth buffalo was developed and used by commercial fishermen in 1952 and afterward (Fig. 1 and 2). The commercial fishermen using wing nets were required by the U. S. Fish and Wildlife

Service to furnish monthly catch reports. In the years 1950-1959, 1,376,770 pounds of fish were removed from the lake by wing-net fishermen, or an average of 137,677 pounds per year. During the fishing months of 1951-1954, wing-net fishermen were required to deliver all crappies and white bass caught by them to a live crib located on the lake near the Natural History Survey Laboratory. Some of the white bass were tagged by our staff and returned to the lake. The other fish were given to the Illinois Department of Conservation for disposition.

COMMERCIAL TROTLINE FISHING.—Most of the commercial trotline fishing at Lake Chautauqua was done illegally. Estimated weights of channel catfish removed illegally and sold by trotline fishermen were obtained by us through contacts at local fish markets. The illegal removal of catfish by trotline fishermen in 1950-1959 was estimated to be 67,500 pounds.

COMMERCIAL SEINING.—Each September, 1951-1958, a program of commercial seining was conducted in the lake. No seining had been allowed before 1951, and there has been no seining since 1958. The drag seines used in the program were operated by local commercial fishermen who had previously signed a special seining contract with the Illinois Natural History Survey and the Illinois Department of Conservation. The fishermen were under bond to carry out the stipulations of the contract under the supervision of the senior author. The lengths of the seines ranged from 500 to 1,450 yards; the bags of these seines were of 1½-inch-square mesh and the remainder of 3-inch-square mesh or larger. During the 8 years of September seining, 348 hauls were made; the cumulative total was equivalent to 310,210 yards of seine. Fishermen furnished us with daily weight receipts covering the sales of their fish. Weights of gizzard shad and

Fig. 2.—Commercial wing nets set for roundup fishing. This method of fishing proved to be an efficient way to catch bigmouth buffalo during periods of low water at Lake Chautauqua.

garfishes removed and discarded were estimated by fishermen and the senior author. On most hauls, we made counts of the various species of sport fishes caught. In the 1951–1958 period, seiners removed 1,271,854 pounds of fish.

TEST-NET FISHING.—In late September and early October of each year, 1950–1959, test-netting with 1-inch-square-mesh wing nets with leads was done by our staff at 11 or 12 sites on the lake. The number of net-days of fishing in a fall varied from 47 to 94. During the 10-year period, 14,373 fish were caught in the 1-inch-square-mesh wing nets.

MINNOW SEINING.—In the years 1950–1959, 196 minnow seine hauls were made by our staff at various places on the lake. Most of the hauls were made with either a 20- or a 30-foot *Common Sense* minnow seine (one-eighth-inch mesh). In the minnow seine collections, 23,527 fish were taken.

USE OF ROTENONE.—Each summer, 1952–1959, one or two small areas (about one-eighth to one-fourth acre each) were treated by our staff with either powdered or emulsifiable rotenone. An attempt was made to collect with dip nets all of the fish that surfaced in the treated areas. The fish collected were identified, counted, and measured in the laboratory. In the rotenone operations, 1,484 fish were collected.

ELECTROFISHING.—A boom shocking device (230-volt a-c generator with three electrodes) was used by our staff to collect fish in 1959; 509 fish were collected with this shocker.

DEPARTMENT OF CONSERVATION FISHING.—Each year of the study, large numbers of sport fishes were removed from the lake by Department of Conservation personnel for the stocking of other lakes and ponds. These fish were caught in 1-inch-square-mesh wing nets. Records of the numbers of these fish were maintained.

TAGGING.—Several thousand fish, principally crappies and white bass, were caught in test-netting or commercial fishing operations, tagged, and returned to Lake Chautauqua. Each of these fish was marked either on the opercular bone or dorsal spine (few white bass) with No. 3 monel strap tags. Tagging operations were confined to the fall and early spring months.

In September and October in the years 1950–1954, 4,295 crappies of 7 inches or longer, total length, were tagged and returned to the lake. Most of the marked crappies that were recaptured were caught by angling or by commercial wing-net fishing.

In the years 1951–1954, 605 white bass were caught in commercial seines and commercial wing nets, tagged, and returned to the lake. Most of the marked white bass that were recaptured were caught by angling and commercial wing-net fishing.

Classification of Fishes

In this study, we have followed the classification of fishes as used by Bailey (1956, 1960) or by Trautman (1957). Upon recommendation of Dr. Bailey (letter of November 4, 1964, to Dr. Philip W. Smith, Taxonomist, Illinois Natural History Survey), the spelling of the author name Lesueur (LeSueur formerly) is emended as it will appear in future editions of the list of fish names.

Most of the specimens collected were identified in the field. Representative specimens that could not be identified in the field were preserved for later determination by ourselves in the laboratory or were, in a few instances, submitted to Dr. Trautman or Dr. Bailey for identification. Specimens of the uncommon species of Lake Chautauqua fishes were deposited in the collections of the Illinois Natural History Survey, the Chicago Natural History Museum, or the Ohio State University Museum.

Measurements and Aging Materials

Length and weight data, and scales, spines, and opercular bones for aging fish, were obtained from fish collected at Lake Chautauqua by test-netting, commercial seining, wing netting, angling, and electrofishing. We measured the total lengths, rather than the standard lengths, of fish to the nearest 0.1 inch; we determined weights to the nearest 0.01 pound on Chatillon scales. During the investigation, we weighed and measured 52,214 fish and, in addition, measured 12,814 small fish.

Of the fish collected, we aged 23,812. For species other than carp and catfish, we used only scales in making age determinations. For carp, we used scales, opercular bones, and dorsal spines. For catfish, we used pectoral spines. In aging fish by the scale method, we used a Bausch & Lomb microprojector for magnification of the scales. Most of the scales and spines were collected in September or October, and we considered a summer of growth prior to September 1 as a full year of growth. In the tables that show lengths of fish of various ages, an age 2 fish has one annulus, but it has completed two summers of growth. For example, a fish spawned in May, 1954, is classified as a 2-year-old fish in September, 1955. We made back calculations from the scales of several species to determine the first year's growth.

In 1953 and 1954, we collected opercular bones and scale samples from 466 carp. We were unable to separate the many checks and false annuli from the true annuli on these carp scales. In some instances, scales collected from carp that we thought were 1-year-old fish showed as many as four possible annuli. Other workers also have experienced difficulties in the use of scales for determining the ages of carp (McConnell 1952:138; English 1952:530–531). The method of aging carp from opercular bones, described by McConnell (1952:141, 143) and English (1952:536–538), we attempted with the Lake Chautauqua material. The first and second annuli appeared to be quite distinct on the opercular bones; however, on fish of 3 years and older we could not ascertain the annuli with any certainty.

To further explore the problem of aging carp, we decided in 1957 to look for annuli on the dorsal spines. With this objective, we removed 263 dorsal spines from carp taken in the September commercial seine hauls of 1957 and 1958.

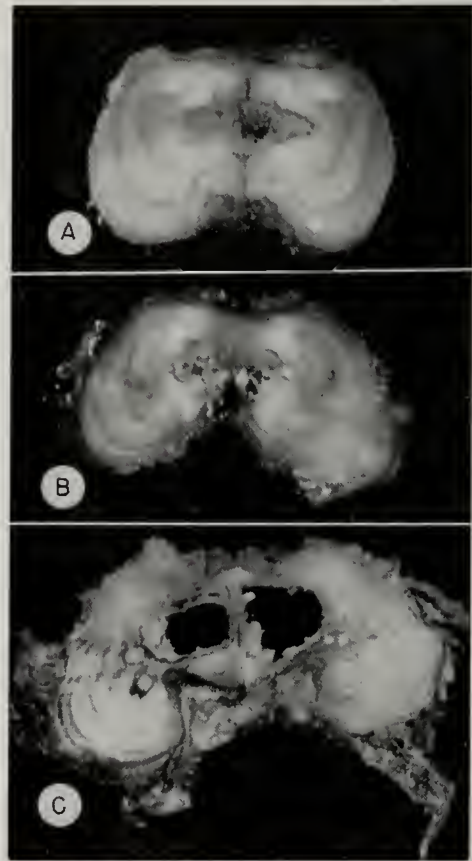


Fig. 3.—Magnified cross sections of carp spines collected at Lake Chautauqua. The cross sections show, **A**, two annuli, **B**, three annuli, and, **C**, six annuli.

After the spines were thoroughly dry, we cut four thin cross sections of each with a jeweler's saw. The first section in each instance included the base of the spine. We placed the sections from each spine in a petri dish containing water and examined them under a binocular dissecting microscope. The annuli appeared as translucent lines on the sections (Fig. 3). English (1952:536–538) found that sections of the dorsal spine were satisfactory for determining the age and growth of carp up to 2 years old but difficult to interpret on older fish; he reported that the opercle was more satisfactory for aging carp of various ages. We believe that for aging Lake Chautauqua carp the dorsal spine was better than the opercular bone. In examining the 263 dorsal spines, we disagreed on the agings of 10 fish. Those fish were not included in our age data of carp.

We aged catfish by counting the annuli on cross sections of pectoral spines. Following a method similar to the one described by Sneed (1951:176–177) we cut the cross sections through the articulating portions of the spines with a jeweler's saw. We then placed the cross sections in a petri dish containing water, examined them under a dissecting microscope, and counted the annuli in the cross sections.

Calculations

For some of the abundant species of fish in Lake Chautauqua, we calculated the relationship between length and weight, the average index of condition, and the growth index.

LENGTH-WEIGHT RELATIONSHIPS.—To calculate weights (Lagler 1956:164–165) for various species of Lake Chautauqua fishes, we used the least squares method. In calculating weights for species in which only a limited number of data on lengths and weights were available, we combined the data for all years. For most of the abundant species, we calculated length-weight relationships from data collected each year in the months of September and October. The yellow bass, however, was an exception since the data for this species were collected in the spring months, rather than in September and October.

The length-weight relationship data for the various species have been deposited with the Illinois Natural History Survey Library, Urbana, Illinois, and with the Midwest Inter-Library Center, 5721 Cottage Grove Avenue, Chicago 37, Illinois, and are available upon request from either library.

AVERAGE INDICES OF CONDITION, C.—Average fall indices of condition, C, were computed for eight abundant species in the lake. In computing C for the various species of fish, we used only length and weight data collected in September and early October, except that in 1954 we combined the November bluegill data with data for early fall.

First, we computed the index of condition (Thompson & Bennett 1939:17) for each one-half-inch length group of a given species by determining the value of C in the following formula

$$C = \frac{W\ 10{,}000}{L^3}$$

in which W is the mean weight and L the length for the group. Then we computed the C value for the species by calculating the average of the C values determined for the various one-half-inch length groups of the species.

The one-half-inch length groups for each species remained constant throughout the study. Ranges of total lengths used in calculating average C for the various species were as follows: freshwater drum, 10.5–16.5 inches; bigmouth buffalo, 16.0–25.5 inches; gizzard shad, 10.0–14.0 inches; carp, 16.5–24.5 inches; channel catfish, 14.5–19.5 inches; bluegill, 5.5–8.0 inches; black crappie, 7.0–10.5 inches; and white crappie, 7.5–10.5 inches.

GROWTH INDICES.—To show year-to-year changes in growth patterns of Lake Chautauqua fish, we calculated growth indices for each of six species. Each index figure was a measure of the deviation from an 8- or 10-year average of the total lengths for a given species. The growth indices provided measurements that could be used for comparing growth with population changes, fish removal, and varying water levels.

The method used for determining a growth index was based on a formula used by Purkett (1958:1–2):

$$\text{Factor} = \frac{1}{\text{Average length}} \times 100$$

Instead of using the average length for a year, as was done by Purkett, we used the sum of the average lengths for as many years as we had reliable data. In the following computation of the 1951 growth index for the drum, the data are from Table 1:

$$\text{Factor} = \frac{1}{38.8} \times 100 = 2.577$$

The factor is then applied to the appropriate figure in the column "Sum of Average Lengths for Given Year," Table 1. For 1951, this figure is 39.4.

$$39.4 \times 2.577 = 101.5$$

The growth index for the drum in 1951 is 101.5 − 100.0 or + 1.5, as shown in Table 1. This index indicates that the growth of the drum in 1951 was above the average for the species in the 1951–1958 period.

Our indices of growth were based on data from 12,432 fish.

STATISTICS.—The various statistical analyses used in this paper were based on formulas stated in the references given below. The analysis of variance (F) of the commercial seine haul data was done in accordance with formulas and procedures given by Simpson, Roe, & Lewontin (1960:272). Determinations of sample size relative to the number of seine hauls necessary to detect fluctuations in population were based on formulas presented by Paloumpis (1958:585). The t tests made in conjunction with the seine haul data were computed from formulas given by Starrett & Barnickol (1955:342–344). Correlation coefficients (r) used on the age and C factor data relative to water levels and population size were determined in accordance with the statistical methods of Snedecor (1946: 138–167).

Table 1.—Growth indices of freshwater drum in Lake Chautauqua, 1951–1958, and data used in computing them. Lengths given are in inches and are total, rather than standard, lengths of fish.

Year	*Average Length at Indicated Age in Given Year*			*Sum of Average Lengths for Given Year*	*Sum as Per Cent of 38.8 (Sum of Averages for All Ages and Years)*	*Growth Index*
	3 Years	4 Years	5 Years			
1951	11.8	13.1	14.5	39.4	101.5	+1.5
1952	11.8	12.9	14.5	39.2	101.0	+1.0
1953	11.4	12.8	14.3	38.5	99.2	−0.8
1954	11.7	13.0	14.1	38.8	100.0	0.0
1955	11.2	12.4	13.8	37.4	96.4	−3.6
1956	11.6	12.7	13.7	38.0	97.9	−2.1
1957	11.8	13.2	14.4	39.4	101.5	+1.5
1958	11.9	12.7	13.9	38.5	99.2	−0.8
Average	*11.7*	*12.9*	*14.2*	*38.8**		

*Sum of three averages to the left.

RECORDS OF WATER LEVELS.—Of the water level records used in this paper, those for Lake Chautauqua were furnished by the U. S. Fish and Wildlife Service. Records of Illinois River stages at Havana were obtained from the daily Upper Mississippi River Stage and Forecast Bulletins issued by the U. S. Department of Commerce.

FISH REMOVAL

One of the ultimate objectives of this study was to increase the removal of fishes from Lake Chautauqua and to determine if the increased removal had any effects upon the fish populations. The methods of fish removal are described in this section of the paper. The effects of increased fish removal are discussed in a later section.

Fishing pressure on Lake Chautauqua prior to 1951 was comparatively light. Commercial fishing on the lake up to that year was restricted by government regulations to the use of individual wing nets. However, some local fishermen engaged in illegal trotline fishing.

The reported legal commercial removal of fish in the period 1942–1949 ranged from a low of 21,912 pounds in 1947 to a high of 123,106 pounds in 1948. (Statistics prior to 1950 were furnished by the late Lou Ellebrecht of the U. S. Fish and Wildlife Service.) These weights do not include several thousand pounds of fish that were removed each year by fishermen using trotlines illegally. Sport fishing pressure was comparatively light on the lake both before and during the study period. In the period 1942–1949, we believe, the total annual removal of fish from the lake by all methods (legal and illegal) ranged from an estimated low of 12 pounds per acre to a high of 45 pounds per acre, with an average annual removal of 30 pounds per acre.

Removal by Commercial Wing-Net Fishing

In 1950 and 1951, the water levels at Lake Chautauqua were unusually favorable for commercial fishing with individual wing nets. The reported commercial wing-net catches at the lake in 1950 totaled 145,753 pounds and in 1951 they totaled 154,479 pounds, as shown in Table 2. These were the highest annual catches made with individual wing nets in the period 1942–1959; the annual wing-net catches given in Table 2 after 1951 included the roundup catches made with wing nets.

In 1952, two commercial fishermen began roundup fishing with wing nets and in August and September of that year caught 17,304 pounds of fish, of which buffalofishes accounted for 96.8 per cent (Table 3). In most years, very few fish were caught in the individual wing-net sets after the first of July.

Roundup fishing offered the commercial fishermen a method of catching fish with their wing nets during sum-

Table 2.—Estimated pounds of fish removed from Lake Chautauqua by various fishing devices and methods, 1950–1959.

Year	*Pole-and-Line*	*Trotline*		*Commercial Wing Net*	*Commercial Seine*	*Conservation Department (Wing Nets)*	*Total*
		Legal Angling	Illegal Commercial				
1950	17,717	. .	8,000	145,753	. . .	1,023	172,493
1951	22,180	196	8,000	154,479	84,685	1,537	271,077
1952	21,535	70	8,000	130,910	170,405	10,034	340,954
1953	9,414	50	8,000	156,403	86,426	163	260,456
1954	36,442	14,309	8,000	136,983	222,680		418,414
1955	23,023	11,033	8,000	148,427	149,407	2,850	342,740
1956	15,510	7,194	8,000	115,158	140,401	2,300	288,563
1957	21,252	7,575	8,000	124,723	266,055	3,200	430,805
1958	14,362	7,492	2,000	108,274	151,795	3,889	287,812
1959	12,988	5,395	1,500	155,660		2,274	177,817
Total	*194,423*	*53,314*	*67,500*	*1,376,770*	*1,271,854*	*27,270*	*2,991,131*

Table 3.—Catches made by commercial fishermen with individual wing nets and with wing nets used in the roundup method of fishing at Lake Chautauqua, 1952–1954.

Method of Fishing and Year	*Carp*		*Buffalofishes*		*Freshwater Drum*		*Channel Catfish*		*Other Species*		*Total*
	Pounds Caught	Per Cent of Catch	Pounds Caught	Per Cent of Catch	Pounds Caught	Per Cent of Catch	Pounds Caught	Per Cent of Catch	Pounds Caught	Per Cent of Catch	
1952											
Individual wing nets	30,188	26.6	62,179	54.7	4,263	3.8	3,576	3.1	13,400	11.8	113,606
Roundup wing nets	532	3.1	16,746	96.8	8	*	18	0.1	0	..	17,304
1953											
Individual wing nets	4,666	12.6	29,389	79.1	815	2.2	139	0.4	2,136	5.7	37,145
Roundup wing nets	5,473	4.6	110,857	93.0	2,285	1.9	603	0.5	40	*	119,258
1954											
Individual wing nets	2,194	16.9	7,754	59.9	447	3.4	203	1.6	2,353	18.2	12,951
Roundup wing nets	7,286	5.9	113,552	91.5	2,480	2.0	697	0.6	17	*	124,032

*Less than 0.1 per cent.

mer months when water levels were usually low and catches in individual wing nets were poor. In the years 1952–1954, catches from roundup sets and individual wing nets were recorded separately. A summary of these separated catch data is presented in Table 3. In 1953 and 1954, the individual wing-net catches were quite poor compared with those made in the 3 previous years (Tables 2 and 3). The roundup method of fishing produced a relatively high catch during periods in which the catch usually was poor with individual wing nets. The catch data in Table 3 clearly indicate the selectivity of the roundup method for buffalofishes. The combined catch of both methods of wing-net fishing in the years 1950–1959 amounted to 1,376,770 pounds. Without the adoption of roundup fishing, the wing-net catch probably would have been less than one-half of this amount. We were unable to obtain accurate data on the catch per net day because of irregularity in the raising of nets by the fishermen.

Removal by Commercial Seining

Commercial seining was done each year in September, 1951–1958. The effort expended in seining is shown in Table 4.

Table 4.—Number of completed commercial seine hauls, yards of seine used (cumulative yardage), and number of seine crews fishing in September at Lake Chautauqua, 1951–1958.

Year	*Number of Hauls*	*Yards of Seine (Cumulative)*	*Number of Seine Crews*
1951	13	14,200	3
1952	24	23,400	4
1953	47	34,500	4
1954	57	49,650	6
1955	66	56,250	6
1956	50	46,C80	4
1957	43	42,680	5
1958	48	43,450	5
Total	*348*	*310,210*	*11*°

°Number of seine crews that fished during program.

In most years, 1951–1958, the take of fish with seines was about equal to the catch by all other methods combined (Table 2). By fishing the lake with seines, fishermen removed fairly large poundages of gizzard shad, freshwater drum, and channel catfish that would not have been taken with wing nets. The yield from seining amounted to 42.5 per cent of the weight of fish removed by all methods and devices in the 1950–1959 period.

Removal by Angling

The estimated weight of fish removed by anglers or pole-and-line fishermen in the period 1950–1959 is presented in Table 2. After 1950, anglers' catches amounted to less than 10 per cent of the fish removed from the lake by other methods and devices of fishing. The sport fish removal by angling during the period of the study averaged only 5.5 pounds per acre per year. In 1954, a year of good fishing, the pole-and-line fishing pressure amounted to only 22 hours per acre. During the 1950–1959 period, we estimated, anglers removed 194,423 pounds of fish from the lake (Table 2). Most of these fish were white crappies, black crappies, bluegills, yellow bass, and freshwater drum.

Removal by Trotline Fishing

The illegal trotlines of commercial fishermen took mainly channel catfish. In most years of the investigation, we estimated, they took 8,000 pounds of catfish annually (Table 2). Fishermen and fish dealers noted that the commercial trotline catch dropped considerably in 1958 and 1959; they believed the drop was related to a decline in the catfish population.

The legal trotlines of anglers took principally channel catfish, freshwater drum, and bullheads. The estimated catch of these and other kinds of fish is shown in Table 2.

Table 5.—Estimated number of pounds of fish removed from Lake Chautauqua in each ing, commercial fishing (including crappies in experimental program), and fishing with wing

Kind of Fish	*1950*	*1951*	*1952*	*1953*	*1954*
Carp	52,495	80,442	52,566	25,438	60,314
Buffalofishes	68,114	136,833	186,816	165,361	186,800
Freshwater drum	22,027	13,781	34,904	34,626	73,197
Channel catfish	16,877	15,342	17,922	13,270	30,255
Gizzard shad	1,500	3,930	12,050	13,700	35,755
Crappies	4,047	12,936	27,666	6,013	19,859
Bluegill	2,034	2,990	3,077	635	6,041
Other fishes	5,399	4,823	5,953	1,413	6,193
Total pounds	*172,493*	*271,077*	*340,954*	*260,456*	*418,414*
Pounds per acre	48.4	76.1	95.7	73.1	117.5

Removal by Department of Conservation

The Department of Conservation used wing nets in Lake Chautauqua to obtain fish for stocking other waters. An estimate of the catch made with the Department's nets is given in Table 2. Crappies, bluegills, and yellow bass were the principal species taken.

Total Removal

As mentioned previously, in the period 1942–1949, the annual total yield of fish from Lake Chautauqua averaged about 30 pounds per acre. In 1950, the yield was 48.4 pounds per acre (Table 5). In the following year, when the lake was seined for the first time, the yield was increased to 76.1 pounds per acre (Table 5). In 1954, the yield jumped to 117.5 pounds per acre, largely as a result of the concerted efforts of the seiners and roundup fishermen. The highest yield was in 1957, 121.0 pounds per acre. During the 10-year period of investigation, the yield was 2,991,131 pounds, or 839.7 pounds per acre. Buffalofishes (most of them bigmouth buffalo) accounted for 49.1 per cent of this yield. The combined catch of carp and drum comprised 29.4 per cent of the total yield. After 1953, until 1959 (no seining after 1958), gizzard shad formed an increased part of the total yield, but, during the study period, shad made up only 7.9 per cent of the total catch. Channel catfish accounted for 6.9 per cent of the catch. The combined catch of bluegills and crappies comprised 5.0 per cent of the total. The remaining 1.7 per cent of the catch consisted largely of bullheads, carpsuckers, white bass, largemouth bass, bowfin, and garfishes.

DESCRIPTION OF LAKE CHAUTAUQUA

Both the historical background and the present status of Lake Chautauqua are relevant to our study.

Historical Background of the Lake

The area now occupied by Lake Chautauqua was formerly a series of bottomland lakes connected with the Illinois River (Fig. 4 and 5). The water levels of these lakes fluctuated with the river. Largemouth bass fishing in these lakes was considered by the old timers as excellent. The Illinois Fisherman's Association (Cohen, Bartlett, & Lenke 1899:7) reported that in the year ending January 15, 1898, the commercial catch of "black bass" was 13,061 pounds at Havana. Most of this catch was believed to have been taken from the series of lakes now occupied by Lake Chautauqua and the Thompson Lake Drainage and Levee District (Fig. 4 and 5).

By 1925, nearly all of these lakes, including those in the area now oc-

year, 1950–1959. The figures include removal by sport fishing, legal and illegal trotline fish-
nets operated by Illinois State Department of Conservation personnel.

1955	*1956*	*1957*	*1958*	*1959*	*Total Pounds*	*Per Cent of Total Pounds of All Species*
36,189	30,234	86,024	74,711	33,154	531,567	17.8
161,406	142,300	191,620	116,015	112,388	1,467,653	49.1
62,888	30,521	39,804	29,649	4,279	345,676	11.6
29,732	31,897	27,607	13,020	10,185	206,107	6.9
29,571	37,660	63,670	36,865	2,000	236,701	7.9
8,724	4,468	7,432	3,456	1,521	96,122	3.2
9,314	9,603	10,129	6,953	3,941	54,717	1.8
4,916	1,880	4,519	7,143	10,349	52,588	1.7
342,740	*288,563*	*430,805*	*287,812*	*177,817*	*2,991,131*	
96.2	81.0	121.0	80.8	49.9	839.7	

cupied by Lake Chautauqua (Fig. 5), had been drained and leveed off from the river for agricultural uses. In 1924, a fair crop of corn was produced in the Lake Chautauqua Drainage and Levee District. Flood waters of the Illinois River in the fall of 1926 broke the levees surrounding the Chautauqua District and flooded the area (Mulvihill & Cornish 1929:54). The district was not reclaimed for agricultural purposes. Fishes from the Illinois River became established in the newly formed lake. Various species of submerged aquatic plants attractive to waterfowl abounded in the reflooded area. In 1936, personnel of the U. S. Biological Survey (predecessor to the U. S. Fish and Wildlife Service) found the area suitable for use as a refuge for migratory waterfowl and initiated purchase of the drainage district. The federal agency repaired the levees and installed spillways and control gates. By 1940, the refuge manager was able to maintain a stable water level in the lake during moderate to low river stages; the stable water level was for the purpose of propagating duck food plants. Longleaf pondweed, *Potamogeton americanus*, and coontail, *Ceratophyllum demersum*, were the most abundant plants at Lake Chautauqua in 1938 and among the most abundant in 1939 and 1940 (Bellrose 1941:243).

In the spring and early summer months of 1943 and 1944, near-record floods occurred in the Illinois River valley. The flood waters were heavily laden with silt, and vast deposits of silt were made in the lake. The siltation that occurred during those two flood periods evidently produced drastic changes in the ecology of the lake. Prior to 1943, the lake bottom was fairly firm. The fine sediments deposited in the lake during the floods formed a soft, silty layer over the bottom. According to Frank C. Bellrose of the Illinois Natural History Survey (personal communication, 1952), most of the formerly abundant aquatic and marsh plants disappeared from the lake following the floods in 1943 and 1944 and failed to become re-established. The yellow perch population in the lake declined drastically following the disappearance of aquatic vegetation formerly available to this species for spawning (Starrett & McNeil 1952:21–22). According to local commercial fishermen, freshwater drum and channel catfish increased in abundance after 1944. Boat liverymen interviewed stated that largemouth bass fishing seriously declined in the lake after 1944.

Present Status of the Lake

Lake Chautauqua is a lateral-levee lake, similar to Type 58 described by

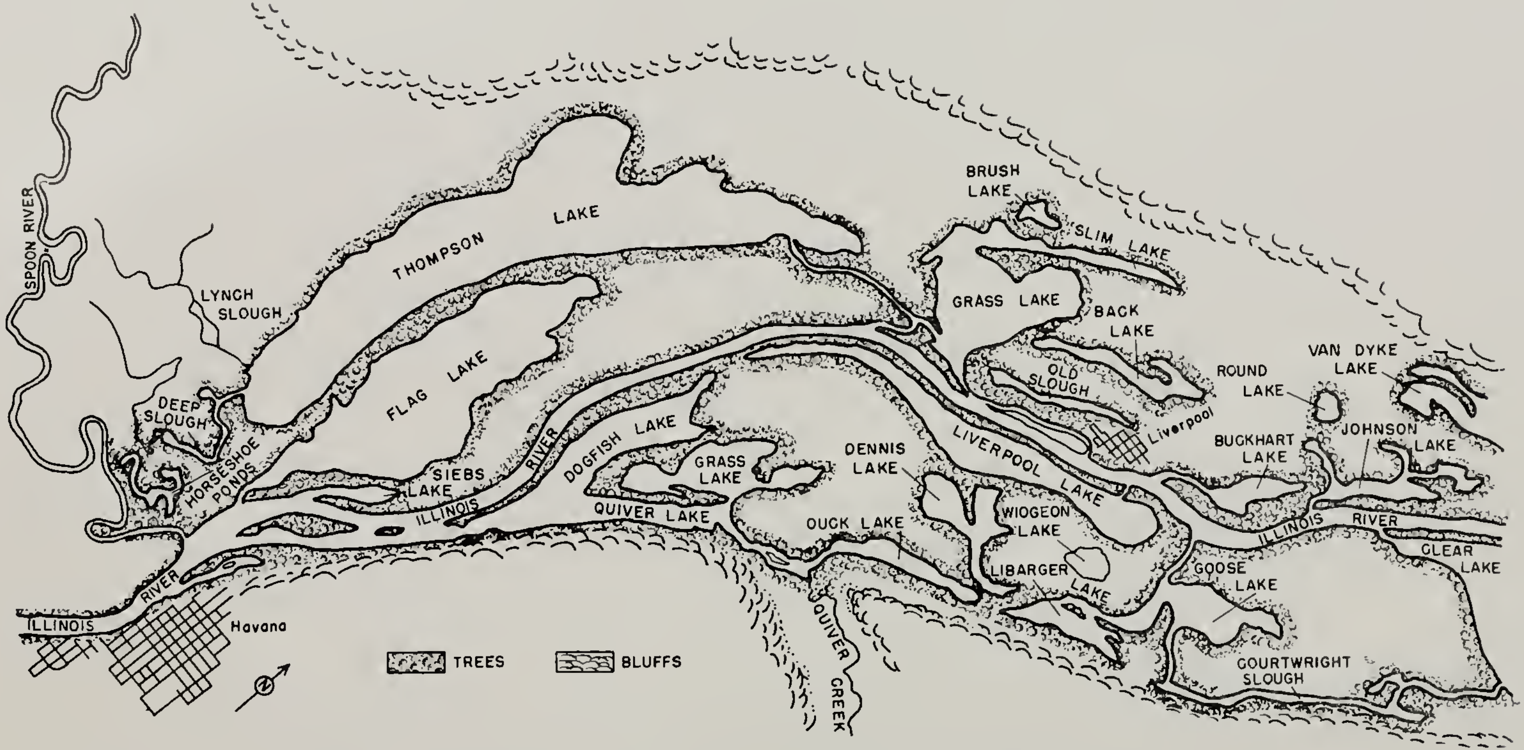


Fig. 4.—Map of the Illinois River and its adjoining bottomland lakes above Havana before 1912. The map was based on original plat maps filed in the court house at Lewistown, Illinois, and on an old sketch map, which was owned by Paul Riddle of Liverpool, Illinois. It was checked by William Riley and Frank Rudolph, commercial fishermen residing in Havana; both had fished in the various lakes shown on the map. Between 1916 and 1922, most of the lakes shown north of the river were drained. The area covered by this map is the same as that depicted in Fig. 5.

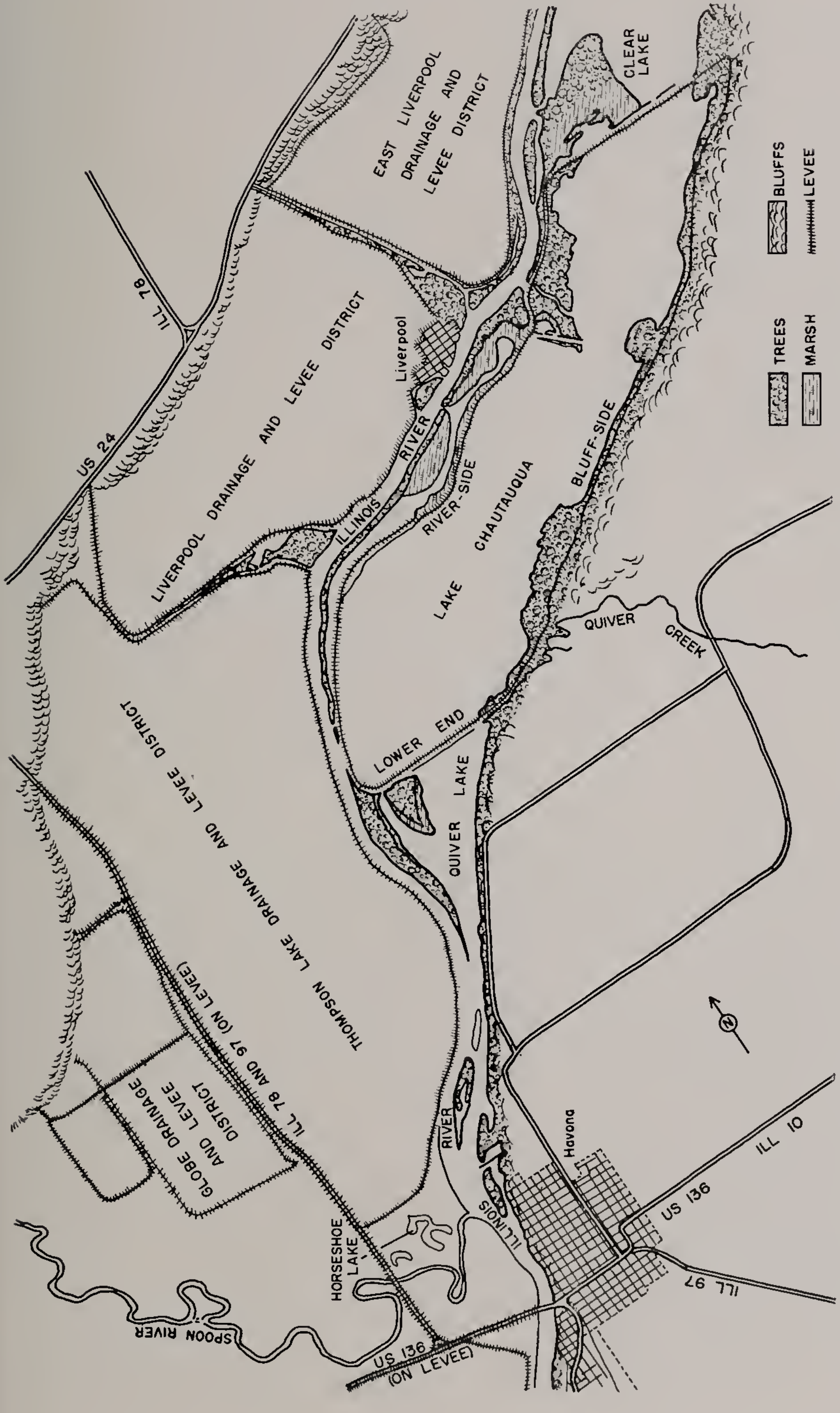


Fig. 5.—Map of the Illinois River and its adjoining bottomland lakes above Havana in 1960. This map shows that the lakes north of the river in Fig. 4 have been drained and leveed off from the river. After World War I, the area now occupied by Lake Chautauqua was drained and surrounded by levees. The Lake Chautauqua Drainage District was flooded in 1926 and was not reclaimed for agricultural uses.

Hutchinson (1957:123–125). The lake is over 6 miles long and varies in width from one-half mile to 1½ miles. At normal pool elevation (435.0 feet above mean sea level), the surface area of the lake is 3,562 acres (Stall & Melsted 1951:10). The depth of Lake Chautauqua, which depends upon the magnitude and duration of high waters occurring in the Illinois River, varies considerably each year; at normal lake stage, most of the lake is 2 to 3 feet in depth.

WATER LEVELS.—During the period of our 10-year study, water levels at Lake Chautauqua were not affected by flood waters of the Illinois River until the latter reached heights of about 437.5 feet above mean sea level. At this stage, river water began to flow into the lake and increased the depth of the lake 2.5 feet or more, the depth depending upon the magnitude of the flood. Usually personnel of the U. S. Fish and Wildlife Service would open the control gates between the lake and the river before the 437.5-foot stage was reached. The fluctuations of the water levels at Lake Chautauqua and the Illinois River at Havana are discussed in another section of this paper.

VEGETATION.—Since 1944, sago pondweed, *Potamogeton pectinatus*, has been the only submergent aquatic plant to grow abundantly in Lake Chautauqua. Its abundance in the period 1950–1959 varied considerably from year to year. Sago pondweed was seen growing only during the warmest months of the year; it flourished only in years when the water levels were stable during the growing season.

During the period 1950–1959, there were only two growing seasons (1953 and 1956) in which the Illinois River did not overflow into the lake. In those two years, the growth of sago pondweed was heavy, whereas, in other years (except 1959), the growth of pondweed varied from none to moderate, the extent of growth depending upon the time high water levels occurred and the duration of their occurrence. In 1959, water levels reached 437.5 feet on only one day, in early June; after that date, the lake level was dropped by the U. S. Fish and Wildlife Service personnel to a level of 6 inches lower than in any previous summer during the study. The shallow, stable water levels in 1959 resulted in the heaviest stand of sago pondweed observed in the lake.

SEDIMENTATION AND TURBIDITY.—The sedimentation survey of the lake made in 1950 revealed that silt or sediments deposited in Lake Chautauqua during flood periods on the Illinois River in 23.8 years had reduced the lake's storage capacity by 18.3 per cent (Stall & Melsted 1951:1). Jackson & Starrett (1959:160) stated that

> The sediments in Lake Chautauqua are mostly of a fine texture and form a loose, flocculent "false bottom" (not similar to the type found in bog lakes) over the original lake bottom. A slight disturbance of the "false bottom" causes particles to become resuspended and so increases the turbidity of the water. According to Stall and Melsted [1951], the largest sediment particles of Lake Chautauqua begin to settle after the disturbance ceases; however, it takes from 7 to 12 days for much of the sediment in the lake to settle to the bottom.

Observed turbidity in the years 1953–1957 "ranged from less than 25 to 800 p.p.m." (or units).

In the absence of sago pondweed, the turbidity of the lake, caused by resuspension of sediment particles, was affected by wave action and water depth. The relatively low turbidity resulting from the presence of vegetation in years of low stable water levels might be expected to favor sight-feeding fish. In years of low and stable water levels, additional food was available in the form of the vegetation itself and of immature insects, which tended to flourish on the sago pondweed.

WATER AND SOIL CHEMISTRY.—A summary of chemical analyses of water samples taken at Lake Chautauqua in 1953 and 1954 by Paloumpis & Starrett (1960:407) showed the following mean chemical determinations in parts per million or units: pH (8.2), PO_4 (0.4), SiO_2 (5.7), SO_4 (68.8), NO_3 (1.1), NH_4 (0.3), Na (8.5), alkalinity as $CaCO_3$ (141.7), and hardness as $CaCO_3$ (209.8).

We believe that waterfowl as well as flood waters of the Illinois River have increased the fertility of Lake Chautauqua. Paloumpis & Starrett (1960:427) estimated that in the fall, winter, and spring of 1954–55, waterfowl deposited organic material in the lake on a per-acre basis as follows: 12.8 pounds of nitrogen, 17.1 pounds of total phosphate, and 8.1 pounds of soluble phosphate. Stall & Melsted (1951:12) reported the chemical and physical characteristics of four sediment samples collected at Lake Chautauqua. These authors stated that

> The total carbon and total nitrogen values are extremely high, indicating an accumulation of organic matter in the lake far in excess of any amounts that could be accounted for through soil erosion. These large accumulations of nitrogen and carbon must, therefore, be attributed to wildlife excreta.

Jackson (1954:82) did not detect any thermal stratification in Lake Chautauqua. He attributed the lack of stratification to the shallowness of the lake. During our 10-year investigation at Lake Chautauqua, the senior author observed only two summer fish kills, one of which is described by Jackson & Starrett (1959:164). Both of these kills were localized, and they occurred during periods of prolonged hot weather and in the presence of heavy blooms of blue-green algae.

Bottom Fauna.—Bottom fauna studies conducted on Lake Chautauqua in 1952–1956 by Paloumpis & Starrett (1960:420) showed that the lake supported a large dipterous larva population composed principally of the genera *Pelopia*, *Procladius*, *Coelotanypus*, and *Tendipes*. The maximum annual production of dipterous larvae, in terms of weight, was estimated to be approximately 2,400 pounds per acre.

Sport Fishery.—In 1950–1954, the annual pole-and-line catch per fisherman at Lake Chautauqua varied from 0.6 to 0.8 fish per hour (Starrett 1958: 43). Most of the fish caught by anglers were crappies, bluegills, yellow bass, and freshwater drum. In this period, the number of anglers fishing the lake annually varied from 5,675 to 13,717. Their total annual catches in that period ranged from 9,414 to 36,442 pounds

Fig. 6.—Anglers fishing for crappies at a man-made brush pile in Lake Chautauqua. In 1950–1954, the annual number of anglers at the lake ranged from 5,675 to 13,717.

of fish. Most of the fish were caught by still fishing (Fig. 6) in which live bait was used.

Freshwater drum, bullheads, and channel catfish comprised most of the trotline catch by sport fishermen in 1954 (Starrett 1958:44).

COMMERCIAL FISHERY.—The reported annual catch of fish taken legally by commercial fishermen at Lake Chautauqua in 1950-1959 ranged from 144,254 to 326,808 pounds. Bigmouth buffalo, carp, freshwater drum, and channel catfish were the principal species taken by the commercial fishermen. These figures do not include some of the fish included in Table 2.

KINDS OF FISHES IN THE LAKE

During periods of high water levels in the Illinois River, Lake Chautauqua is contiguous with the river and at such times the various species of fish in the river have easy access to the lake. Since 1926, the year the property of the Lake Chautauqua Drainage and Levee District was flooded, perhaps 90 or more species of fish have had an opportunity to invade Lake Chautauqua from the river. In the present study, we identified 64 species of fish taken from Lake Chautauqua. At least 30 of these species were either rare or rare-occasional in their occurrence. Most of these rare or rare-occasional species collected were probably transient individuals that had moved into the lake during high water and had failed to move out when the river water receded. Twenty-one additional species ranged in abundance from occasional to common in the lake. Of the 64 species recorded for the lake, only 13 occurred abundantly or very abundantly in 1 or more years. They are the following:

- Bigmouth buffalo (very abundant)
- Gizzard shad (very abundant)
- Carp (very abundant)
- Freshwater drum (very abundant)
- Bluegill (very abundant)
- White crappie (very abundant)
- Black crappie (very abundant)
- Yellow bass (common to very abundant)
- Channel catfish (abundant)
- Shortnose gar (fairly abundant)
- Emerald shiner (scarce to abundant)
- Spottail shiner (scarce to abundant)
- Brook silverside (scarce to abundant)

Several biologists studied the fishes of Lake Chautauqua prior to the present investigation. Schloemer (1939:60) included a series of bluegills collected from Lake Chautauqua in his age and growth study of that species. Hansen (1942:198), who conducted a partial creel census on the lake in 1941 and 1942, reported that anglers caught the following kinds of fish: the largemouth bass, smallmouth bass, bluegill, crappie (kind or kinds not specified), other sunfish, yellow perch, yellow bass, sheepshead, bullhead, channel catfish, buffalo, dogfish, eel, carp, and others. Hansen (1943:175) also reported a large die-off of the yellow bass and smaller die-offs of the white crappie, black crappie, sheepshead, gizzard shad, and bluegill at Lake Chautauqua. In a later paper, Hansen (1951:234, 256) mentioned the occurrence of lymphocystis on the white crappie in Lake Chautauqua and recorded total length of two age-classes of this species in the lake. In a paper on sport fishing at Lake Chautauqua, Starrett & McNeil (1952:8) listed the species commonly caught by anglers at the lake. Larimore (1957:65), in his paper on the ecology of the warmouth in Illinois, included age and growth data on 30 individuals of that species taken from Lake Chautauqua. All of the species reported above by other workers were taken in the present investigation except the smallmouth bass.

In this section, we include all of the species taken by us in the period 1950–1961 and indicate the relative abundance of each species as determined from our collections.

Family Petromyzontidae

This family was represented by one species in the Lake Chautauqua collections. Starrett, Harth, & Smith (1960: 345), who studied the parasitic lampreys of Illinois rivers, considered lampreys scarce in the Illinois River above Florence, which is several miles below the La Grange navigation dam near Beardstown.

CHESTNUT LAMPREY, *Ichthyomyzon castaneus* Girard: Rare.—Beginning in 1949, commercial fishermen were requested by the senior author to save all lampreys taken from Lake Chautauqua. In the period 1949–1960, only two specimens were collected. Both were identified as the chestnut lamprey. One specimen (7.4 inches total length) was collected from a carp on May 12, 1959. The other specimen (6.3 inches) was found on April 11, 1960, in the bottom of a fisherman's boat shortly after he had raised his nets. No lamprey-scarred fish was noted by us in the commercial catches.

Family Polyodontidae

The paddlefish is the only representative of this family in North America.

PADDLEFISH, *Polyodon spathula* (Walbaum): Occasional.—During the investigation, only 214 pounds of paddlefish were removed from Lake Chautauqua by commercial fishermen. This species, which has some local commercial value, is sold under the name "spoonbill cat." The largest paddlefish taken from the lake weighed 29 pounds. Another specimen measured 47.5 inches in length and weighed 21 pounds. Paddlefish were taken in Lake Chautauqua only during years of sustained high water levels, such as occurred in 1950 and 1951. We are of the opinion that the specimens taken in Lake Chautauqua had moved up the Illinois River during high river stages. At a high river stage, the wickets of the La Grange navigation dam near Beardstown are lowered, thereby allowing fish to pass through without obstruction from the Mississippi River up the Illinois River to Havana. The paddlefish is not known to spawn in the Illinois River system. Forbes & Richardson (1920:17) in about 1908 considered the paddlefish as "rather rare" in the Illinois River above Meredosia.

Family Lepisosteidae

At the time of our study, the garfishes were of no commercial value in the Havana area. The shortnose gar was fairly abundant, and the longnose gar was taken occasionally. Gars taken by commercial fishermen were usually killed and discarded. Anglers using minnows for bait frequently hooked garfish. Only a very few anglers considered the gar as a desirable food fish.

We believe that garfishes spawned in Lake Chautauqua; however, only three young of this family (shortnose gars of 1.0 to 4.0 inches) were taken in minnow seine collections. In 1958, approximately 5 pounds of garfishes were caught per 100 yards of commercial seine.

The spotted gar, *Lepisosteus oculatus* (Winchell), which closely resembles the shortnose gar, was not found at Lake Chautauqua, Lake Matanzas, Quiver Lake, or in our Illinois River collections above Havana. The only spotted gars collected in the immediate area were three specimens taken on February 12, 1960, in a commercial seine haul at Ben's Lake, a small overflow lake adjacent to the Sangamon River, in Mason County. The specimens ranged from 13.6 to 13.9 inches in length. The silted waters and lack of permanent vegetation in Lake Chautauqua evidently provided a more favorable habitat for shortnose gar than for spotted and longnose gars.

SHORTNOSE GAR, *Lepisosteus platostomus* Rafinesque: Fairly abundant.—The heaviest shortnose gar measured 28.3 inches long and weighed 3.29 pounds. The average weight of shortnose gars in the test-net collections was 1.57 pounds.

LONGNOSE GAR, *Lepisosteus osseus* (Linnaeus): Occasional.—This species was much less abundant in Lake Chautauqua than the shortnose gar. The largest longnose gar measured 47.1 inches total length and weighed 12 pounds.

Family Amiidae

The only Lake Chautauqua representative of the bowfin family is of minor importance as a commercial species in Illinois. It is sometimes sold as "catfish" to unsuspecting customers. Most people do not care for the bowfin as food because of its "mushy" flesh.

BOWFIN, *Amia calva* Linnaeus: Common.—At the time of our study, the bowfin was not abundant enough in Lake Chautauqua to have much effect on the fishery as a predator. Anglers occasionally caught bowfins while fishing with minnows for bass or crappies. The commercial catch of bowfins at Lake Chautauqua in 1950–1959 amounted to 3,271 pounds. The largest bowfin caught in a 1-inch-mesh wing net measured 27.1 inches long and weighed 7.45 pounds. No young bowfin was collected during the study, but we believe that the species probably spawned in the lake.

Family Clupeidae

The skipjack herring and the gizzard shad were the only members of the herring family taken at Lake Chautauqua.

SKIPJACK HERRING, *Alosa chrysochloris* (Rafinesque): Rare.—On October 2, 1951, two adult specimens of this species were collected while we were test-netting at Lake Chautauqua (17.6 inches, 1.89 pounds; and 15.6 inches, 1.30 pounds). The specimens probably entered the lake from the Illinois River during a period of high water.

GIZZARD SHAD, *Dorosoma cepedianum* (Lesueur): Very abundant.—This species was one of the most abundant fishes in Lake Chautauqua during the period of our study. It was of no direct value to the sport or commercial fisheries of the lake; however, it was thought to be of great importance as a forage fish for the crappies, largemouth bass, white bass, garfishes, channel catfish, freshwater drum, and possibly the yellow bass and the bowfin. The largest shad collected was 16.5 inches long and weighed 1.57 pounds.

Family Hiodontidae

A few adults of the mooneye family were taken at Lake Chautauqua. In all probability, these fish had entered the lake from the river during periods of high water. Anglers occasionally hooked a goldeye or a mooneye. These fish were too scarce in the lake to have been of any importance to the fishery.

GOLDEYE, *Hiodon alosoides* (Rafinesque): Occasional.—The goldeye appeared to be less abundant in the lake than the mooneye. The largest goldeye taken was 12.0 inches long and weighed 0.61 pound.

MOONEYE, *Hiodon tergisus* Lesueur: Occasional.—The largest mooneye taken in the test-net collections was 10.6 inches long and weighed 0.39 pound.

Family Esocidae

The grass pickerel and the northern pike were the only members of the pike family taken in Lake Chautauqua.

GRASS PICKEREL, *Esox americanus vermiculatus* Lesueur: Rare to occasional.—A single specimen of this species was taken at Lake Chautauqua in 1950. None was collected after 1950 until 1959. In 1959, six adult specimens were caught in nets, and one was caught by an angler. During high water, the grass pickerel probably moves into the lake from adjoining Quiver Creek, where the species is quite common. The largest grass pickerel taken in Lake Chautauqua was 13.3 inches long.

NORTHERN PIKE, *Esox lucius* Linnaeus: Rare.—We have the record of a single specimen from Lake Chautauqua. On April 3, 1961, a female pike, 24.1 inches in total length and 4.02

pounds in weight, was taken in a commercial wing net set in the lake by Sam Kelly. The northern pike is now rather rare in the Havana area, and the specimen taken had probably entered the lake during high water. We have only one recent record of a pike that was caught in waters near Lake Chautauqua. On February 26, 1958, Edward W. Kelly brought us a northern pike (23.2 inches in total length and 2.61 pounds in weight), which he had just captured in a commercial wing net set in Quiver Lake. Quiver Lake lies adjacent to Lake Chautauqua, and the two lakes connect with one another during high water.

Family Cyprinidae

This large family, the minnows and carps, was represented by 15 species in Lake Chautauqua. Carp, emerald shiner, and spottail shiner were the only species of this family that we found occurring abundantly in the lake.

CARP, *Cyprinus carpio* Linnaeus: Very abundant.—This was one of the most abundant fishes occurring in Lake Chautauqua in the years of our study. Few carp were caught by anglers, but the species was of some importance to commercial fishermen. In the period 1950–1959, commercial fishermen removed from the lake 522,704 pounds of carp valued at $22,540. The average weight of carp taken in the commercial seine hauls at Lake Chautauqua was 4.82 pounds. The largest carp handled was 36.4 inches long and it weighed 28 pounds. Only one carp observed from the lake exhibited the knothead condition usually associated with polluted water (Thompson 1928:317). This individual probably originated from upstream in the Illinois River, where pollution was more severe than in the Havana area and where the knothead condition of carp was quite common.

GOLDFISH, *Carassius auratus* (Linnaeus): Rare.—An orange-colored goldfish was taken in a commercial seine haul at Lake Chautauqua in 1957. The specimen was 10.0 inches long and weighed 0.78 pound. Goldfish were very abundant in the polluted waters of the Des Pla nes River, part of the Illinois River system, and in the upper part of the Illinois River above the Starved Rock navigation dam. We have caught as many as 103 adult goldfish per net-day in our sets made in the Des Plaines River. Most of the specimens collected by us in the Illinois River and the Des Plaines River were brownish or bronze in color. Goldfish were taken only occasionally in the Illinois River below Pekin. One goldfish-carp hybrid was caught at Lake Chautauqua in a commercial seine haul in 1956. The fish weighed 5.44 pounds and was 20.4 inches in length. Both the goldfish and the goldfish-carp hybrid probably came into the lake from the river.

CREEK CHUB, *Semotilus atromaculatus* (Mitchill): Rare.—Two immature creek chubs were collected from Lake Chautauqua in 1958. These fish probably came into the lake from the river during a period of high water.

GOLDEN SHINER, *Notemigonus crysoleucas* (Mitchill): Common.—This species varied in abundance from year to year during our 10-year investigation. Most of the specimens taken at the lake were less than 3 inches in length. One specimen 7.5 inches long was taken in a 1-inch-mesh wing net. The golden shiner was not sufficiently abundant in Lake Chautauqua to be of much importance as a forage fish. The occurrence of the golden shiner in minnow seine collections was 2.3 fish per haul. This species spawned in the lake.

SUCKERMOUTH MINNOW, *Phenacobius mirabilis* (Girard): Rare. — Only four specimens of this minnow were collected from Lake Chautauqua. These fish had probably moved into the lake from the river during high water levels.

EMERALD SHINER, *Notropis atherinoides* Rafinesque: Scarce to abundant. —This species and the spottail shiner were the only abundant minnows other than carp collected from Lake Chautauqua. No specimen of the emerald shiner was collected in the lake in 1954 and 1956; in 1957, this species was very abundant and averaged 49.2 fish per minnow seine haul. The emerald shiner averaged 14.4 fish per haul in the minnow seine collections of 1950–1959. This shiner spawned in Lake Chautauqua.

Spottail Shiner, *Notropis hudsonius* (Clinton): Scarce to abundant.—In the minnow seine collections of 1950–1959, this species averaged 15.7 fish per haul. Our data for the 10-year study showed the spottail shiner slightly more abundant in the lake than the emerald shiner. The spottail shiner spawned in Lake Chautauqua. The emerald shiner and the spottail shiner were both considered important forage fishes.

Bigmouth Shiner, *Notropis dorsalis* (Agassiz): Rare to occasional. — This typical stream fish was taken in 10 different minnow seine hauls at the lake. The specimens collected probably entered the lake during high water. The average occurrence of this species in all the minnow seine collections was 0.2 fish per haul.

Red Shiner, *Notropis lutrensis* (Baird & Girard): Rare to occasional.—The occurrence of this species in the minnow seine collections at Lake Chautauqua was 0.1 fish per haul. The red shiners collected probably entered the lake during high water levels.

Sand Shiner, *Notropis stramineus* (Cope): Rare to occasional.—Prior to 1958, only one specimen of the species had been reported taken in Lake Chautauqua. In 1959, 94 sand shiners were taken with the minnow seine over sand bottom. This species may have had some success in spawning and establishing itself in the lake. Its occurrence in the minnow seine collections was 0.6 fish per haul.

Silvery Minnow, *Hybognathus nuchalis* Agassiz: Rare to occasional.—This species was taken at Lake Chautauqua only in 1959. However, in that year, it was caught in six different minnow seine hauls. We have taken the silvery minnow quite regularly in our Illinois River collections in the vicinity of Havana. The specimens collected at Lake Chautauqua probably came into the lake from the river. Occurrence of the silvery minnow in the minnow seine collections at Lake Chautauqua in 1950–1959 averaged 0.1 fish per haul.

Bullhead Minnow, *Pimephales vigilax* (Baird & Girard): Occasional.—A few specimens of the bullhead minnow were collected from the lake in most years of our 10-year study. The occurrence of this species in the minnow seine collections averaged 0.1 per haul.

Bluntnose Minnow, *Pimephales notatus* (Rafinesque): Rare to occasional. —The bluntnose minnow was collected at the lake in three different years. Altogether, 36 fish of this species were taken, none of them adults. The occurrence of the bluntnose minnow in the minnow seine collections averaged 0.2 fish per haul.

Fathead Minnow, *Pimephales promelas* Rafinesque: Rare. — Only eight specimens of this species were collected from Lake Chautauqua for our study.

Stoneroller, *Campostoma anomalum* (Rafinesque): Rare.—During our investigation, only seven specimens of this species were collected from Lake Chautauqua. This typical stream species probably entered the lake during high water. Its occurrence in the 196 minnow seine collections, 1950–1959, averaged less than 0.1 fish per haul.

Family Catostomidae

Members of the sucker family, other than the bigmouth buffalo, were not abundant in Lake Chautauqua in the period 1950–1959. Nine species of this family were collected.

Bigmouth Buffalo, *Ictiobus cyprinellus* (Valenciennes): Very abundant. —In terms of standing crop (pounds of fish per acre), the bigmouth buffalo was the most abundant fish in Lake Chautauqua. Evidently the shallow and often turbid water of the lake furnished a good habitat for the bigmouth buffalo. This species probably spawned each year; however, only in 1953 during our 10-year study was a large brood produced. During the study, only a few buffalo were caught by anglers.

The bigmouth buffalo was the most important commercial fish in the lake. In the period 1950–1959, commercial fishermen caught 1,467,389 pounds of buffalo, of which nearly all were the bigmouth. The value of the catch to the fishermen during that period was $156,-045. The average weight of the bigmouth buffalo in commercial seine hauls was 6.21 pounds (1951–1958); the largest bigmouth buffalo measured 32.5 inches long and weighed 26.5 pounds.

SMALLMOUTH BUFFALO, *Ictiobus bubalus* (Rafinesque): Occasional.—The smallmouth buffalo probably moves into Lake Chautauqua from the Illinois River, where it is sometimes taken by commercial fishermen. The largest specimen handled weighed 18.5 pounds.

BLACK BUFFALO, *Ictiobus niger* (Rafinesque): Occasional.—This species, like the smallmouth buffalo, was not abundant enough in Lake Chautauqua to be of any commercial importance. Most of the black buffalo were readily distinguishable from the smallmouth buffalo; a few fish appeared to be intergrades between the black buffalo and the smallmouth buffalo. The largest black buffalo handled was 28.9 inches long and weighed 16 pounds.

QUILLBACK, *Carpiodes cyprinus* (Lesueur): Occasional to common. — We experienced difficulty in accurately separating *Carpiodes cyprinus* from *forbesi* collected from the Illinois River and Lake Chautauqua. A series of adult specimens from the river and Lake Chautauqua was submitted to Dr. Milton B. Trautman of the Ohio State Museum. Dr. Trautman informed us (personal communication, June 23, 1960) that: "At present, I believe that this is a hybrid population. You have typical *forbesi*, typical *cyprinus*, and a nice series of intergrades in between." Later, Bailey & Allum (1962:81) stated that they regarded *forbesi* not as a separate species but as a modification of *cyprinus*. We are in agreement with this conclusion and therefore name all of our specimens of the *forbesi-cyprinus* pair as *cyprinus*. The largest quillback identified by us was 17.5 inches long and weighed 2.62 pounds.

RIVER CARPSUCKER, *Carpiodes carpio* (Rafinesque): Common.—The adult and subadult river carpsuckers were easily distinguished in the field from other species of *Carpiodes* occurring in Lake Chautauqua. The river carpsucker occurred more abundantly in Lake Chautauqua than did the other species of carpsucker. Carpsuckers were not taken by anglers. A few pounds of carpsuckers, largely of this species, were caught each year commercially and sold as silver carp or carp. The largest river carpsucker handled was 19.3 inches long and weighed 4.4 pounds.

NORTHERN REDHORSE, *Moxostoma macrolepidotum* (Lesueur): Rare to occasional.—In the years 1950–1953, 13 adult specimens of the northern redhorse were taken in the test-net collections at Lake Chautauqua; no adult was taken after 1953. A few young-of-the-year fish identified as *Moxostoma* sp. were caught with a minnow seine in later years; these may have included young northern redhorses. The northern redhorses taken in the test-net collections ranged in length from 10.9 to 17.2 inches. The heaviest weighed 2.55 pounds.

WHITE SUCKER, *Catostomus commersoni* (Lacépède): Rare.—A single specimen of the white sucker was collected at Lake Chautauqua in 1951. The fish was 12.9 inches long and weighed 0.92 pound. In 2 months of continuous wing-net fishing at Lake Chautauqua in 1940, Donald F. Hansen of the Illinois Natural History Survey (personal communication, January 13, 1963) caught 16 white suckers. Evidently the species was more abundant in 1940 than in the period of our study.

Spotted Sucker, *Minytrema melanops* (Rafinesque): Rare.—One specimen of this species was taken in a 1-inch-mesh wing net at Lake Chautauqua in 1952. It was 8.1 inches long and weighed 0.28 pound.

Western Lake Chubsucker, *Erimyzon sucetta kennerlyi* (Girard): Rare.—Five adult chubsuckers were taken at Lake Chautauqua in 1958 and 1959. In 1958, James La Buy of the Illinois Department of Conservation (personal communication in September, 1958) found a rather large population of this species in Rice Lake, an Illinois River bottomland lake 6 river miles upstream from Lake Chautauqua. Permanent types of submergent vegetation flourished in Rice Lake at the time La Buy made his investigation. Donald F. Hansen of the Illinois Natural History Survey (personal communication of January 13, 1963) considered chubsuckers scarce in the lake in 1940. In 2 months of netting, he caught only three chubsuckers.

Family Ictaluridae

Seven species of catfishes were recorded from Lake Chautauqua during our investigation. The channel catfish was the only one of these species that occurred quite abundantly. The lack of permanent stands of submergent vegetation and the abundance of predatory fishes in the lake probably had an adverse effect upon the bullheads. The blue catfish and the flathead catfish were the only species of catfish taken that did not spawn in the lake.

Blue Catfish, *Ictalurus furcatus* (Lesueur): Rare.—Only two specimens of this species were taken at Lake Chautauqua during our investigation (17.6 inches, 2.00 pounds; 19.4 inches, 2.92 pounds). Both fish were aged as 4-year-olds. These specimens were taken in commercial seines in 1958. Blue catfish are occasionally taken in the Illinois River at Havana by commercial fishermen during periods of high water. Specimens of blue catfish examined by us at a commercial fish market in Havana were about the sizes of fish taken at Lake Chautauqua. Local commercial fishermen informed us that they have never caught large blue catfish in the Havana area. Evidently only the blue catfish of small sizes move up the Illinois River from the Mississippi River during high water. Forbes & Richardson (1920:179) in about 1908 considered the blue catfish to be rare in the Illinois River.

Channel Catfish, *Ictalurus punctatus* (Rafinesque): Abundant.—During the period of our study, this species was important both as a sport and a commercial fish at Lake Chautauqua (Starrett 1958:43, 46). Seines and trotlines were the two most effective devices used for taking catfish. Channel catfish were a premium fish for the commercial fishermen since the wholesale undressed price during the 1950's remained consistently at about $0.25 per pound. The other abundant commercial fishes fluctuated in price and were usually sold for less than $0.10 per pound. The reported legal commercial catch of catfish for the lake (1950–1959) was 87,863 pounds valued in the rough at $21,146. The average weight of catfish in the commercial seine hauls ranged from 1.8 pounds in 1958 to 3.4 pounds in 1952. The largest channel catfish examined in the investigation was 32.5 inches long and it weighed 16.75 pounds.

Yellow Bullhead, *Ictalurus natalis* (Lesueur): Occasional.—Only very few specimens of this species were taken at Lake Chautauqua after 1953. Of the two largest yellow bullheads measured, one was 15.6 inches long (1.82 pounds) and the other was 15.0 inches long (2.10 pounds).

Brown Bullhead, *Ictalurus nebulosus* (Lesueur): Common.—Most of the bullheads caught in the commercial seine hauls at Lake Chautauqua were brown bullheads. The majority of these fish weighed over 1 pound apiece. The largest brown bullhead handled was

15.6 inches long and weighed 1.80 pounds. The brown bullhead was not nearly so abundant as the channel catfish but was more abundant than the black bullhead.

BLACK BULLHEAD, *Ictalurus melas* (Rafinesque): Common.—This species was the most common bullhead taken by anglers at Lake Chautauqua. Commercial fishermen legally removed 1,452 pounds of bullheads, all species combined, from the lake in 1950–1959. Most of these fish were black bullheads and brown bullheads. The heaviest black bullhead handled was 14.4 inches long and it weighed 1.80 pounds.

FLATHEAD CATFISH, *Pylodictis olivaris* (Rafinesque): Rare.—Two flathead catfish weighing approximately 2 pounds apiece were taken by fishermen at Lake Chautauqua; they were identified by the senior author. Also, commercial fishermen reported catching a few pounds of flathead catfish in their wing nets. The flathead catfish occurs in the Illinois River and its large tributary streams and evidently strays only occasionally into Lake Chautauqua when there is high water.

TADPOLE MADTOM, *Noturus gyrinus* (Mitchill): Occasional.—This small catfish was of no direct value to the fishery at Lake Chautauqua. In one area of less than one-quarter acre to which rotenone was applied, 19 madtoms were collected. The largest specimen taken from the lake was 3.1 inches long.

Family Anguillidae

The American eel is the only member of its family occurring in Illinois waters. Very few eels are taken commercially in the state, and there is very little demand for them as food in Illinois.

AMERICAN EEL, *Anguilla rostrata* (Lesueur): Rare to occasional.—During the 5-year complete creel census program at Lake Chautauqua (1950–1954), anglers caught 21 eels. In 1954, trotline fishermen captured 8 eels. During the fall test-netting program, 8 eels were caught; their sizes ranged from 27.5 inches long (1.82 pounds) to 39.0 inches long (4.75 pounds). The mesh of the nets usually used by commercial fishermen is too large to retain eels.

Family Cyprinodontidae

This family has several representatives in Illinois waters. However, only one species was taken in our collections at Lake Chautauqua.

BLACKSTRIPE TOPMINNOW, *Fundulus notatus* (Rafinesque): Rare.—One adult specimen of this species was collected from Lake Chautauqua with a minnow seine in 1958.

Family Poeciliidae

Forbes & Richardson (1920:216) reported taking *Gambusia affinis* (Baird & Girard) as far north as Pekin (probably 1903 or before); they reported the species as common in extreme southern Illinois. Krumholz (1948:5) mentioned a report that "Gambusia," or the mosquitofish, was taken in 1941 from the Illinois River at seven places between Pekin and the mouth of the river. In 1957, 10 mosquitofish were collected by us in a series of four minnow seine hauls at Lake Matanzas near Havana. These were the only mosquitofish we took in the Havana area in the 1950–1959 period. The mosquitofish was not collected from Lake Chautauqua; however, the presence of the species in nearby waters indicated that it might sometimes occur in Lake Chautauqua.

Family Percopsidae

In some parts of the United States, the trout-perch is usually considered as a fish found in deep waters where there is a sand or gravel bottom (Trautman 1957:465). In Illinois, however, this species is frequently taken in shallow waters over a soft mud bottom.

TROUT-PERCH, *Percopsis omiscomaycus* (Walbaum): Rare.—The trout-perch was taken with a minnow seine on three different occasions in Lake Chautauqua. This species has occurred regularly in our minnow seine and electrofishing collections from the Illinois River. Seventeen trout-perch were taken by us in one minnow seine haul at nearby Quiver Lake in 1959.

Family Aphredoderidae

In central Illinois, the pirate perch is usually found only in small sluggish streams over mud bottom.

PIRATE PERCH, *Aphredoderus sayanus* (Gilliams): Rare.—A single adult pirate perch was taken in an area treated with rotenone at Lake Chautauqua in 1959.

Family Serranidae

This large family of sea basses is represented in Illinois waters by the white bass and the yellow bass. Both of these species are considered important sport fishes in the rivers of the state.

WHITE BASS, *Roccus chrysops* (Rafinesque): Common.—The size of the white bass population at Lake Chautauqua varied considerably from year to year during our investigation, and, as a result, the species was of only sporadic importance to anglers. In the 5 years of the complete creel census at Lake Chautauqua, the anglers' catch of white bass was as follows: 14 fish in 1950, 805 in 1951, 909 in 1952, 69 in 1953, and 319 in 1954 (Starrett 1958:43). Most of the white bass taken by anglers were 1- or 2-year-old fish. The largest white bass measured at Lake Chautauqua during this study was 16.3 inches long; it weighed 2.46 pounds.

YELLOW BASS, *Roccus mississippiensis* (Jordan & Eigenmann): Common to very abundant.—Fishing success for yellow bass at Lake Chautauqua varied from year to year and depended upon the size of the population and the water levels. Anglers usually had their best success in the spring months when the water was high. The best yellow bass fishing occurred in 1959, when the anglers' catch was estimated to be 13,000 fish. The yellow bass taken by anglers in most years were of satisfactory size; the average weight of yellow bass caught by anglers was 0.46 pound. The largest yellow bass observed from Lake Chautauqua was caught by an angler in 1950; this fish was 12.2 inches long and it weighed 1.07 pounds.

Family Centrarchidae

Eight species of the sunfish family were collected in Lake Chautauqua during our investigation. Crappies and bluegills were the only members of the family that occurred abundantly in the lake. All eight species spawned in the lake with varying degrees of success.

SMALLMOUTH BASS, *Micropterus dolomieui* Lacépède: Possible occurrence.—Although Hansen (1942:198) reported the catch of a single smallmouth bass by an angler at Lake Chautauqua, he told us (personal communication, November 20, 1961) that he did not see this fish and suggested that we not accept his report as a positive record of occurrence of the smallmouth in Lake Chautauqua. We had a report from a boat liveryman that in 1950 a smallmouth bass had been taken in Lake Chautauqua and brought to his boatyard. Since we did not observe the smallmouth bass in any of our collections from Lake Chautauqua, we prefer to list the species as of only possible occurrence in the lake. The species is known to occur in some of the Illinois River tributary systems within the general area of Lake Chautauqua. However, to date, we have not taken the smallmouth bass in any of our collections from the Illinois River between Browning and Pekin. It is quite possible that a smallmouth bass could move from a tributary stream into the Illinois River and thence into Lake Chautauqua during a period of high water.

LARGEMOUTH BASS, *Micropterus salmoides* (Lacépède): Common.—In the years of our study, very few anglers came to Lake Chautauqua to fish specifically for largemouth bass. Most of the bass that were caught were taken by anglers fishing for bluegills and crappies (Starrett 1955:6). The annual catch of largemouth bass taken by anglers in the period 1950–1954 ranged from 564 to 1,347 fish. Anglers took very few bass over 15.0 inches in length. Bass larger than 15.0 inches were scarce in our collections made with the various fishing devices employed in this study, including commercial seines. The largest bass handled from the lake was 20.2 inches long; it weighed 4.45 pounds.

Warmouth, *Chaenobryttus gulosus* (Cuvier): Common. — The warmouth never occurred abundantly in the lake during the 1950–1959 period. This species was of only minor importance as a sport fish. The largest warmouth measured was 8.3 inches long; it weighed 0.57 pound.

Green Sunfish, *Lepomis cyanellus* Rafinesque: Common.—This species was taken less frequently by anglers than the warmouth. The largest green sunfish handled was 7.0 inches long; it weighed 0.30 pound.

Pumpkinseed, *Lepomis gibbosus* (Linnaeus): Occasional.—This species was too scarce in Lake Chautauqua to be of any importance to the sport fishery. The largest pumpkinseed measured was 8.1 inches long; it weighed 0.56 pound.

Bluegill, *Lepomis macrochirus* Rafinesque: Very abundant.—The bluegill was one of the most important sport fishes occurring in Lake Chautauqua during our investigation. Bluegill fishing was particularly good at the lake in the years 1954–1958. In all years, the best bluegill fishing occurred in the months of May and June. In most years, anglers were pleased with the sizes of the bluegills they were able to catch (0.34 pound average). The largest bluegill observed during our study was 9.2 inches in length and 0.77 pound in weight.

Orangespotted Sunfish, *Lepomis humilis* (Girard): Common.—Orangespotted sunfish in Lake Chautauqua seldom attained a size large enough to attract the interest of anglers. An orangespotted sunfish 4.8 inches long and weighing 0.10 pound was kept by an angler. Nearly all of the specimens collected were taken with the minnow seine.

White Crappie, *Pomoxis annularis* Rafinesque: Very abundant.—The white crappie was one of the most abundant fishes occurring in Lake Chautauqua. This species spawned in the lake each year of our study except possibly 1953; however, the strength of year-classes was quite variable. The white crappie formed an important part of the anglers' catch, particularly in the years 1950–1956. In most years, it occurred in the lake much more abundantly than the black crappie. The average weight of white crappies taken by anglers was 0.41 pound. Very few white crappies were observed that weighed over a pound. The largest white crappie observed was 14.1 inches in length and 1.53 pounds in weight.

Black Crappie, *Pomoxis nigromaculatus* (Lesueur): Very abundant.—The black crappie was usually less abundant at Lake Chautauqua than the white crappie. The average weight of the black crappie in the anglers' catches was 0.39 pound. The largest black crappie measured was 12.6 inches long; it weighed 1.38 pounds.

Family Percidae

Six species of fish of the perch family were taken at Lake Chautauqua in the period of our study. Only the yellow perch and the logperch were common in our collections.

Sauger, *Stizostedion canadense* (Smith): Rare.—Only three saugers were collected at Lake Chautauqua in the period of our study; they were taken in our 1-inch-mesh wing nets. One specimen (13.7 inches long, 0.78 pound) was caught in October, 1952, and two more were taken in April, 1961 (13.7 inches long, 0.91 pound; 13.9 inches long, 0.90 pound). The last two specimens were nearly ripe females. The saugers collected at Lake Chautauqua evidently came into the lake from the

Illinois River during high water. Saugers are now caught occasionally in the river by commercial fishermen. We have not collected any young-of-the-year saugers from the lake or from the river in the Havana area.

Yellow Perch, *Perca flavescens* (Mitchill): Common.—Earlier in this paper, we mentioned that the yellow perch was formerly abundant in Lake Chautauqua. In the period 1950–1959, perch spawned in the lake in most years but failed during this period to produce a single large year-class. We attributed this poor spawning success to the lack of submergent vegetation during the spawning season. Prior to 1943, submergent vegetation flourished in the lake, and the yellow perch was abundant and formed an important part of the anglers' catch (Hansen 1942:198). Fishing was very poor for perch in the 1950–1959 period. The anglers' annual catches of the yellow perch in the years 1950–1954 ranged from 194 to 806 fish. The perch caught by anglers were usually of a size satisfactory to them. The largest yellow perch we observed was 11.5 inches long; it weighed 0.70 pound.

River Darter, *Percina shumardi* (Girard): Rare.—A single specimen of this species was taken in a minnow seine haul at the lake in 1959. Our identification of this specimen was confirmed by Dr. Milton B. Trautman of Ohio State University (personal communication, January 22, 1960).

Logperch, *Percina caprodes* (Rafinesque): Common.—This was the only species of darter taken regularly in our collections at Lake Chautauqua. Young-of-the-year logperch were taken in several different years. Seven specimens of this species were submitted to Dr. Reeve M. Bailey of the University of Michigan for examination. He informed us (personal communication, March 4, 1960) that the specimens from Lake Chautauqua appeared to be of a subspecies intermediate between *P. caprodes carbonaria* and *P. caprodes semifasciata*.

Bluntnose Darter, *Etheostoma chlorosomum* (Hay): Rare to occasional.—Nineteen specimens of this species were collected from Lake Chautauqua through our use of rotenone and minnow seines. This darter possibly spawned in Lake Chautauqua, as evidenced by several small specimens taken in our collections.

Mud Darter, *Etheostoma asprigene* (Forbes): Rare.—Forbes & Richardson (1920:307–309) reported that the mud darter, known to them as *Etheostoma jessiae*, was very common in the Illinois River at Havana (probably 1903 or before). This species has occurred only occasionally in our collections from the Illinois River at Havana. Three specimens of the mud darter were collected at Lake Chautauqua; these were taken in areas treated with rotenone.

Family Sciaenidae

The freshwater drum is the only representative in Illinois of a large family of marine fishes. This drum, known in Illinois as the white perch and the sheepshead, is of importance as both a commercial and sport fish in the Illinois River and the Mississippi River.

Freshwater Drum, *Aplodinotus grunniens* Rafinesque: Very abundant. —The freshwater drum was one of the most abundant fishes in Lake Chautauqua during our study. In most years of our study, this species spawned quite successfully in the lake. The drum formed an important part of the creel in years of high water levels. Starrett & McNeil (1952:22–23) reported that the best fishing conditions for the drum in 1950 and 1951 were in periods of high or rising water. In 1950, an exceptionally good year for drum fishing because of the high water levels, anglers caught 9,459 drum. The drum comprised 15.2 per cent by weight of the legal reported commercial catch at Lake Chautauqua in the years 1950–1959. In this period, commercial fishermen removed from the lake 312,946 pounds of drum valued at $19,807. The largest drum caught during the investigation was 28.2 inches long; it weighed 11.64 pounds. The average weight of individuals in the commercial seine hauls ranged from 0.94 pound in 1956 and 1958 to 1.46 pounds in 1954.

Family Atherinidae

Only one member of this family occurs in Illinois waters.

BROOK SILVERSIDE, *Labidesthes sicculus* (Cope): Scarce to abundant.—The numbers of this species caught in the minnow seine collections varied considerably from year to year (0.0 to 20.9 fish per haul). The species was most abundant in 1950, 1957, and 1958. In those years, it was probably of some importance as a forage fish because of the size and abundance of individuals.

GROWTH AND AGE OF FISHES

From the age and length data collected during our investigation of Lake Chautauqua, we determined the growth rates of 14 species of fishes and the age composition of the catch of 9 species.

Growth Rates of Species

The statistics pertinent to the growth rates of 14 species of fishes collected at Lake Chautauqua in the period 1950–1959 are presented in this section. In determining growth rates of a fish, we considered a growing season, ending August 31, equivalent to a year of life of the fish. For example, a fish collected in September with scales or spine showing two annuli plus a summer's growth was called a 3-year-old fish and was placed in age group III of Fig. 7–16.

BLUEGILL GROWTH RATES.—Age and length data for the Lake Chautauqua bluegills we studied in 1950–1959 are summarized in Tables 6–9.

The size distribution of young bluegills taken in the 1959 minnow seine and rotenone collections (Table 6) was rather typical of the distribution found in the collections made in previous years. The data indicated evidence of at least two major spawning periods in 1959. By early fall, the majority of the young bluegills in the minnow seine collection were 1.0–2.0 inches in length. The calculated first-year growth of bluegills of four different year-classes averaged 1.8 inches in length (Table 7). The first year's growth of bluegills at Lake Chautauqua was considered as

Table 6.—Number of bluegills of less than 1 year old in each of several size groups in the 1959 minnow seine and rotenone collections at Lake Chautauqua.

Date of Collection	*Total Length of Individual Fish in Inches*					*Number of Fish Measured*
	0.5	1.0	1.5	2.0	2.5	
July 10*	33	36	0	0	0	69
August 12†	0	4	71	15	0	90
August 12*	0	5	27	1	0	33
August 27*	6	66	57	18	0	147
September 17*	0	75	141	19	0	235
October 8*	1	66	88	58	1	214

*Minnow seine sample.
†Rotenone sample.

Table 7.—Average calculated total length, in inches, of Lake Chautauqua bluegills of each of four year-classes at ages of 1 year and 2 years.

Year Class	*Age of Fish*		*Number of Fish*
	1 Year	2 Years	
1948	1.8	4.7	58
1950	1.5	4.4	16
1952	1.9	5.1	46
1955	2.0	5.1	78
Average or total	*1.8*	*4.8*	*198*

being only fair compared with growth made by bluegills in Clear Lake, Iowa. Di Costanzo (1957:23) determined the first year's growth of bluegills in that lake to be 2.39 inches. The average first year's growth in 56 northern Indiana lakes was 1.5 inches (Ricker 1942; data summarized by Carlander 1953: 184).

Table 8.—Average observed lengths and weights of bluegills of various ages, excluding 1-year-old fish, at Lake Chautauqua.

Age in Years	*Average Total Length in Inches*	*Range in Length, Inches**	*Average Weight in Pounds*	*Range in Weight, Pounds**	*Number of Fish Aged*
2	4.7	3.8–5.2	0.08	0.03–0.11	235
3	6.2	5.6–6.5	0.22	0.17–0.29	1,299
4	7.1	6.9–7.3	0.34	0.27–0.40	1,461
5	7.8	7.4–8.1	0.45	0.35–0.52	728
6	8.5	8.3–8.6	0.56	0.46–0.64	108
7	9.1	9.0–9.2	0.74	0.67–0.77	4
Total					3,835

*Range based on mean annual lengths or weights.

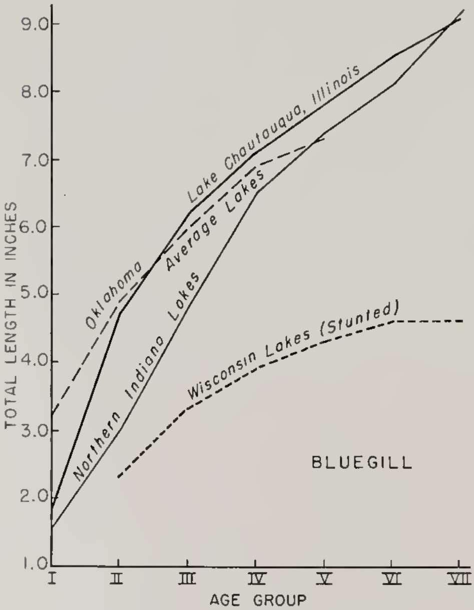


Fig. 7.—Growth of bluegills in Lake Chautauqua and in certain other waters of the United States. The graph was based on references included in the text and on Table 8 (except that length of 1-year-old fish at Lake Chautauqua was calculated). It indicates that Lake Chautauqua bluegills had excellent growth rates after their first year of life. It was not intended to give the impression that bluegills at Lake Chautauqua had better growth rates than those of all other waters. Some other waters, particularly newly created lakes and ponds, have produced bluegills with better growth rates than the Lake Chautauqua bluegills.

Table 9.—Average total lengths (inches) of bluegills of various ages for each year, 1949–1959, at Lake Chautauqua.

Year	*3-Year-Old Fish*	*4-Year-Old Fish*	*5-Year-Old Fish*
1949	6.2	7.3	8.1
1950	6.0	7.0	7.9
1951	6.1	7.2	7.8
1952	5.6	6.9	7.7
1953	6.0	7.1	7.9
1954	6.5	7.1	7.7
1955	6.3	7.3	7.9
1956	6.2	7.2	8.0
1957	6.5	7.2	8.0
1958	6.2	6.9	7.4
1959	6.4	7.2	7.7
Average	*6.2*	*7.1*	*7.8*

After the first year, the growth rates of bluegills in Lake Chautauqua were very good compared with the growth rates of bluegills in other midwestern bodies of water not newly created (Table 8; Fig. 7; Bennett 1945:395; Jenkins, Elkin, & Finnell 1955:14; Ricker 1942; Snow, Ensign, & Klingbiel 1960:7; Upper Mississippi River Conservation Committee 1946:20; and others). Very few bluegills lived more than 6 years in Lake Chautauqua, our study showed. Throughout our entire study period, only four bluegills were found that had reached an age of 7 years (Table 8). Schloemer (1939:13, 60), who examined scales of 115 bluegills collected from Lake Chautauqua in 1936, did not find any of the fish to be over 5 years of age. He aged too few bluegills from Lake Chautauqua over 2 years of age (12 fish) to give any real comparison with the age data in the present study.

Average sizes attained by bluegills each year in the period 1949–1959 are presented in Table 9. Data in the table show that the 3-year-old fish tended to vary in size slightly more from year to year than did the 4- and 5-year-old fish. Because in most years too few 2- and 6-year-old fish were aged to furnish information of much value to this study, fish in these age-groups were not included in Table 9.

LARGEMOUTH BASS GROWTH RATES.—The age determinations for the bass collected at Lake Chautauqua in 1950–1959 indicated that the growth rates of these bass were fairly good compared with the growth rates of bass in some other waters (Table 10; Fig. 8; Beckman 1949:78; Bennett 1937:107; Jenkins & Hall 1953:18; McCaig & Mullan 1960:29; Schoffman 1953:4; Stroud 1948:61; and others). As indicated in Table 10, very few bass from Lake Chautauqua were found that had lived more than 4 years, and no bass more than 7 years of age were found. Natural mortality rather than poor growth was believed responsible for the scarcity of large bass in Lake Chautauqua.

WARMOUTH GROWTH RATES.—A summary of age determinations made from scales of warmouths collected during the Lake Chautauqua study is presented in Table 11. The growth rates of Lake Chautauqua warmouths aged by us in the present study were much better than the growth rates of the Lake Chautauqua warmouths aged by Larimore (1957:65). Larimore aged only 30 warmouths from this lake. Perhaps his sample was too small or he had sampled a different segment of the population at Lake Chautauqua. The growth rates of Lake Chautauqua warmouths we aged were quite good for warmouths of Illinois waters (Larimore 1957:65). The

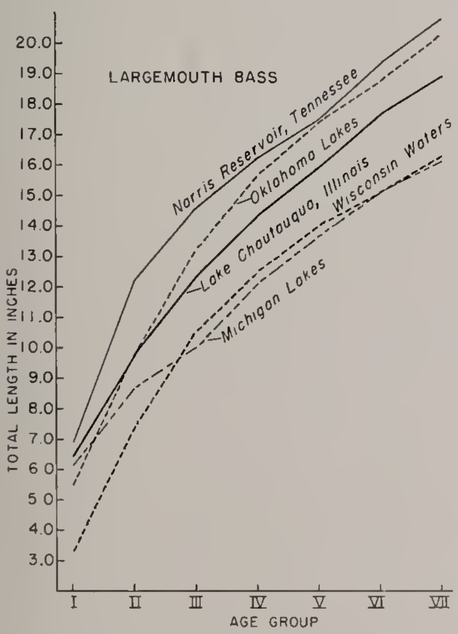


Fig. 8.—Growth of largemouth bass in Lake Chautauqua and in certain other waters of the United States. The graph is based on references included in text and on Table 10.

Table 10.—Average observed lengths and weights of largemouth bass of various ages at Lake Chautauqua, 1950–1959.

Age in Years	*Total Length in Inches*	*Average Weight in Pounds*	*Number of Fish*
1	6.4*	0.15*	62
2	9.8	0.51	252
3	12.3	1.05	120
4	14.3	1.69	41
5	15.9	2.32	16
6	17.7	3.29	11
7	18.9	4.20	3
Total	.		505

*Figures probably not representative of the age group, as many of the fish were taken by angling. Angling probably sampled only that segment of the population represented by the largest members of the 1-year-old brood.

Table 11.—Average observed lengths and weights and calculated lengths of warmouths of various ages at Lake Chautauqua, 1950–1959.

Age in Years	*Observed* Total Length in Inches	Average Weight in Pounds	Number of Fish	*Calculated* Total Length in Inches	Number of Fish
1	. .	. .	0	1.5	98
2	4.7	0.08	9	3.9	98
3	5.4	0.13	65	5.5	98
4	6.3	0.22	74	6.4	95
5	6.9	0.32	29	7.0	33
6	8.1	0.53	2	8.1	2
Total		.	*179*	. .	.

oldest warmouths we aged from Lake Chautauqua were 6 years old.

Pumpkinseed Growth Rates.—Age data for the relatively few pumpkinseeds we collected from Lake Chautauqua are presented in Table 12. Our data indicate that the growth rates of the pumpkinseed in Lake Chautauqua were comparatively good for the species in midwestern lakes (Table 12; Beckman 1949:72; Di Costanzo 1957:31; and others).

Table 12.—Average observed lengths and weights of pumpkinseed of various ages at Lake Chautauqua, 1950–1959.

Age in Years	*Total Length in Inches*	*Average Weight in Pounds*	*Number of Fish*
2	4.1	0.06	2
3	5.6	0.16	21
4	6.5	0.26	25
5	7.1	0.33	8
6	8.1	0.56	1
Total			57

Green Sunfish Growth Rates.—Scales were collected from only 48 green sunfish at Lake Chautauqua during the fall and spring months of the 1950–1959 period. The results of age determinations from these scales are presented in Table 13. If we can judge the growth rates of the green sunfish from this limited sample of scales, then the growth rates of the species in Lake Chautauqua were good compared with its growth rates in other midwestern waters (Bennett 1945:398; Cross, Deacon, & Ward 1959:164; Purkett 1958:36; Sprugel 1955:714; and others).

Table 13.—Average observed lengths and weights of green sunfish of various ages at Lake Chautauqua, 1950–1959.

Age in Years	*Total Length in Inches*	*Average Weight in Pounds*	*Number of Fish*
2	4.2	0.05	7
3	5.5	0.15	25
4	6.5	0.25	15
5	7.1	0.27	1
Total			48

White Crappie Growth Rates.—The age and growth data on white crappies of 2 years and older collected at Lake Chautauqua in 1950–1959 are summarized in Tables 14–16.

One-year-old white crappies taken in our test-net and minnow seine collections ranged from 3.0 to 4.0 inches in length. The average growth rate of white crappies of 2 years and older at Lake Chautauqua was quite good compared with growth rates of white crappies of the same ages in other waters (Table 14; Fig. 9; Hall, Jenkins, & Finnell 1954:7; Hansen 1951:252; Lewis 1950*a*:310; Purkett 1958:19; Ricker & Lagler 1942:89; Schoffman 1960:5; Stroud 1949:68; and Witt 1952:177). Fish over 5 years of age were not common in any of our white crappie collec-

Table 14.—Average observed lengths and weights of white crappies of various ages at Lake Chautauqua, 1949–1959.

Age in Years	*Average Total Length in Inches*	*Range in Length, Inches**	*Average Weight in Pounds*	*Range in Weight, Pounds**	*Number of Fish*
2	7.5	6.3– 8.3	0.23	0.12–0.31	1,952
3	9.3	8.6– 9.9	0.44	0.30–0.57	1,854
4	10.4	10.0–10.8	0.63	0.52–0.72	860
5	11.1	10.9–11.4	0.79	0.73–0.82	589
6	11.8	11.3–12.2	0.93	0.85–1.01	177
7	12.8	11.6–14.1	1.16	0.88–1.51	26
Total					5,458

*Range based on mean annual lengths or weights.

Table 15.—Average total lengths of white crappies of various ages at Lake Chautauqua, 1950–1959.

Year	*Age of Fish in Years*				
	2	3	4	5	6
1950	6.6	8.9	10.4	11.2	12.2
1951	6.9	8.6	10.0	11.0	11.8
1952	6.3	9.0	10.1	10.8	11.3
1953	8.1	9.7	10.4	11.1	11.3
1954	8.3	9.6	10.4	11.1	11.6
1955	7.2	9.5	10.5	11.1	11.7
1956	7.8	9.5	10.8	11.4	12.0
1957	8.0	9.3	10.2	11.1	12.1
1958	8.0	8.8	10.4	...	...
1959	8.1	8.9	10.0	10.9	...
Average	*7.5*	*9.2*	*10.3*	*11.1*	*11.8*

Table 16.—Sex ratios of white crappies of various ages; data from a sample of 401 fish taken March 24–April 2, 1954, in commercial wing nets at Lake Chautauqua.

Age in Years	*Male*		*Female*		*Number of Fish*
	Total Length in Inches	Per Cent of Collection Males	Total Length in Inches	Per Cent of Collection Females	
3	10.0	47.3	9.9	52.7	226
4	10.6	51.1	10.7	48.9	94
5	11.2	33.3	11.2	66.7	24
6	11.2	10.5	11.5	89.5	57
Total					*401*

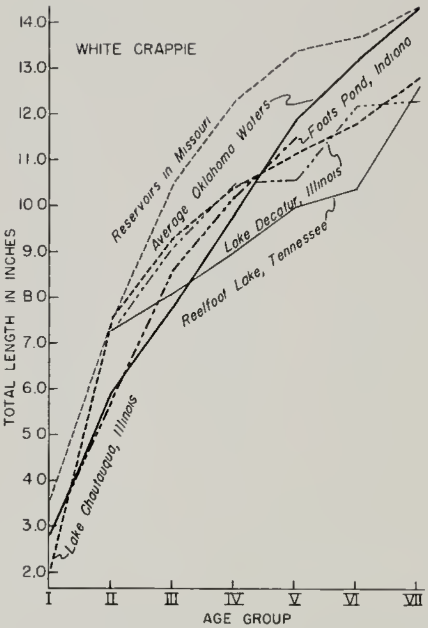


Fig. 9.—Growth of white crappies in Lake Chautauqua and in certain other waters of the United States. The graph was based on references included in the text and on Table 14 (except that length of 1-year-old fish at Lake Chautauqua was calculated).

tions. Only 26 of the white crappies that we examined had attained 7 years of age, and all but 4 of these fish were survivors of the large 1948 year-class.

After 1952, considerable increase occurred in the average lengths of Lake Chautauqua white crappies in their second summer of life (Table 15). The older fish also showed some increases in length after 1952 but did not maintain these increases in the later years of the investigation, as did the 2-year-old fish.

There appeared to be little or no difference in growth rates between the sexes of the 3-year-old and older white crappies at Lake Chautauqua (Table 16). The sex ratios of the 3- and 4-year-old fish considered together indicated a slight predominance of females. The comparatively large sample of 6-year-old white crappies showed that the females lived longer than the males. Hansen (1951:230-232) found at Lake Decatur, Illinois, that in the young white crappies he examined the number of males was greater than the number of females. He found a predominance of females in the fish older than 2 years of age. Witt (1952:119) determined from his study of reservoirs in Missouri, other than Niangua, that the female white crappie outlived the male.

Black Crappie Growth Rates.—In our investigation, 3,070 black crappies from Lake Chautauqua were aged (Tables 17 and 18). Apparently, very few black crappies in Lake Chautauqua lived more than 5 years. Most of the black crappies, as well as the white crappies, taken from the lake were less than 5 years of age. We took no fish of either species more than 7 years old. Our findings on age composition of the crappie populations were quite similar to those of Hall, Jenkins, & Finnell (1954:7, 23) in Oklahoma and Stroud

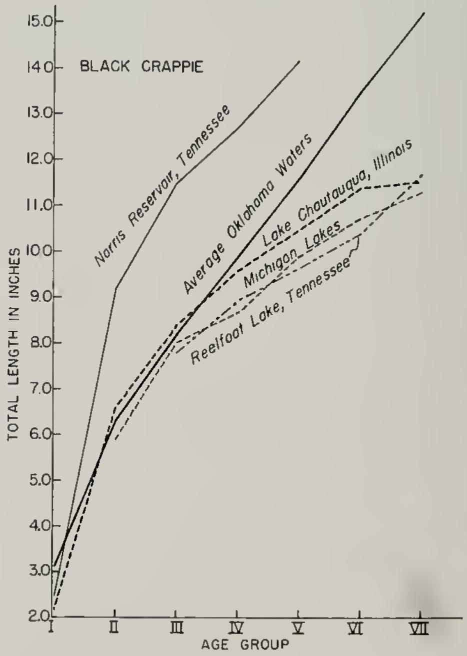


Fig. 10.—Growth of black crappies in Lake Chautauqua and in certain other waters of the United States. The graph was based on references included in the text and on Table 17 (except that length of 1-year-old fish was calculated).

(1948:67) in Tennessee. The studies of Huish (1958:302) in the Southeast indicated that black crappies with slow growth tended to live longer than those with fast growth. The fast growth of the crappies in Oklahoma, Tennessee, and Lake Chautauqua may have affected their life span.

One-year-old black crappies captured by minnow seine and test nets at Lake Chautauqua ranged from 3.0 to 4.0 inches in length. The growth rate of black crappies after their first year of life in Lake Chautauqua compared favorably with the growth rates of black crappies in other states (Table 17; Fig. 10; Beckman 1949:76; Hall, Jenkins, & Finnell 1954:23; Lewis 1950*a*:307; Purkett 1958:18; Schoffman 1940:28; and Stroud 1948:74 and 1949:67). The average lengths of black crappies of Lake Chautauqua at various ages are presented in Table 18. The average lengths of 2- and 3-year-old black crappies were slightly greater after 1952 than before. The average lengths of the older fish varied from year to year, as shown in Table 18.

YELLOW PERCH GROWTH RATES.—Few of the Lake Chautauqua perch that we aged had lived more than 4 years (Table 19). Parsons (1950:88) found that only a small percentage of the perch from Clear Lake, Iowa, were over 3

Table 17.—Average observed lengths and weights of black crappies of various ages at Lake Chautauqua, 1950–1959.

Age in Years	*Average Total Length in Inches*	*Range in Length, Inches**	*Average Weight in Pounds*	*Range in Weight, Pounds**	*Number of Fish*
2	6.6	5.8– 7.2	0.16	0.10–0.22	835
3	8.4	7.7– 9.2	0.35	0.23–0.51	1,022
4	9.6	9.0–10.2	0.53	0.47–0.67	776
5	10.5	9.9–10.9	0.71	0.54–0.77	331
6	11.3	10.8–11.8	0.90	0.83–1.07	97
7	11.5	11.2–11.7	0.91	0.84–0.97	9
Total					*3,070*

*Range based on mean annual lengths or weights.

Table 18.—Average total lengths of black crappies of various ages at Lake Chautauqua, 1950–1959.

Year	*Age of Fish in Years*				
	2	3	4	5	6
1950	6.0	7.7	10.0	10.9	11.7
1951	5.9	7.9	9.3	10.7	11.8
1952	5.8	7.8	9.1	9.9	11.8
1953	6.7	8.3	9.0	10.1	10.8
1954	7.2	8.5	9.5	10.4	
1955	7.1	9.2	9.8	10.3	11.0
1956	6.8	9.2	10.2	10.8	11.2
1957	7.1	8.5	9.7	10.7	11.3
1958	6.4	8.5	9.6	10.8	
1959	6.6	8.3	9.4	10.6	11.2
Average	*6.6*	*8.4*	*9.6*	*10.5*	*11.3*

Table 19.—Average observed lengths and weights of yellow perch of various ages at Lake Chautauqua, 1950–1959.

Age in Years	*Total Length in Inches*	*Average Weight in Pounds*	*Number of Fish*
2	7.1	0.16	23
3	8.3	0.29	52
4	9.7	0.44	52
5	10.7	0.60	2
Total			*129*

years old. He mentioned that in most populations perch are not particularly a long-lived fish. The growth rates of yellow perch at Lake Chautauqua, as shown by a limited sample, were at least fairly good compared with growth rates of perch elsewhere in the United States (Table 19; Beckman 1949:70; Jobes 1952:227; Lewis 1950*a*:313; McCaig & Mullan 1960:29; Van Oosten & Deason 1957:43; and others).

Channel Catfish Growth Rates.—The spines we used for aging channel catfish were collected from individuals taken in the commercial seine hauls during the month of September, 1953–1958 (Tables 20 and 21). The large mesh size of commercial seines used and the 13.0-inch size limit on catfish taken with commercial fishing devices in Illinois virtually eliminated young fish from our collections. Consequently,

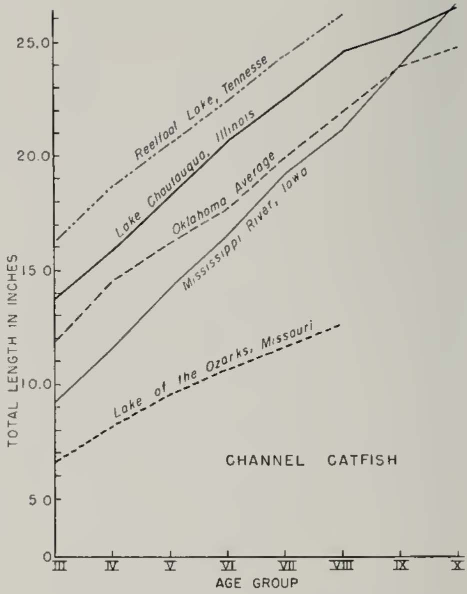


Fig. 11.—Growth of channel catfish in Lake Chautauqua and in certain other waters of the United States. The graph was based on references included in text and on Table 20.

Table 20.—Average observed lengths and weights of channel catfish of various ages at Lake Chautauqua, 1953–1958.

Age in Years	*Average Total Length in Inches*	*Range in Length, Inches**	*Average Weight in Pounds*	*Range in Weight, Pounds**	*Number of Fish*
3	13.7	13.2–14.4	0.79	0.69– 0.91	2C8
4	15.8	15.2–16.8	1.29	1.13– 1.59	865
5	18.2	17.8–18.8	2.10	1.93– 2.32	519
6	20.6	19.6–21.2	3.22	2.74– 3.43	221
7	22.4	20.3–23.6	4.38	2.87– 5.17	105
8	24.6	22.6–25.9	5.91	4.63– 6.65	65
9	25.3	24.5–27.0	6.56	5.67– 7.97	39
10	26.5	23.9–29.2	7.98	5.46–10.75	24
11	26.6	23.2–27.8	8.41	4.21–10.28	11
12	28.1	26.6–29.2	10.16	6.79–12.50	4
13					0
14	30.5		13.50		1
15	28.8	26.5–31.1	11.75	8.37–15.13	3
Total					*2,065*

*Range based on mean annual lengths or weights.

Table 21.—Average total lengths of channel catfish of various ages at Lake Chautauqua, 1953–1958.

Year	Age of Fish (Years)				
	3	4	5	6	7
1953	...	15.4	17.9	20.5	23.3
1954	13.2	15.6	17.9	20.8	23.4
1955	14.0	16.0	18.4	21.2	23.6
1956	14.4	16.8	18.5	20.3	21.8
1957	13.2	15.9	18.8	19.6	20.3
1958	13.7	15.2	17.8	20.9	21.8
Average	*13.7*	*15.8*	*18.2*	*20.6*	*22.4*

the 13.7 inches total length average for the Lake Chautauqua 3-year-old channel catfish was biased because of the scarcity of fish under 13.0 inches in our samples. The growth rates of channel catfish in Lake Chautauqua were excellent compared with the growth rates of these catfish in some other waters of the mid-continent (Tables 20 and 21; Fig. 11; Appelget & Smith 1951:123; Finnell & Jenkins 1954:10; Schoffman 1954:5; Marzolf 1955:247; Harrison 1957:662; and Muncy 1959:130). Data on the average lengths of Lake Chautauqua channel catfish of various ages (Table 21) indicate that only minor variations occurred in the year-to-year growth rates of these catfish.

FRESHWATER DRUM GROWTH RATES.—The scales used for aging 2,345 freshwater drum at Lake Chautauqua were collected from fish taken in the commercial seines used on the lake each September, 1951–1958. Age and growth information is given in Tables 1 and 22. The average length of 9.7 inches shown in Table 22 for 2-year-old fish is probably too high because of two known biases in our samples. In Illinois, it is illegal to take drum under 10.0 inches in length (undressed) with commercial fishing devices. The large mesh size of the seines used on the lake allowed the escape of most of the drum under 9.0 inches in length. The drum aged in this study as 2-year-olds, and to a lesser extent the drum aged as 3-year-olds, were probably the largest members of their year-classes.

The growth rates of drum at Lake Chautauqua were fair compared with growth rates recorded from some other waters (Tables 1 and 22; Fig. 12; Butler & Smith 1950:51; Greer & Cross 1956:362; Houser 1960*a*:10 and 1960*b*:11; Jenkins 1951:92; Schoffman 1941:108; and Van Oosten 1938:656). The average lengths of drum of various

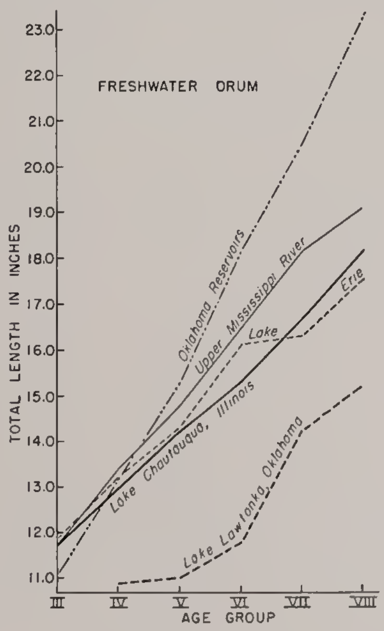


Fig. 12.—Growth of freshwater drum in Lake Chautauqua and in certain other waters of the United States. The graph was based on references included in text and on Table 22.

Table 22.—Average observed lengths and weights of freshwater drum of various ages at Lake Chautauqua, 1951–1958.

Age in Years	*Average Total Length in Inches*	*Range in Length, Inches**	*Average Weight in Pounds*	*Range in Weight, Pounds**	*Number of Fish*
2	9.7	9.1–10.4	0.41	0.33–0.53	159
3	11.7	11.2–11.9	0.74	0.64–0.79	492
4	12.9	12.4–13.2	1.04	0.88–1.14	636
5	14.2	13.7–14.5	1.37	1.14–1.55	646
6	15.3	14.8–15.7	1.72	1.40–1.94	303
7	16.7	16.2–17.5	2.18	1.77–2.56	87
8	18.2	17.4–20.0	2.77	2.30–3.86	15
9	18.9	18.6–19.2	3.00	2.59–3.40	2
10	21.6	19.5–21.6	4.55	3.56–5.53	2
11	23.3	....	8.46	....	1
12	23.8	....	7.81	....	1
13	...	....	...	....	0
14	28.2	....	11.64	....	1
Total				....	*2,345*

*Range based on mean annual lengths or weights.

ages (Table 1) show that some variations occurred from year to year in growth rates of the species in Lake Chautauqua. The average lengths indicated particularly poor growth rates in the fish caught in 1955 and 1956.

Bigmouth Buffalo Growth Rates. —The scales used in aging the Lake Chautauqua bigmouth buffalo were collected each September of our study from fish taken with commercial seines. The average observed lengths of bigmouth buffalo of various ages are presented in Tables 23 and 24. Most of the buffalo in the commercial seine hauls were 3 to 8 years of age (Table 23).

Table 23.—Average observed lengths and weights of bigmouth buffalo of various ages at Lake Chautauqua, 1951–1958.

Age in Years	*Average Total Length in Inches*	*Range in Length, Inches**	*Average Weight in Pounds*	*Range in Weight, Pounds**	*Number of Fish*
2	11.8	10.8–12.9	0.96	0.72– 1.14	38
3	15.3	14.8–15.7	2.12	1.85– 2.33	233
4	17.0	16.7–17.5	2.97	2.79– 3.16	606
5	18.9	18.4–19.3	4.27	3.85– 4.54	604
6	20.7	20.0–21.0	5.67	5.18– 5.94	420
7	22.2	21.7–22.9	7.04	6.76– 7.64	247
8	23.3	23.0–23.9	8.49	8.01– 9.48	157
9	24.5	24.1–24.9	9.95	9.65–10.51	118
10	25.7	25.2–26.5	11.59	10.61–13.75	97
11	26.5	24.8–27.6	12.93	10.92–14.17	78
12	27.5	26.9–28.1	14.43	13.25–15.63	66
13	28.9	27.5–30.6	16.89	15.00–19.75	44
14	29.3	27.9–30.5	18.18	16.88–20.38	25
15	30.3	29.2–31.0	19.85	18.42–22.00	15
16	30.7	30.5–30.9	22.88	22.00–23.50	6
17	31.0	.	18.25	.. ..	1
Total				....	*2,755*

*Range based on mean annual lengths or weights.

The growth rates of the 2- and 3-year-old bigmouth buffalo at Lake Chautauqua were very good. However, the growth rates of the older fish of this species were only fair compared with the growth rates of comparable individuals in other waters (Tables 23 and 24; Fig. 13; Eddy & Carlander 1939:9 and 1942:21; Frey & Pedracine 1938:516, species of buffalo not separated; Gowanlock 1951:12; Greer & Cross 1956:359; Jenkins 1953:61; Jenkins, Leonard, & Hall 1952:77; and Schoffman 1943:39). Variations in the growth rates from year to year were very slight, as indicated by average lengths in Table 24.

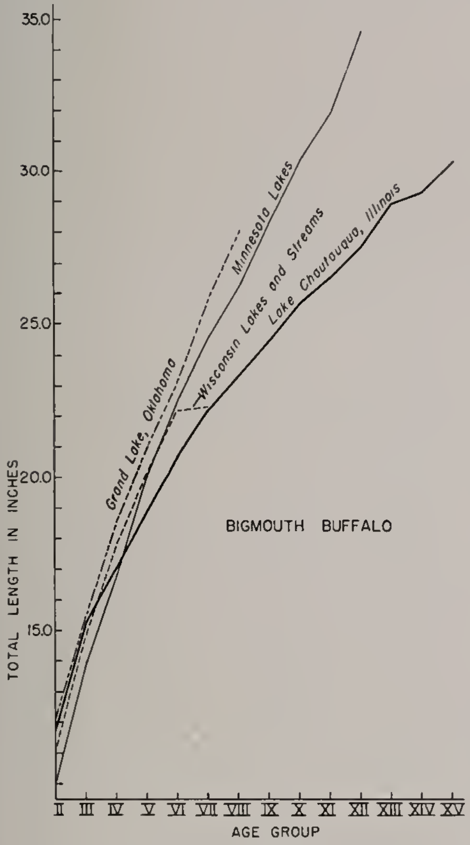


Fig. 13.—Growth of bigmouth buffalo in Lake Chautauqua and in certain other waters of the United States. The graph was based on references included in text and on Table 23.

CARP GROWTH RATES.—The difficulties involved in aging carp from scales have been discussed by Frey (1942: 217) and others. In the present study, we aged carp from cross sections of the dorsal spine. We do not place complete confidence in our age determinations, since the method we used apparently has not been validated with fish of known ages.

A summary of the carp age determinations we made from dorsal spines is presented in Table 25. The growth rates of Lake Chautauqua carp should perhaps be regarded as intermediate compared with the growth rates of carp in some other waters (Table 25; Fig. 14; English 1952:534; Jackson 1955:13; Jenkins 1953:73; McConnell 1952:146; Patriarche 1953:249; Purkett 1958:10; Schoffman 1942:71; and Thompson 1950:29). The average annual weight

Table 24.—Average total lengths of bigmouth buffalo of various ages at Lake Chautauqua, 1951–1958.

Year	Age of Fish (Years) 3	4	5	6	7	8	9	10
1951	15.4	17.1	19.0	20.8	22.9	23.7	24.5	25.7
1952	14.8	16.9	18.7	20.5	22.0	23.0	24.3	25.6
1953	14.9	16.7	19.0	20.8	22.5	23.9	24.9	25.6
1954	15.4	17.5	19.2	21.0	22.0	23.1	24.8	25.3
1955	15.7	16.9	19.0	20.6	21.8	23.2	24.4	25.9
1956	15.6	17.1	19.3	20.9	22.7	23.1	24.7	26.5
1957	15.1	16.8	18.7	20.6	21.7	23.0	24.1	25.2
1958	15.4	16.7	18.4	20.0	21.9	23.1	24.4	25.6
Average	*15.3*	*17.0*	*18.9*	*20.7*	*22.2*	*23.3*	*24.5*	*25.7*

increment of carp after the second year through the sixth year at Lake Chautauqua was about 1 pound.

White Bass Growth Rates.—Age and growth data for the white bass at Lake Chautauqua in the period 1950–1958 are summarized in Table 26. The growth rates of these fish were about average compared with the growth rates of white bass in some other waters of the United States (Table 26; Fig. 15; Lewis 1950*b*:274; Jenkins & Elkin 1957:7; Patriarche 1953:249; Sigler 1949*a*:217 and 1949*b*:313; Thompson 1951:107; Tompkins & Peters 1951:8; Upper Mississippi River Conservation Committee 1946:20; Van Oosten 1942: 316; and Ward 1951:78). The white bass in Lake Chautauqua were short-lived. Very few were found that had

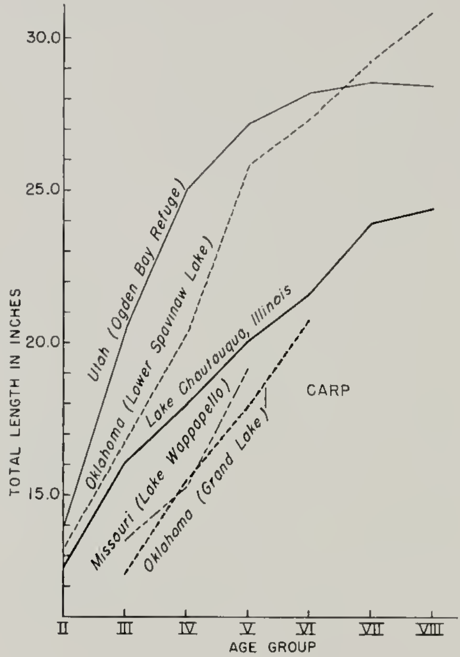


Fig. 14.—Growth of carp in Lake Chautauqua and in certain other waters of the United States. The graph was based on references included in the text and on Table 25.

Table 25.—Average observed lengths and weights of carp of various ages at Lake Chautauqua, September of 1957 and 1958.

Age in Years	*Average Total Length in Inches*	*Average Weight in Pounds*	*Number of Fish*
2	12.6	1.08	59
3	16.1	2.02	33
4	18.0	2.88	46
5	20.1	3.89	40
6	21.6	4.88	21
7	23.9	6.74	16
8	24.4	7.41	7
9	27.5	10.42	9
10	27.3	10.20	14
11	28.7	11.42	5
12	30.9	15.83	3
Total			253

Table 26.—Average observed lengths and weights of white bass of various ages at Lake Chautauqua, 1950–1958.

Age in Years	*Average Total Length in Inches*	*Average Weight in Pounds*	*Number of Fish*
1	7.2	0.19	194
2	11.4	0.76	316
3	13.1	1.20	223
4	14.2	1.50	119
5	15.6	2 04	14
Total			866

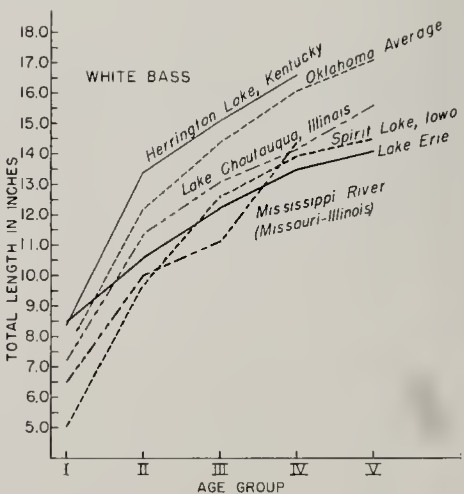


Fig. 15.—Growth of white bass in Lake Chautauqua and in certain other waters of the United States. The graph was based on references included in text and on Table 26.

Table 27.—Size distribution of young-of-the-year yellow bass in the 1958 minnow seine haul collections at Lake Chautauqua.

Date of Collection	Number of Fish of Indicated Total Length in Inches						Total Number of Fish
	1.0	1.5	2.0	2.5	3.0	3.5	
July 2	1	18	3	0	0	0	22
July 11	0	21	12	0	0	0	33
July 18	0	6	129	4	0	0	139
August 28	0	0	1	5	41	2	49

Table 28.—Average lengths and weights of yellow bass of various ages at Lake Chautauqua, 1950–1952, 1954, and 1957–1959.

Age in Years	Average Total Length in Inches	Range in Length, Inches*	Average Weight in Pounds	Range in Weight, Pounds*	Number of Fish
2	7.1	7.0– 7.4	0.18	0.15–0.20	192
3	8.4	8.1– 8.7	0.31	0.28–0.38	309
4	9.5	9.1– 9.7	0.46	0.39–0.54	225
5	10.3	10.1–10.6	0.61	0.51–0.72	308
6	11.0	10.6–11.3	0.74	0.61–0.81	195
7	11.7	11.5–12.0	0.92	0.87–0.96	12
Total	...	....	...	......	*1,241*

*Range based on mean annual lengths or weights.

lived more than 3 years. A similar situation was noted in Lake Erie by Van Oosten (1942:313). The oldest white bass taken from Lake Chautauqua were 5 years of age (Table 26).

YELLOW BASS GROWTH RATES.—The lengths of young-of-the-year yellow bass at Lake Chautauqua in the summer of 1958 are presented in Table 27. These data indicate that most of the young fish were 3.0 inches long by late August. At Lake Chautauqua, spawning by the yellow bass occurred in late

Table 29.—Average total lengths of yellow bass of various ages at Lake Chautauqua, each spring, 1950–1952, 1954, and 1957–1958.

Year	Age of Fish (Years)				
	2	3	4	5	6
1950	7.4	8.4	9.7	10.3	11.2
1951	7.0	8.4	9.1	10.2	10.8
1952	7.0	8.7	9.6	10.4	11.0
1954		8.1	9.4	10.2	10.8
1957	7.0	8.5	9.7	10.6	11.2
1958	7.1	8.4	9.5	10.1	11.3
1959	7.1	8.5	9.3	10.1	10.6
Average	*7.1*	*8.4*	*9.5*	*10.3*	*11.0*

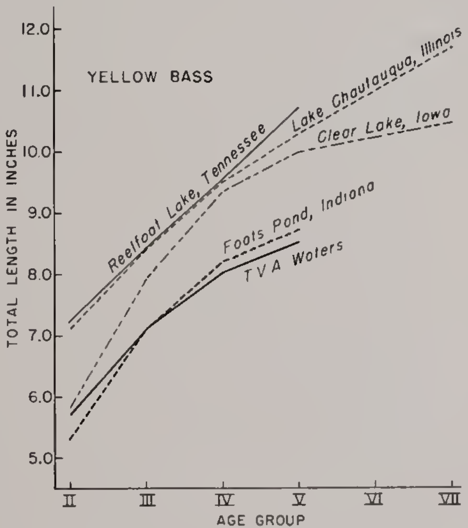


Fig. 16.—Growth of yellow bass in Lake Chautauqua and in certain other waters of the United States. The graph was based on references included in text and on Table 28.

April and May. The growth rates of the yellow bass at Lake Chautauqua were excellent compared with growth rates of the species reported elsewhere (Table 28; Fig. 16; Carlander, Lewis, Ruhr, & Cleary 1953:97; Lewis & Carlander 1948:191; Ricker & Lagler 1942:94; Schoffman 1940:40 and 1958:102; and Stroud 1947:82). At Lake Chautauqua, the growth rates of yellow bass continued to be good throughout life; however, most of the yellow bass did not live beyond 5 years and none lived more than 7 years. Anglers at Lake Chautauqua who fished for yellow bass were dependent largely upon 2-, 3-, 4-, and 5-year-old fish. Only slight variations occurred from year to year in the growth patterns of the fish (Table 29).

Age Composition of Catch

The preceding section demonstrated that growth rates in most of the common and abundant fish species in Lake Chautauqua compared favorably with growth rates of these species in other waters and that in a few species the growth rates were excellent. Lack of stunted fish or slow growth of the fishes studied indicated that the fish populations of Lake Chautauqua were not overcrowded during the years of our investigation. However, the aging studies revealed that in some species the population was dominated for several years by one or two year-classes.

The present section is largely concerned with the age composition of the catch of nine species of fishes and the fluctuations that occurred from year to year in their age composition. In some instances it was possible to trace a year-class of a species in the commercial or sport fishery back to its occurrence as young-of-the-year in the minnow seine hauls. We made minnow seine hauls each summer in the period 1950–1959 in an attempt to determine spawning success of various species. A summary of these seine hauls for seven important species is given in Table 30. In 1951 and 1954, only limited numbers of hauls were made.

Freshwater Drum: Age Composition of Catch.—Each year in the period 1951–1958, the age composition of the commercial seine hauls of drum at Lake Chautauqua was determined. The data are presented graphically in Fig. 17, which indicates that the bulk of the catch was composed of 3-, 4-, and 5-year-old fish. We believe that the commercial seine haul collections were fairly accurate samples of the popula-

Table 30.—Number of young-of-the-year of certain fishes caught in minnow seine hauls during the summer months at Lake Chautauqua, 1950–1959.

Year and Number of Hauls	*Freshwater Drum*		*Bigmouth Buffalo*		*Carp*	
	Number Caught	Number Per Haul	Number Caught	Number Per Haul	Number Caught	Number Per Haul
1950 (24)	6	0.3	0	. . .	6	0.3
1951 (5)	2	0.4	0	. . .	0	. . .
1952 (10)	18	1.8	0	. . .	0	. . .
1953 (11)	0	. . .	118	10.7	6,629	602.6
1954 (4)	4	1.0	0	. . .	7	1.8
1955 (10)	3	0.3	0	. . .	6	0.6
1956 (13)	46	3.5	4	0.3	32	2.5
1957 (26)	3	0.1	0	. . .	2	0.1
1958 (34)	25	0.7	1	*	5	0.1
1959 (59)	0	. . .	20	0.3	56	0.9

*Less than 0.01 fish per haul.

tions of 4-year-old and older drum present each year. The 1950 and 1954 year-classes formed important constituents of the commercial catch of drum (1950 year-class shown as 4-year-olds in 1953, 5-year-olds in 1954, and 6-year-olds in 1955; 1954 year-class shown as 3-year-olds in 1956, 4-year-olds in 1957, and 5-year-olds in 1958). No large year-class appeared in the minnow seine collections (Table 30). Fish of the 1953 year-class were not taken as young in the minnow seine collections, and in the fall of 1956 this year-class as 4-year-old fish represented only a very small part of the drum population, as shown in Fig. 17. In 1959, no young-of-the-year drum were taken in 59 minnow seine collections. The later effect on the commercial fishery resulting from the apparent spawning failure in 1959 was not determined.

Very few drum over 6 years of age were taken from the lake in our study period (Table 22). Only seven drum in our collections were determined to be over 8 years of age. Even in 1951, at the beginning of our seining program, fish over 6 years of age were scarce in the seine haul collections. Apparently very few drum in Lake Chautauqua lived more than 8 years. The oldest drum taken at this lake, as shown in Table 22, was 14 years of age. Van Oosten (1938:

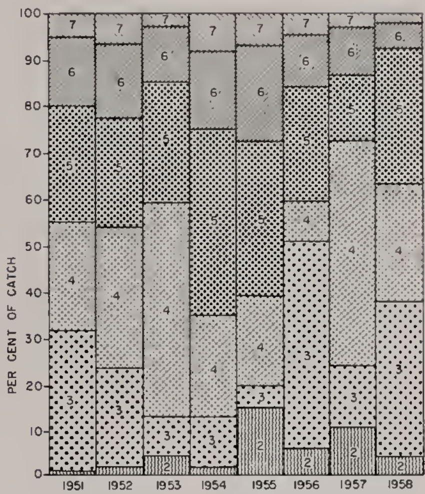


Fig. 17.—Age composition of freshwater drum in the commercial seine hauls at Lake Chautauqua, September, 1951–1958. The portions of the graph representing 7-year-old fish also included those fish that were over 7 years of age.

654) found only two drum in his collections from Lake Erie that were more than 8 years of age. One of his fish was in its 13th year, and the other was at least 17 years of age. The oldest drum that Butler & Smith (1950:46) aged in their study of fish taken from the Upper Mississippi River was 11 years old. They had only 10 drum in their collections from the Mississippi River that were over 8 years of age. Schoffman

Table 30.—Continued

Year and Number of Hauls	*Gizzard Shad*		*Bluegill*		*Crappies*		*Yellow Bass*	
	Number Caught	Number Per Haul	Number Caught	Number Per Haul	Number Caught	Number Per Haul	Number Caught	Number Per Haul
1950 (24)	87	3.6	279	11.6	86	3.6	298	12.4
1951 (5)	150	30.0	1	0.2	8	1.6	2	0.4
1952 (10)	92	9.2	304	30.4	19	1.9	6	0.6
1953 (11)	621	56.5	106	9.6	0		29	2.6
1954 (4)	2,000	500.0	17	4.3	16	4.0	0	. . .
1955 (10)	58	5.8	2,534	253.4	34	3.4	24	2.4
1956 (13)	280	21.5	211	16.2	66	5.1	18	1.4
1957 (26)	80	3.1	879	33.8	52	2.0	369	14.2
1958 (34)	71	2.1	772	22.7	23	0.7	261	7.7
1959 (59)	988	16.7	849	14.4	47	0.8	340	5.8

(1941:103) found only seven drum more than 8 years old (oldest 11 years) at Reelfoot Lake, Tennessee. Houser (1960*b*:4), working on drum in Oklahoma waters, found only a small percentage of the fish were over 8 years of age. The oldest drum in the Oklahoma study was 14 years of age.

Bigmouth Buffalo: Age Composition of Catch.—In our 10 years of min-

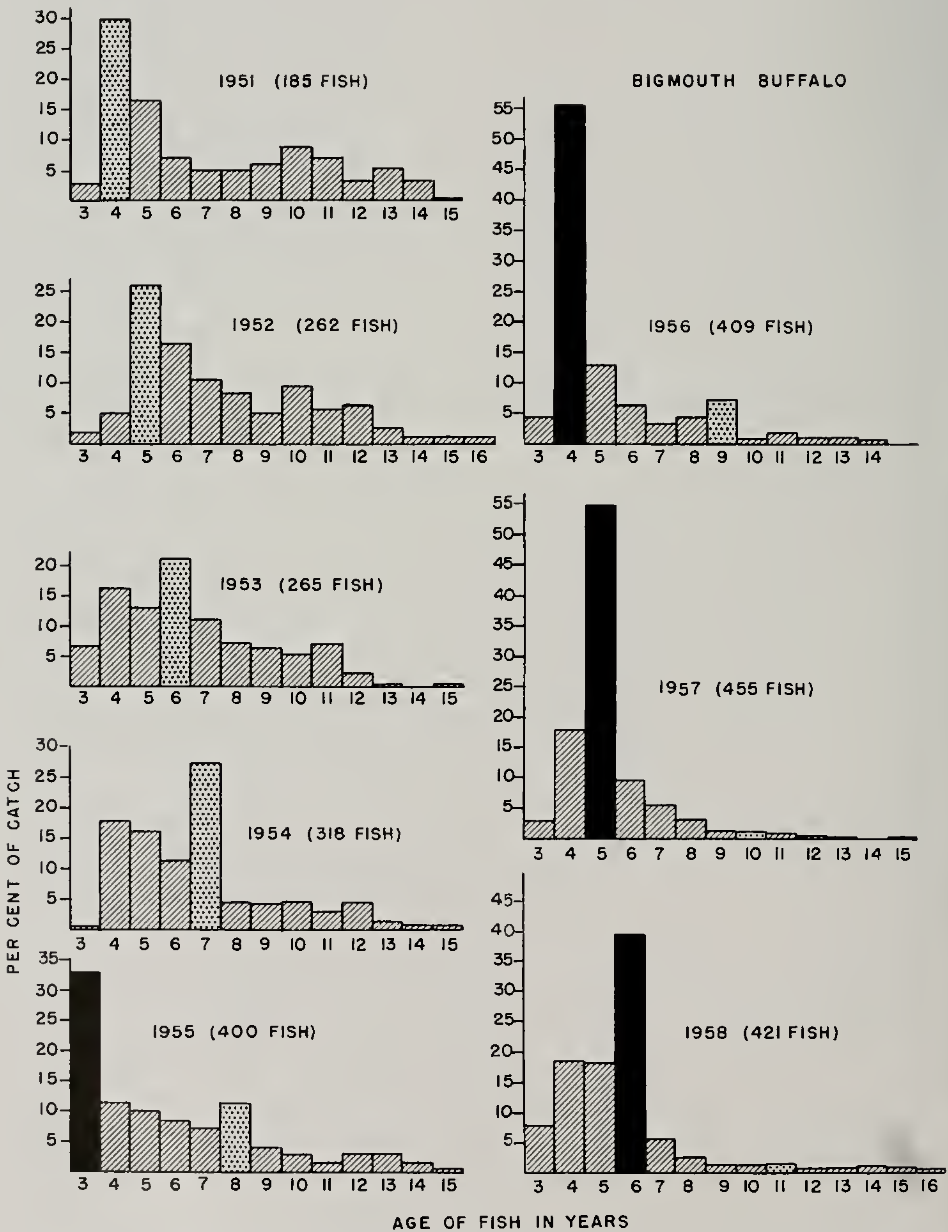


Fig. 18.—Age composition of bigmouth buffalo in the commercial seine hauls at Lake Chautauqua, September, 1951–1958. The large 1948 year-class of buffalo is represented in each of the 1951–1958 graphs by a stippled bar; fish of this year-class are shown in 1951 as 4-year-olds. The solid black bar in each of the graphs in the period 1955–1958 demonstrates the importance of the large 1953 year-class.

now seining at Lake Chautauqua (1950–1959), only one large year-class of bigmouth buffalo appeared in the hauls, that being in 1953 (Table 30). In the fall of 1955, the largest members of the 1953 year-class appeared in the commercial seine collections as 3-year-old fish (Fig. 18). The 1953 year-class is designated on the bar graphs in black. Fig. 18 shows that this year-class dominated the catch from 1955 through 1958. Earlier the buffalo fishery was dominated by the 1948 year-class. In the fall of 1951, this large year-class (stipple on graph) appeared in the commercial seine hauls as 4-year-old fish (Fig. 18). It remained readily distinguishable from other broods in the commercial seine hauls through 1956.

The annual additions of bigmouth buffalo to the adult population were insufficient to maintain a large-size population in the face of heavy fish removal. There appeared to be only a limited amount of recruitment from the Illinois River.

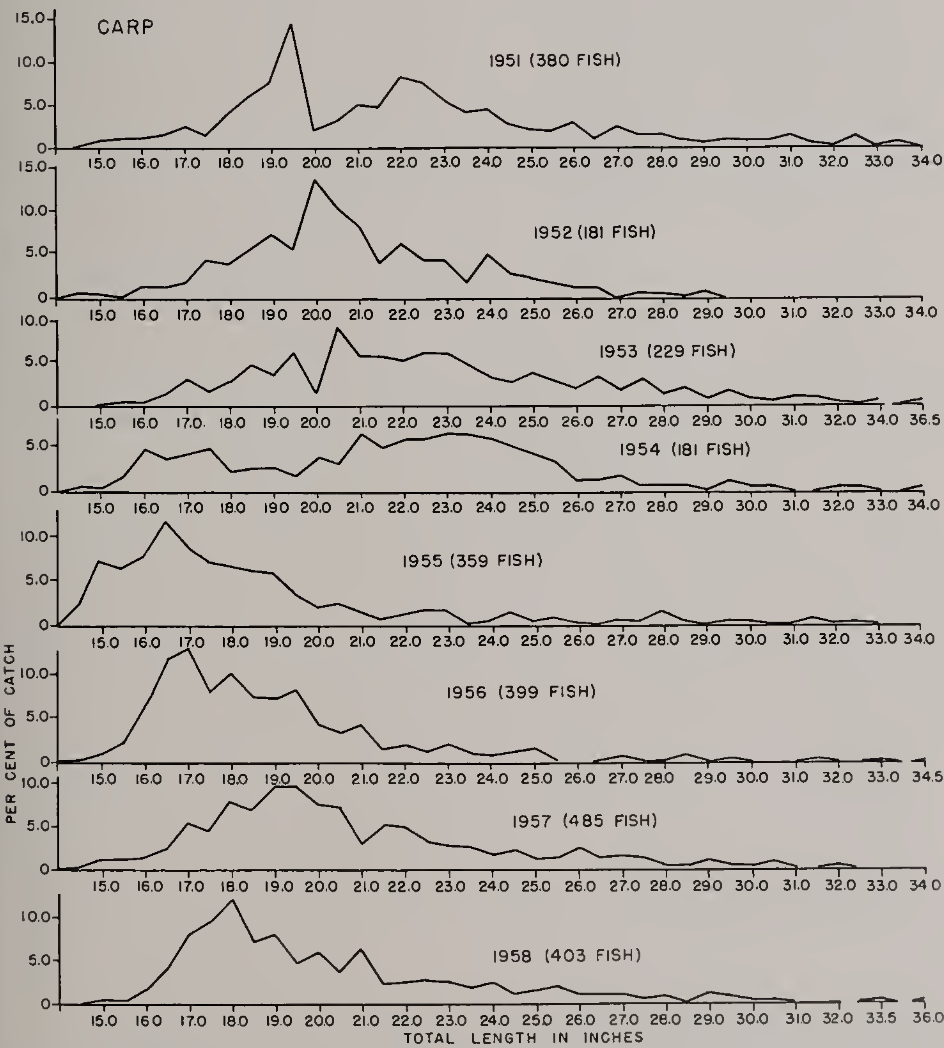
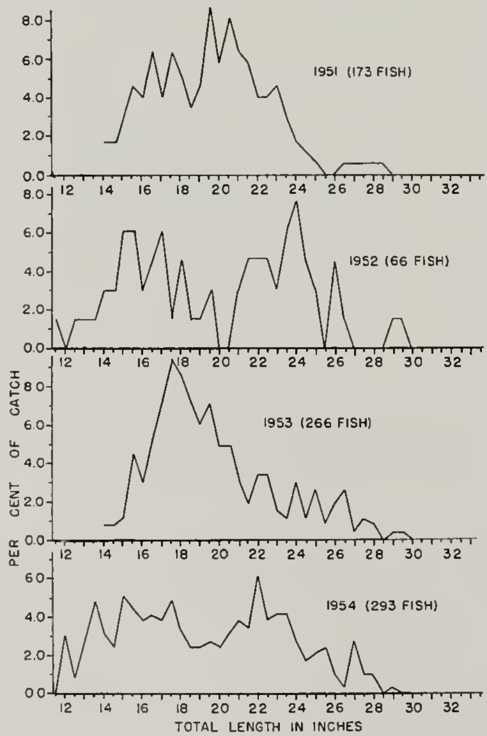


Fig. 19.—Length-frequency distribution of carp in the commercial seine hauls at Lake Chautauqua, September, 1951–1958. The graphs were based on measurements of 2,590 carp.

In the years of our investigation, only two dominant year-classes of bigmouth buffalo appeared in the adult fishery, those of 1948 and 1953. At Spirit Lake, Iowa, O. J. Koch noted that young buffalo appeared in large numbers only about every 5 years (Sigler 1949*a*:210). The presence of a large adult population of fish 6 years and older at Lake Chautauqua in 1951 and 1952 indicated that, with commercial fishing of light intensity (individual wing-net fishing), broods of small to moderate size, coupled with an occasional large brood, were sufficient to maintain a population of bigmouth buffalo of desirable sizes.

The increased removal of bigmouth buffalo after 1951 (Table 5) changed the buffalo population of Lake Chautauqua in 4 years from one containing a high percentage of old, large fish to one of predominantly young, small fish (Fig. 18). The dominant 1953 brood appears in Fig. 18 to have been much stronger in 1956 than the 1948 brood was in 1951. Actually these broods as 4-year-old fish were of about equal strength; the comparatively smaller number of old fish in 1956 than in 1951 was responsible for the apparent difference indicated by Fig. 18.

Carp: Age Composition of Catch.—Age readings indicated that most of the carp taken commercially in the seine hauls at Lake Chautauqua in 1957 and 1958 were 4-, 5-, and 6-year-old fish. The carp taken commercially in the early years of our study were of larger sizes than those taken in 1957 and 1958



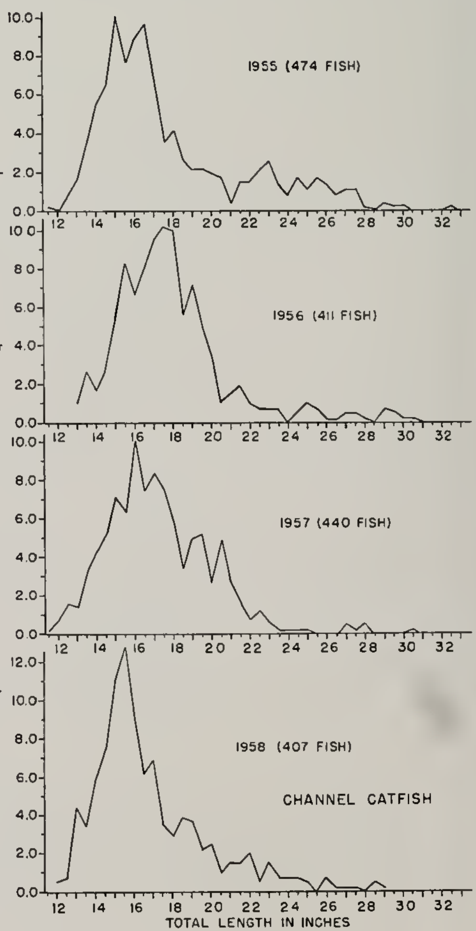


Fig. 20.—Length-frequency distribution of channel catfish in the commercial seine hauls at Lake Chautauqua, 1951–1958. The graphs reveal the changes that occurred in the sizes of catfish as a result of increased fishing pressure on the species.

(Fig. 19) and were probably older fish. A great abundance of young carp in the minnow seine hauls of 1953 indicated a tremendous spawn in that year (Table 30). The 1953 year-class of carp began to be taken as usable-size fish (approximately 15 inches and longer) in the commercial seine hauls in September of 1955. The identity of this large year-class was based on (i) the length-frequency graph (Fig. 19), which showed a high peak for the year 1955 at 16.5 inches, and (ii) the aging study (Table 25), which showed that 3-year-old carp averaged 16.1 inches in length. The 1953 brood also formed an important part of the 1956 catch but was of lesser importance in the 1957 catch. The population statistics discussed in the next section revealed that the 1953 year-class did not materialize into as large a brood of fish as was expected earlier. During the years 1955 and 1956, the population of usable-size carp was at its lowest point (Table 33 and Fig. 19). Much of the 1953 year-class was lost either through escapement into the Illinois River during periods of high water or through natural mortality. We believe the former was the more important cause of loss.

In 1957, both usable-size and subusable-size carp were abundant in the seine hauls. We believe that many carp of both of these groups were recruited from the river after September of 1956. This belief was at least partly confirmed by the presence of only small numbers of usable-size and subusable-size carp in the lake in September of 1956 (Table 33 and Fig. 19) and the small number of young carp in our minnow seine hauls after 1953 (Table 30). Carp of both sizes were quite common in the 1958 commercial seine hauls (Table 33 and Fig. 19).

CHANNEL CATFISH: AGE COMPOSITION OF CATCH.—During our study, a few young-of-the-year channel catfish were taken at Lake Chautauqua each year (other than 1954 and 1955) either in the minnow seine or rotenone collections. The small numbers taken gave no clue to the strength of any of the year-classes.

We did not begin to age channel catfish in the commercial seine haul collections until 1953. The catfish in the

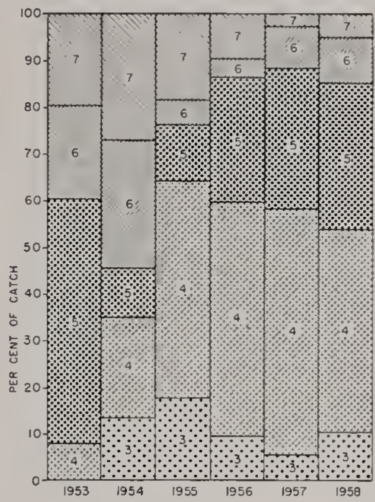


Fig. 21.—Age composition of channel catfish in the commercial seine hauls at Lake Chautauqua, 1953–1958. The bars for the years 1955–1958 show the predominance of 4-year-old fish in the catches. The portions of the graph representing 7-year-old fish also included fish over 7 years of age. Very few channel catfish more than 8 years of age were collected.

seine hauls (Fig. 20) averaged larger in the years 1951–1954 than in subsequent years. Five-year-old and older fish dominated the catfish catch in the seine hauls in 1953 and 1954 (Fig. 21). The comparatively high percentage of large fish taken in the seine hauls in 1951 and 1952 (Fig. 20) indicates that the catfish catch in those 2 years also was composed largely of 5-year-old and older fish. After 1954, the fishery was dependent largely upon 4-year-old fish (Fig. 21). The 4-year-old fish in each year did not represent a large year-class, although Fig. 21 seems to show it did. In 1958, the total catfish population was down in numbers, and the 4-year-old population in that year, even though it dominated the fishery, was small compared to the 4-year-old population in

1956. The change in the fishery from one predominantly of 5-year-old and older fish before 1955 to one of younger fish after 1954 was believed by us to have been caused by the increased commercial removal of catfish from the lake, beginning in 1954 (Table 5).

Finnell & Jenkins (1954:5) aged 7,717 channel catfish from 107 different waters in Oklahoma and reported none more than 14 years of age. They concluded that few channel catfish live more than 7 years in Oklahoma. Our findings at Lake Chautauqua tend to corroborate the Oklahoma studies on the longevity of channel catfish. Only three of the channel catfish that we aged were more than 14 years old (Table 20). Few Lake Chautauqua catfish lived more than 7 or 8 years. Increased fishing pressure on catfish after 1953 no doubt had an effect on their survival; however, the age determinations made on the catfish caught in 1953 and 1954

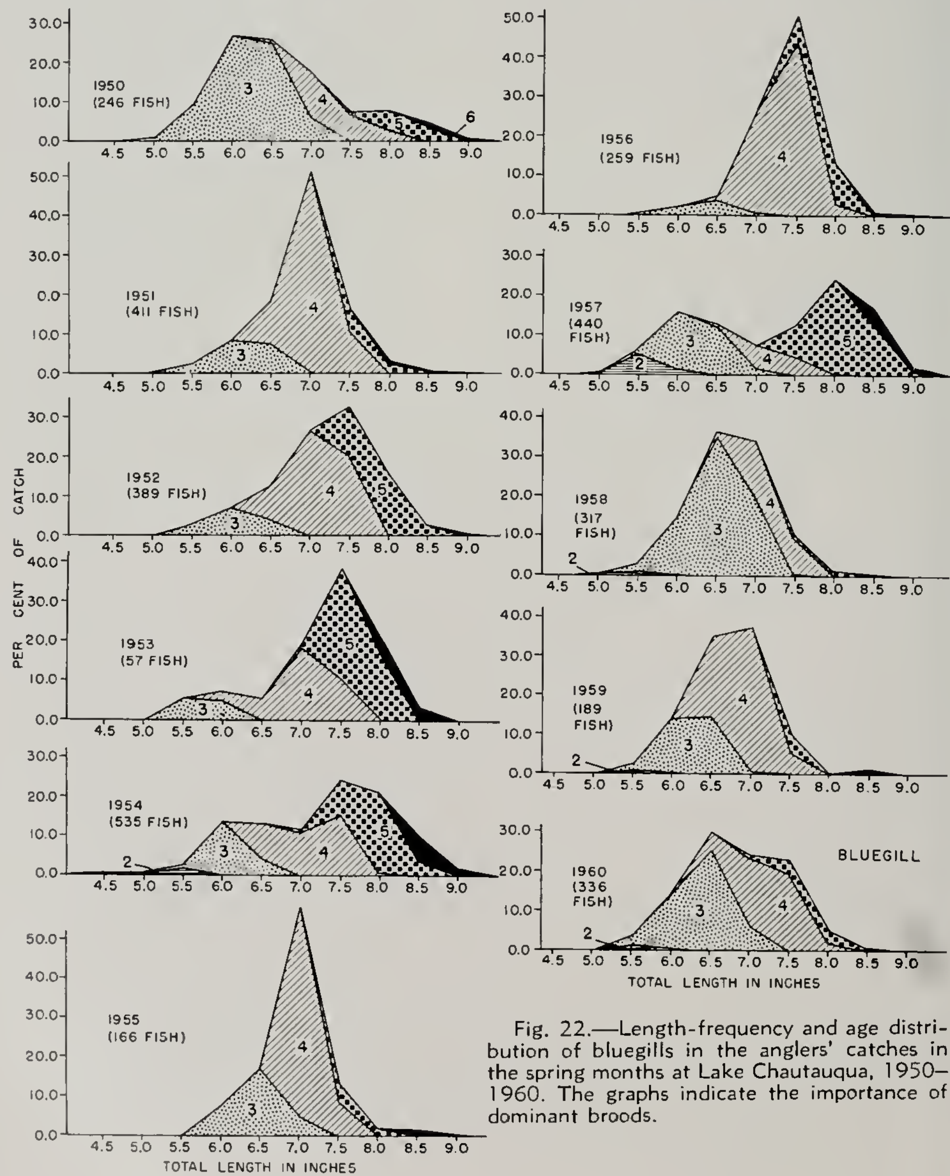


Fig. 22.—Length-frequency and age distribution of bluegills in the anglers' catches in the spring months at Lake Chautauqua, 1950–1960. The graphs indicate the importance of dominant broods.

did not indicate the presence of many fish over 8 years of age.

Bluegill: Age Composition of Catch.—The changes that occurred in the age composition of the bluegill population of 3-year-old and older fish at Lake Chautauqua is illustrated by the anglers' catches in the spring months of 1950–1960 (Fig. 22). The graphs reveal that, in most years, the bluegill population was made up of members of several broods, of which one brood had better representation than the others. Minnow seine hauls showed that bluegills spawned with varying degrees of success in the years of our study (Table 30). The success of the several year-classes varied considerably in later life. The sport fishery was largely dependent upon 3-, 4-, and 5-year-old fish, as shown in Fig. 22.

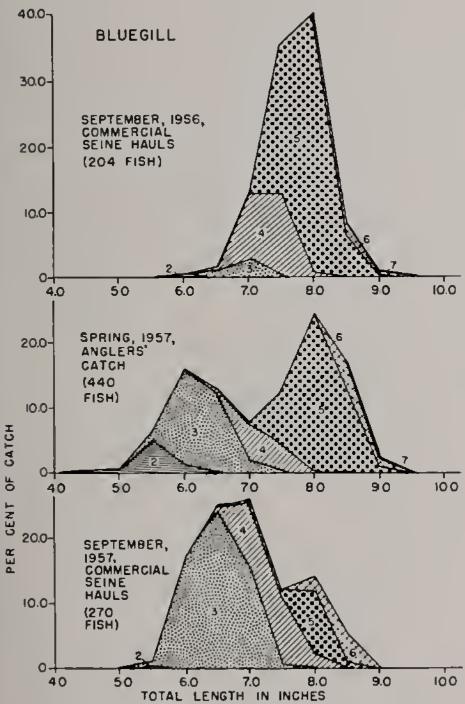


Fig. 23.—Length-frequency and age distribution of bluegills in the September, 1956 and 1957, commercial seine hauls and in the spring, 1957, anglers' catches at Lake Chautauqua. The graphs show the relative abundance of the 1952 year-class of bluegills as 5-year-olds in the September, 1956, seine collections and in the spring, 1957, anglers' catches. The September, 1957, commercial seine hauls revealed the scarcity of fish of the 1952 year-class as 6-year-olds; this scarcity indicated that high mortality of these fish as 5-year-olds occurred during the summer months of 1957.

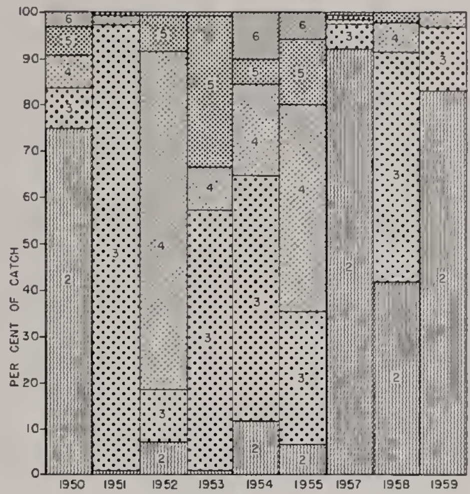


Fig. 24.—Age composition of white crappies in the anglers' catches in the spring months at Lake Chautauqua, 1950–1955 and 1957–1959. Fish of the large 1948 brood are shown as 2-year-olds in 1950.

We caught many more young-of-the-year bluegills in the minnow seine hauls in 1955 than in any other year (Table 30). Fish of the 1955 year-class appeared in large numbers as 3-year-olds in the sport fishery in the spring of 1958 and as 4-year-olds in the spring of 1959 (Fig. 22). They constituted only a minor year-class as 5-year-old fish in the spring of 1960. The strength of the 1955 year-class, in our opinion, was not as great as that of the 1952 year-class, which formed an important part of the sport fishery even as 5-year-old fish in the spring of 1957 (Fig. 22). The minnow seine hauls in 1952 indicated only a moderately successful spawn of bluegills in that year (Table 30). The minnow seine collections showed that young-of-the-year gizzard shad were more abundant in 1952 than in 1955. We suggest the possibility that, as a buffer species against predators of young bluegills, young shad served more effectively in 1952 than in 1955.

If our suggestion has validity, then we may assume that the better survival of the 1952 year-class of bluegills can be explained by the buffer action of the larger number of shad in that year.

The anglers' catch and commercial seine haul data indicate that bluegills over 5 years of age formed only a small part of the bluegill population in Lake Chautauqua during our study (Fig. 22 and 23). Bluegills hatched in 1952 dominated the commercial seine haul catch of bluegills in September, 1956, when classified as 5-year-olds (Fig. 23). Members of the 1952 brood survived through the winter of 1956–57 in sufficient numbers, still as 5-year-olds, to provide an important part of the anglers' catch in the spring of 1957 (Fig. 22). By the fall of 1957, members of the 1952 brood, as 6-year-old fish, were quite scarce (Fig. 23). Perhaps many

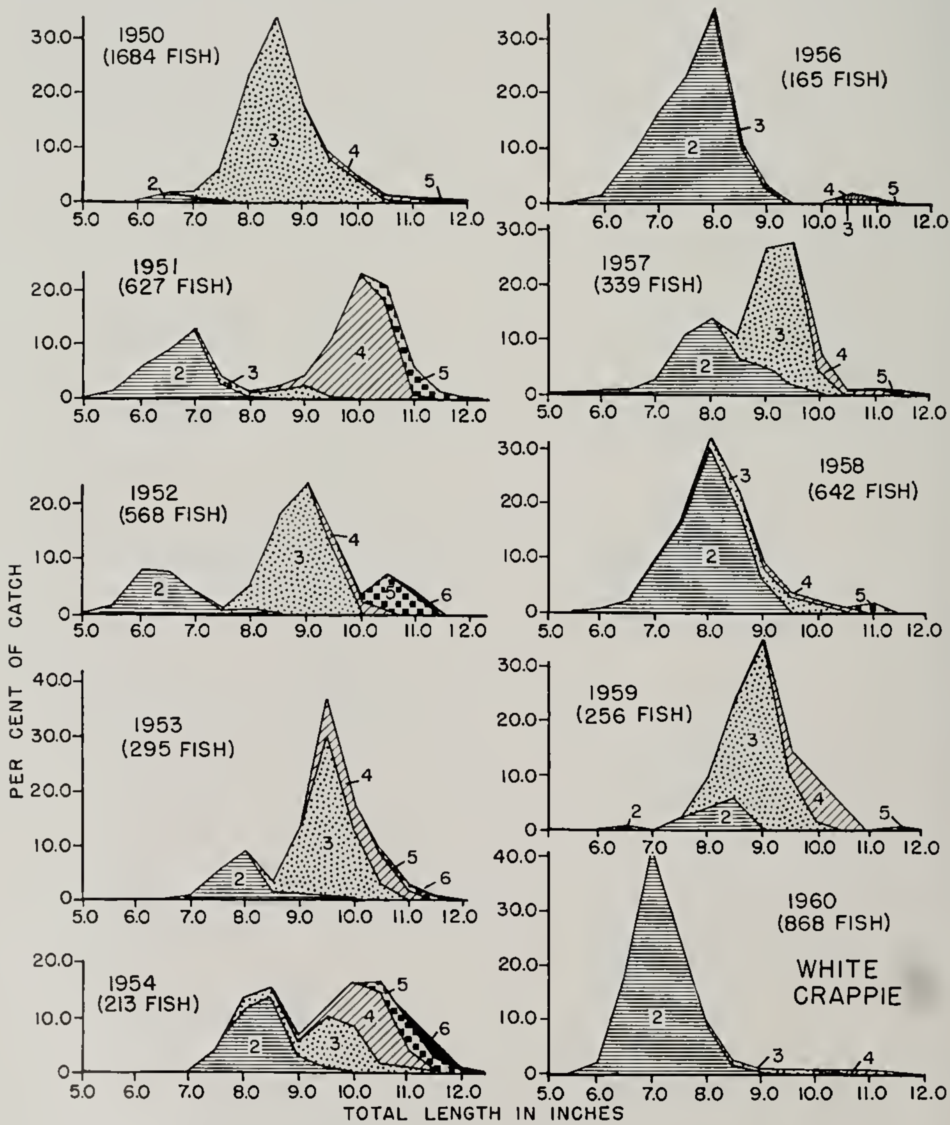


Fig. 25.—Length-frequency and age distribution of white crappies in test-net collections at Lake Chautauqua, late September and early October, 1950–1954 and 1956–1960.

members of the formerly abundant 1952 brood died from natural causes during the summer of 1957 (as 5-year-old fish). Ricker (1945:423) found that the mortality rate of bluegills at Muskellunge Lake, Indiana, was greater in summer than in winter. He stated that "it seems certain that cold-weather mortality is of an entirely different and smaller order of magnitude from that during the warm months."

WHITE CRAPPIE: AGE COMPOSITION OF CATCH.—Sport fishing for white crappies at Lake Chautaqua was largely dependent upon the presence of a large year-class of 2-, 3-, or 4-year-old fish (Fig. 24). In the spring of 1950, 2-year-old white crappies hatched in 1948 dominated the anglers' catch. In the fall following, members of this 1948 year-class, as 3-year-old fish, formed the bulk of the catch of white crappies in the test-net collections (Fig. 25). In the spring months of 1951 and 1952, members of the 1948 year-class, as 3-year-old fish in the spring of 1951 and 4-year-old fish in the spring of 1952, dominated the anglers' catch of white crappies (Fig. 24). As 4-year-old fish, they also dominated the fall test-net collections of 1951 (Fig.

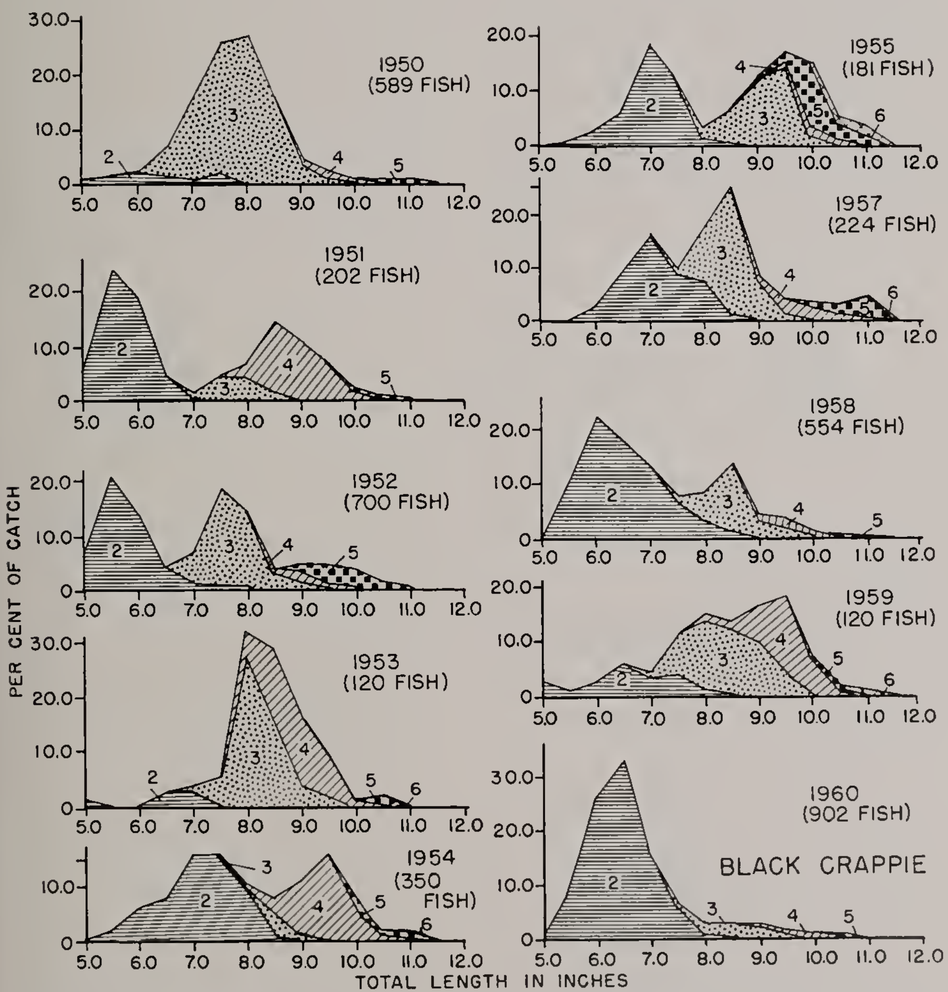


Fig. 26.—Length-frequency and age distribution of black crappies in test-net collections at Lake Chautauqua, late September and early October, 1950–1955 and 1957–1960.

25). The 1948 year-class suffered heavy natural mortality in the summers of 1952 and 1953, but its members were present in some abundance as 5-year-old fish in the anglers' catch in the spring of 1953 (Fig. 24). During the sixth summer of life, the 1948 year-class experienced heavy mortality, as evidenced by a scarcity of 6-year-old fish in the 1953 fall test-net collections. Only a few members of the large 1948 brood attained 7 years of age. The 1948 year-class was the only extremely large brood of white crappies to appear in the lake during our study.

Young-of-the-year crappies were taken in the minnow seine collections in each year except 1953 (Table 30). In no year did we catch large numbers of white crappies or black crappies in the minnow seine hauls. The survival of the different year-classes of the white crappie apparently varied, as indicated by the scarcity in some years of 2- or 3-year-old fish (Fig. 24 and 25). The scarcity of 4- and 5-year-old fish indicated the absence of dominant broods in all but one year. Evidently, natural mortality was so high during the fourth summer of life that only a few members of a small year-class attained 4 years of age.

Black Crappie: Age Composition of Catch.—In most years of our study at Lake Chautauqua, black crappies were less abundant than white crappies. The 1948 year-class of black crappies was a dominant brood (Fig. 26) but of much smaller size than that of the white crappies. The age composition of the fall test-net collections of black crappies was in most years quite similar to those of white crappies (Fig. 25 and 26). The oldest black crappies taken during our study were 7 years of age.

Yellow Bass: Age Composition of Catch.—Young-of-the-year yellow bass were collected from Lake Chautauqua

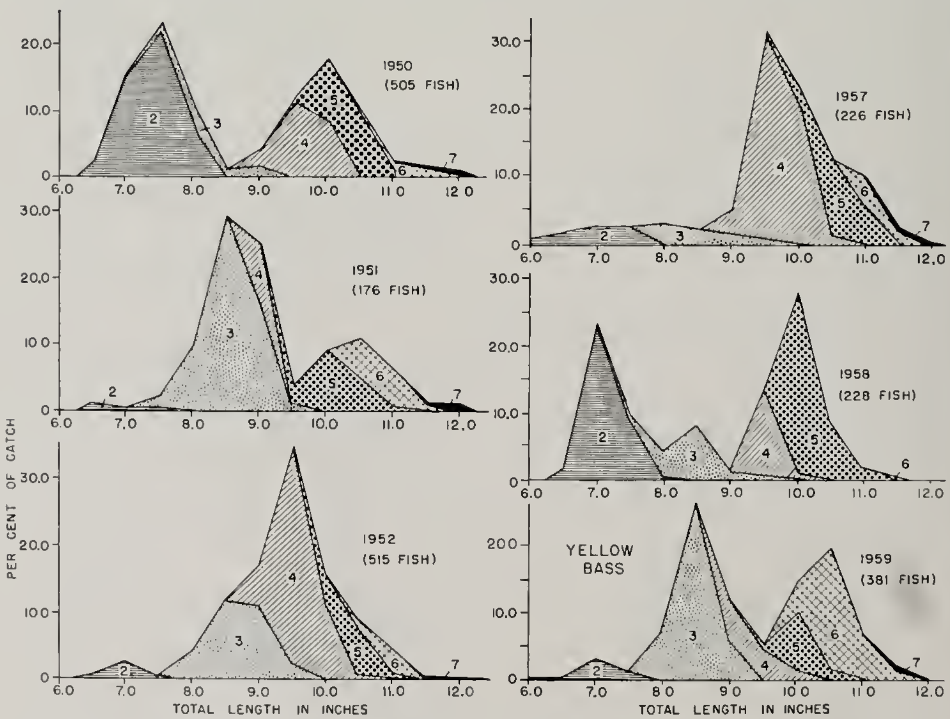


Fig. 27.—Length-frequency and age composition of yellow bass taken by anglers during the spring months at Lake Chautauqua, 1950–1952 and 1957–1959. The graphs reflect the fluctuations that occurred among year-classes in the yellow bass population.

in each summer during our investigation except that of 1954 (Table 30). The strength of the year-classes varied considerably (Fig. 27). Bailey & Harrison (1945:69) noted variations in the strength of year-classes of yellow bass at Clear Lake, Iowa.

We believe that our data on the anglers' spring catch at Lake Chautauqua gave a fair representation of the age composition of the population of yellow bass of 2 years and older. Fig. 27, pertaining to the spring months of 1950–1952, indicates that a fairly large year-class spawned in 1948. Members of this year-class appeared as 2-year-old fish in 1950 (Fig. 27). Our creel data (lengths, weights, and scales) on yellow bass in the years 1953–1955 were too meager to reflect the fate of the 1948 brood after the fourth year. In 1953, another large spawn of yellow bass was produced. The graph for the spring of 1957 shows the relative strength of the 1953 brood as 4-year-old fish (Fig. 27). Members of the 1953 brood appear as 5-year-olds on the 1958 graph and as 6-year-olds on the 1959 graph. A few yellow bass were found to have attained 7 years of age.

WHITE BASS: AGE COMPOSITION OF CATCH.—Spawning success of white bass in Lake Chautauqua was quite sporadic in the years of our study. Young white bass (1.5–3.0 inches total length) were collected in small numbers from the lake in the summer months of 1950, 1951, 1952, 1954, and 1959. Only the 1950 and 1954 year-classes appeared in subsequent years as broods of even moderate size. Our tagging studies indicated that a large percentage of the white bass over 1 year old moved out of the lake in periods of high water. Length-frequency distribution graphs of white bass in the commercial seine hauls of September, 1951, 1952, and 1956 are presented in Fig. 28. In some years, white bass (10.0 inches or more total length) were too scarce in the commercial seine hauls to provide enough specimens to make a length-frequency study. The length-frequency graphs for the years 1951 and 1952 reflect the strength of the 1950 year-class and the scarcity of fish of other year-classes. In 1956, the white bass population was dominated by a single year-class, that of 1954 (Fig. 28).

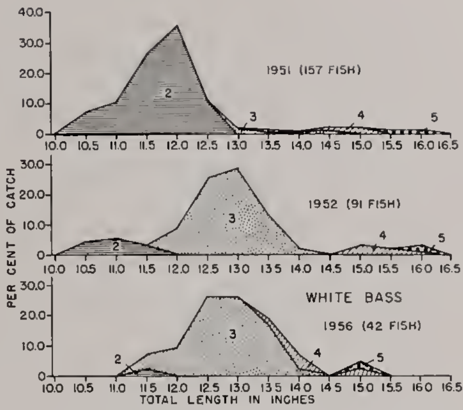


Fig. 28.—Length-frequency and age distribution of white bass in commercial seine hauls at Lake Chautauqua during the month of September in 1951, 1952, and 1956. The graphs reveal that the white bass population was dominated by single year-classes.

POPULATION DYNAMICS

The flow or dynamics of a fish population is quite complex and diffcult to follow. Certain data presented in preceding sections show that the age composition of the most abundant species did not remain constant but varied from year to year. They indicate that, likewise, the spawning success and survival of year-classes of these species varied. This section is chiefly concerned with the various aspects of population dynamics dealing with the year-to-year changes in the sizes of populations of the most abundant species.

Sampling Techniques

The optimum time of sampling, the proper sampling techniques, and the number of samples required to obtain adequate population data had to be determined for our study.

At the beginning of our study, available data on the water levels of Lake

Chautauqua and the Illinois River were reviewed. We wanted a sampling period during which the Illinois River would not be connected with Lake Chautauqua—a period in which sampling could be done each year in water of approximately the same depth. Recruitment of fish from the river and escapement of fish from the lake to the river would be eliminated during a sampling period having low water levels. October or November could not be used for a large sampling program because federal regulations designed for the protection of waterfowl restricted activity on the lake during these months. September was selected as the best month for our sampling program. It appeared to provide low and relatively stable water levels and weather that was warm and otherwise favorable for sampling activities. It allowed us to collect scales and spine samples from fish after much of the growth for the year had been completed.

At one time, we considered a plan for sampling the fish populations of the lake by using rotenone to poison the fish in a series of 1-acre plots. We discarded the plan for the following reasons: (i) the number of samples needed to determine population sizes and trends was too large for the limited time and manpower available; (ii) poisoning large numbers of fish would have damaged our relations with fishermen; (iii) the number of fish killed would have been great enough to invalidate our attempts to determine the effects of commercial fishing on the fish populations.

Because of limited time and personnel, an extensive tagging and recovery program was not feasible. However, a few tagging studies designed to give population estimates of crappies, bluegills, and white bass were attempted. The number of bluegills tagged and recovered was too small to be included in our findings.

Creel censuses, test-netting, minnow seine hauls, and to a very limited extent rotenone sampling were used in the population analysis wherever applicable.

The controlled commercial seining that was originally included as part of the program for increasing the removal of fish from the lake appeared to be the best method available for obtaining population statistics on the abundant large fish in the lake.

Commercial Seining as a Sampling Technique.—Moody (1954:163–164) considered the drag or haul seine as the most efficient device for sampling fish populations in large, shallow Florida lakes with relatively level bottoms. He pointed out certain limitations of the seine in sampling: (i) it does not give adequate quantitive samples of those species of fish that are limited in their distribution mainly to the peripheral areas of a lake and (ii), if the sampling is not carried out over a protracted period of time, the catches may be unduly influenced by dispersal or schooling of fish.

The second limitation mentioned by Moody was not overcome in our study of Lake Chautauqua, as the seining was restricted to a single month in each year (September).

The first limitation was possibly of less consequence at Lake Chautauqua than in the Florida lakes studied by Moody (1954:150–158). The Florida lakes had depths that ranged from 3 to 12 feet. Lake Chautauqua had a relatively even depth of 2 to 3 feet. Most or all of the Florida lakes had peripheral or shoreline vegetation that undoubtedly interfered with seining. The lowering of the water of Lake Chautauqua earlier in the season to its level at the time of our seining greatly reduced the acreage of shoreline that could not be fished effectively with seines. The level of the water in September left exposed to the air some of the tree, shrub, and stumpy areas that at higher water levels were part of the lake; in parts of the stumpy areas remaining in the lake the water was too shallow for fish.

Much of the lake as it was in September was seined. The principal large areas that could not be seined were a stumpy area at the upper end of the lake and a narrow portion of the bluffside where the area was restricted to sport fishing.

Our selection of the month of September for sampling proved to be a good one. It gave maximum uniformity in sampling, as we had constant and low water levels each year, 1951–1958. The shortness of the sampling period kept to a small number the fish that, during the period, grew to a size that could be taken in a seine haul (recruitment from within the lake).

Several variables in our seining operations lessened the value of some of our population data. For example, in 1953, heavy stands of vegetation reduced the efficiency of the seines in some areas. Temporary refuge regulations (for 1953 only) designed to protect the vegetation and make it available to ducks later in the year prohibited seining in other areas. Because of the unusual conditions in 1953, most of the data collected in that year were not comparable to the data collected in other years and were considered of little value for reflecting the population trends of fish.

In the first year of seining (1951), we restricted the number of seine hauls to allow the senior author to closely supervise the operations. Close supervision proved to be unnecessary, and the number of seine hauls made in each of the succeeding years was considerably greater than in 1951 (Table 4). In the 8 years of the seining program, 11 different crews operated seines in the lake; however, only 3 to 6 crews operated in any one season.

Individual crews varied from year to year in the size of their catches. For example, as the scatter diagram in Fig. 29 indicates, seine crew No. 1 had a poor catch in 1956, an excellent catch in 1957, and a mediocre or poor catch in 1958. Buffalofishes (nearly all bigmouth buffalo) were the fish most sought after by the seine crews and, for that reason, in constructing our diagram we used only the catch data for these fish. Evidently year-to-year variations in catch

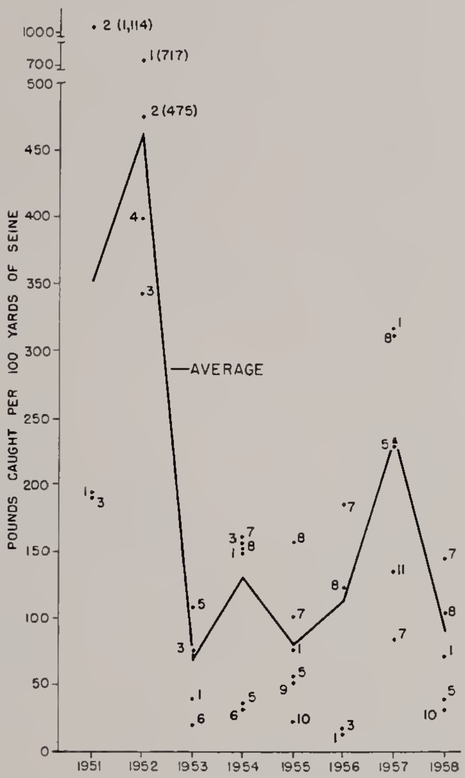


Fig. 29.—Annual catches of buffalo by 11 different commercial seine crews at Lake Chautauqua, 1951–1958. Each dot with a numeral beside it indicates the average number of pounds of buffalo caught per 100 yards of seine employed by a given crew (indicated by numeral) in a given year. Graph is based on data from 348 completed seine hauls.

by seine crews are to be expected. Data from all of the 348 completed seine hauls are included in our analysis, even though variations among hauls were so great that we suspected we had some poor samples.

The variations in catch from haul to haul were evidently a result of several factors: (i) uneven distribution or concentration of fishes in the lake, (ii) movement of fishes within the lake, and (iii) accidental loss of fish from the

Table 31.—Data on carp, buffalofishes, freshwater drum, and channel catfish caught with commercial seines in the three component parts of Lake Chautauqua (Fig. 5) in September of 1954 and 1957. The river-side fish included only those taken in seine hauls landed near the levee along the river. The bluff-side fish included those taken in the middle of the lake as well as those taken in the area near (but not adjacent to) the bluff-side shore. A narrow portion of the bluff-side water was restricted to sport fishing. Most of the bluff-side fish were taken in the middle of the lake. Figures in italics represent range.

Year and Kind of Fish	*Pounds of Fish Per 100 Yards of Seine*						*Analysis of Variance*			*t Value and Degrees of Freedom*		
	Lower Lake		River-Side		Bluff-Side		F Value	Degrees of Freedom		Lower Lake and River-Side	Lower Lake and Bluff-Side	River-Side and Bluff-Side
	Mean and Range	Standard Deviation	Mean and Range	Standard Deviation	Mean and Range	Standard Deviation		n_1	n_2			
1954	(8)*		(30)*		(19)*							
Carp	12.5 *0–52*	16.6	184.8 *0–1534*	337.5	4.4 *0–38*	10.0	3.68†	2	54	2.78† (15)	1.29 (11)	. .
Buffalofishes	147.9 *16–349*	125.6	135.7 *3–528*	150.4	99.3 *0–463*	108.1	0.55	2	54	. .	. .	. .
Freshwater drum	130.6 *19–386*	123.2	85.6 *2–550*	118.3	145.4 *3–475*	150.4	1.32	2	54	. .	. .	. .
Channel catfish	27.3 *3–75*	23.1	27.5 *1–133*	33.8	20.3 *1–148*	33.1	0.31	2	54	. .	. .	. .
1957	(6)*		(14)*		(23)*							
Carp	84.0 *12–250*	94.3	311.7 *13–986*	299.0	48.1 *0–344*	78.1	9.33†	2	40	2.57† (8)	0.86 (11)	3.23† (17)
Buffalofishes	306.5 *20–963*	341.0	171.9 *7–498*	155.5	218.7 *26–538*	164.2	1.01	2	40	. .	. .	. .
Freshwater drum	55.7 *1–122*	49.3	48.6 *0–157*	45.1	101.7 *0–298*	90.0	2.59	2	40	. .	. .	
Channel catfish	35.7 *11–51*	14.4	20.1 *2–43*	12.2	16.5 *0–60*	15.3	4.31†	2	40	2.33† (8)	. .	0.78 (17)

*Number of seine hauls made in designated section of lake.
†Significant difference in catch at 0.05 level for degrees of freedom indicated.

Table 32.—Number of seine hauls required to detect various percentage changes in the populations of carp, buffalofishes, freshwater drum, and channel catfish at Lake Chautauqua in September of 1954 and 1957.*

Year and Kind of Fish	*Number of Hauls Actually Made*	*Number of Hauls Required to Detect a Population Change of the Percentage Indicated*					
		10 Per Cent	40 Per Cent	50 Per Cent	80 Per Cent	90 Per Cent	100 Per Cent
1954	57						
Carp		5,100	318	. .	80	63	51
Buffalofishes		868	54	. .	. .	. .	. .
Freshwater drum		1,060	66	42	. .	. .	. .
Channel catfish		1,252	78	50		. .	. .
1957	43						
Carp		1,866	117	75	29	. .	. .
Buffalofishes		630	39		. .	. .	. .
Freshwater drum		738	46	30	. .	. .	. .
Channel catfish		438	27	. .	. .	. .	. .

*Analysis based on formula used by Paloumpis (1958:585).

seines. The uneven distribution or concentration of fishes in the lake was thought by us to have been the most important cause of catch variations.

Throughout the period of the program, the location of each seine haul was recorded. A simple analysis of the data clearly demonstrated the large variations in the catch between replicate hauls as well as between hauls at different localities in the lake. Detailed analyses were made of the seine haul data collected in 1954 and 1957. These years were selected because of their large aggregate catches (Table 5) and the 3-year interval between the two seining periods. Results of these analyses are given in Tables 31 and 32. In Table 31, the catch data for the carp, buffalofishes, freshwater drum, and channel catfish of commercial or usable sizes were separated into three groups based upon the three sections of the lake (Fig. 5) where the catches were made: (i) river-side (seine landed near levee); (ii) bluff-side (near bluff-side and middle of lake); and (iii) lower lake (from shore adjacent to Quiver Lake levee to about one-half mile into the lake). The ranges and standard deviations of the catches (Table 31) showed that tremendous variations occurred among the hauls made in a given section of the lake. Because of the variations within sections of the lake, the apparently large differences between the mean values for a species in any two sections of the lake usually were found to be insignificant (Table 31).

Carp appear from inspection of the mean values given in Table 31 to have occurred much more abundantly in the river-side section of the lake than elsewhere in 1954 and 1957; the differences are statistically significant. The concentration of carp in this area was observed in our first year of seining (1951). We endeavored after 1951 to seine with approximately equal intensity in all available parts of the lake in order to keep to a minimum the sampling bias caused by fish concentrations in areas favored by the various species.

It appeared from our field observations that catfish occurred more abundantly in the lower lake and river-side sections than in the bluff-side section. Analysis of the catfish data do not completely substantiate these observations, since no statistically significant differences existed among the sections in 1954 (Table 31). However, in 1957 the catch of catfish in the lower lake was significantly greater than the catches in the other sections.

The analysis in Table 31 indicates that no significant differences existed among the mean values for the catches of buffalofishes and drum in the three parts of the lake seined. The catches of these species varied considerably between hauls within a section. Gizzard shad had a distribution similar to the distributions of buffalofishes and drum.

Since so much variation occurred among hauls, we wished to determine the number of hauls required per seining period to detect population changes from year to year. In making our analysis for detecting population changes, we assumed that within 30 days (month of September) very few fish were added to the commercial fishery through growth of fish, and we knew there was no recruitment of fish from the river or escapement of fish to the river during the seining period. The analysis, as we had anticipated, indicated that impractical numbers of seine hauls (438 or more) in 1 month were required to detect a 10 per cent change in the populations of the most numerous fish species (Table 32). Sufficient numbers of hauls were made to detect 40 to 50 per cent changes in the populations of buffalofishes, drum, and channel catfish. The analysis indicated that the data for carp, which were concentrated in one section of the lake, were of little value in detecting other than more drastic population changes.

The carp and bigmouth buffalo of less than commercial sizes taken in the seine hauls were returned to the lake. Sight estimates were made of the occurrence of these subusable-size fish in the seine hauls, and some length and weight data on them were collected.

We were interested in making standing crop estimates of the large abundant fishes from the seine haul data. In making these estimates we needed first to discover a method for determining the area covered by the seines in a seining period so that the catch data could be converted to pounds of fish caught per acre. The pounds of fish caught per acre could then be referred to as a crude estimate of standing crop.

Commercial fishermen at Lake Chautauqua used three basic methods for laying out their seines, each seine usually about 800 to 1,000 yards in length. An important device employed in all three methods was a backstop, a wire mesh fence usually 30 to 50 feet long, tall enough to extend about 4 feet above the water, and held in place with stakes driven into the lake bottom. In the first method, one end of the seine was attached to one end of the backstop, the seine was laid out in the form of an approximate circle, and the other end of the seine was brought to the other end of the backstop. In the second method, the seine was laid out in the form of a trapezoid, with one side of the trapezoid parallel with the backstop and with approximately 100 yards of open water between each end of the backstop and the nearest end of the seine; the open areas were closed soon after the fishermen started hauling in the seine. In the third method, a section of seine 100 or more yards in length was attached to one end of the backstop, extended in line with the backstop, and staked. The seine proper was secured at one end to the free end of the backstop and laid out so that with the backstop and section of staked seine it formed an open end or partial D, with open water between the free end of the seine proper and the staked seine. Finally, the free end of the seine proper was dragged across the open water to the nearer end of the staked seine.

We calculated the areas covered in various seine hauls made by each of the three methods outlined above. The areas were of various shapes, but most of them were roughly circular. We found that close approximations of the actual areas covered in the seine hauls could be made if we considered the seines as the circumferences of circles. The methods we used in estimating the area covered in an average seine haul and in estimating our catch of various species per acre are shown below. The figures are for 1954, in which the cumulative length of seine used in the total number of hauls was 49,650 yards.

1) To estimate the number of linear yards or feet of seine in average haul when 49,650 yards=cumulative length of seines used in 1954 and 57=number of seine hauls made in that year:

$$\frac{49{,}650}{57}=871.1$$

number of yards (2,613.3 feet) of seine in average haul

2) To estimate the number of square feet covered in average seine haul (2,613.3 feet, the length of seine in average haul, is assumed to be equal to the circumference, C, of the roughly circular area covered in a haul):

a) Diameter $(d)=\frac{C}{\pi}$;

radius $(r)=\frac{d}{2}$; $\pi=3.14$

$$d=\frac{2{,}613.3}{3.14}=832.3$$

diameter of area in feet

$$r=\frac{832.3}{2}=416.2$$

radius of area in feet

b) Area $(A)=\frac{Cr}{2}$ (or πr^2)

$$\frac{2{,}613.3\times 416.2}{2}=543{,}827.8$$

number of square feet covered in average seine haul

3) To estimate the number of acres (43,560 square feet in 1 acre) covered in average seine haul:

$$\frac{543{,}827.8}{43{,}560}=12.5$$

number of acres covered in average seine haul

4) To estimate the number of acres covered in the 1954 seine haul program (57 seine hauls):

$$12.5\times 57=712.5$$

number of acres covered in 1954 seine haul program

5) To estimate the catch of buffalo per acre seined when 65,489=pounds in catch and 712.5=acres seined:

$$\frac{65{,}489}{712.5}=91.9 \text{ (or 92)}$$

number of pounds per acre

The estimated catches per acre of usable-size fish of the most important species seined from Lake Chautauqua in 1954 were as follows:

buffalo (15 inches or longer), 65,489 pounds or 92 pounds per acre
drum (10 inches or longer), 61,163 pounds or 86 pounds per acre
channel catfish (13 inches or longer), 13,038 pounds or 18 pounds per acre
carp (15 inches or longer), 49,139 pounds or 69 pounds per acre
gizzard shad (9.5 inches or longer), 33,755 pounds or 47 pounds per acre

In spite of the limitations of the drag or haul seine for determining population trends, we believe that, if about 40 or more hauls were made in a short period of low water levels in a body of water the size of Lake Chautauqua, any major change (40 or 50 per cent) in a population of catchable-size fishes of species other than carp could be detected.

TAGGING AND TEST-NETTING AS SAMPLING TECHNIQUES.—The tagging and recovery of individual fish as a means of estimating the total population of fish in an enclosed body of water has been widely adopted since C. G. J. Petersen discussed the technique in 1896 (Ricker 1958:81).

Although in our Lake Chautauqua studies we tagged and released crappies (both species) and bluegills in 1950–1954 and white bass in 1951–1954, the number of tagged fish recovered was so small that, in estimating populations or standing crops, we were able to use only the data on crappies tagged in 1950 and 1951. We estimated the standing crops of crappies in the fall months of 1950 and 1951 by using Chapman's variation of the Petersen method (Ricker 1958:85), which was based on the number of marked and unmarked fish caught in a given period of time. The procedure we used in 1950 was similar to that described below for 1951.

In October, 1951, the Natural History Survey test-netting crew caught, tagged, and released 547 adult crappies (both species). From October, 1951, through April, 1952, anglers and commercial fishermen removed 21,514 adult crappies from the lake. During that period, 41 tagged fish were recaptured. Crappies caught by anglers were checked for tags by boat liverymen, and those caught by commercial fishermen were checked by Natural History Survey personnel. The computations made in determining the size of the standing crop of the 1951 fall crappie population are shown below. Not considered in the computations was (i) the possibility that the mortality rate of tagged fish might be higher or lower than that of the other fish or (ii) the possibility of recruitment from and loss of fish to the Illinois River. As no tagged white crappie was recovered from the river, we assume that few if any fish of this species were lost to the river.

$$N = \frac{(M+1)\,(C+1)}{R+1}$$

where

N = Number of fish in population at time of marking

M = number of fish marked

C = number of fish caught

R = number of tagged fish recaptured

1) $$\frac{(547+1)\,(21{,}514+1)}{41+1} = 280{,}719$$

number of adult crappies in lake

0.5 pound = average weight of adult crappies

2) $280{,}719 \times 0.5 = 140{,}360$

number of pounds of adult crappies in lake

3,562 = number of acres in lake

3) $$\frac{140.360}{3{,}562} = 39.4 \text{ or approximately } 40$$

number of pounds of adult crappies per acre

Of course, the figure 40 represents only a rough estimate.

Test-nets, fished at 11 or 12 Lake Chautauqua sites in late September and early October of each year, 1950–1959, provided catch data to be used in estimating population trends of the crappies and the gizzard shad. The data were expressed as number of fish caught per net-day. In 1953 and to a lesser extent in 1956, the heavy stands of vegetation appeared to reduce the efficiency of our nets for catching crappies. Our observations indicate that data from catches of the bluegill in our test-nets did not reflect the population trends in this species as well as did the data from the creel censuses and the commercial seine hauls.

Standing Crop

Thompson (1941:209) estimated that the fish populations in floodplain lakes of the Illinois River valley weighed "400 or 500 pounds per acre." The combined 1951 and 1952 commercial seine haul data for Lake Chautauqua indicated that fishermen removed from this lake an average of 385 pounds of commercial-size buffalofishes, carp, freshwater drum, and channel catfish per acre seined (Table 33). Twenty additional pounds of shad were caught per acre seined. These calculated catch values represent a standing crop of about 405 pounds of large fish per acre. The standing crop of adult crappies in 1951 was estimated to be 40 pounds per acre. Test-netting and minnow seining indicated that, in addition to the fish mentioned above, there were probably 50 to 75 pounds of other fish per acre. The total standing crop was estimated to be about 500 pounds per acre in the 1951–1952 period. This estimate is similar to Thompson's.

The removal of fish during the program (Table 5) no doubt reduced the abundance of commercial-size buffalofishes, carp, drum, and channel catfish in Lake Chautauqua. Natural mortality, escapement from the lake to the Illinois River, and recruitment from the river to the lake no doubt contributed to changes in the composition of the fish population in the lake (Table 33). By 1955, the standing crop of the usable-size fish of the four commercial kinds mentioned above and the noncommercial gizzard shad was estimated to be only 189 pounds per acre, but the total standing crop in the lake we believed to be much larger. Our belief was substantiated by the great abundance of small buffalo and the somewhat lesser abundance of small carp that were observed in the seines in 1955 and returned to the lake. In the fall of 1957, the estimated standing crop of usable-size fish of four commercial kinds and gizzard shad was 383 pounds per acre, not far below the estimated standing crop of usable-size fish of these kinds in the 1951–1952 period (Table 33). The species composition of the populations in the two periods was different. Gizzard shad were much more abundant in 1957 than in the earlier period. Also in 1957, undersize or subusable carp were more abundant. Data in Table 37 indicate that, in 1958, much of the poundage of commercial-size gizzard shad lost through the extensive

Table 33.—Calculated poundage of usable-size buffalofishes, carp, freshwater drum, channel catfish, and gizzard shad caught per estimated acre seined at Lake Chautauqua, 1951–1952 and 1954–1958.* Because of restrictions on seining in 1953, the data for that year were not representative and were not used. Estimates were made of abundance of subusable-size buffalofishes and carp in seine hauls.

Year and Number of Hauls	*Pounds of Fish Caught Per Estimated Acre Seined*						*Fish of Subusable Sizes*	
	Buffalo-fishes	Carp	Freshwater Drum	Channel Catfish	Gizzard Shad	Total	Buffalo-fishes	Carp
1951–1952 (37)	251	70	55	9	20	405	Scarce	Scarce
1954 (57)	92	69	86	18	47	312	Scarce†	Scarce†
1955 (66)	58	16	67	13	35	189	Abundant	Common
1956 (50)	75	12	40	23	51	201	Scarce	Scarce
1957 (43)	143	85	52	14	89	383	Common	Abundant
1958 (48)	61	72	40	5	54	232	Scarce	Common

*Most of the usable-size fish of the four commercial kinds were individuals of legal lengths; most of the gizzard shad were 9.5 inches or more total length.
†Young fish were abundant in the lake, but were too small to be caught in seines.

removal of fish in 1957 was replaced by a poundage of shad of less than 9.5 inches in length, which were common in the test-nets.

Thompson's and our estimates of pounds of fish per acre in Illinois River floodplain lakes were slightly higher than estimates made by Lambou (1959: 11) for lakes along the Mississippi River in Louisiana (average of 397 pounds per acre). Lambou (1959:10) found that some species—buffalofishes, white bass, and catfishes—were highly migratory in backwater habitats; they were more abundant in the lakes in periods of high water than in periods of low water. A similar situation probably prevailed at Lake Chautauqua; our observations indicated that movement of some species of fish between the river and the lake occurred during times of high water. However, we believe that certain other species did little migrating; either most individuals of these species remained in the lake during high water levels or they returned to the lake before they could be cut off from the lake by receding water. This belief was at least partly confirmed by our finding of year-to-year continuity in year-classes of certain species and by our tag returns from certain species. Data on the continuity of year-classes in certain species are given in the section of this paper entitled "Age Composition of Catch."

Population Changes

Estimates of the standing crop indicated that the carrying capacity of Lake Chautauqua at the time of our study was at least 500 pounds of fish per surface acre. The population was known to have included as many as 64 different species of fish. Considerable variation in population size of the various species occurred during the years of our study. The bulk of the population, as estimated by weight of the catch, was composed of nine species: bigmouth buffalo, carp, freshwater drum, channel catfish, gizzard shad, white crappie, black crappie, bluegill, and yellow bass. These were considered by us as the influential species in the lake, and the variations in their abundance probably affected the entire fish population. Although other species also varied in abundance, most of them were not abundant enough to have had more than minor roles in the ecology of the lake.

Freshwater Drum: Population Changes.—The trends in the freshwater drum population at Lake Chautauqua are reflected in Table 34. Because of poor seining conditions and unusually restrictive fishing regulations in 1953, we have omitted the catches for that year from the analysis of the catch data. The means of the catches per 100 yards of seine used varied from year to year; however, these differences must be evaluated carefully because of the large variations in catch among the hauls, as discussed in the subsection "Commercial Seining as a Sampling Technique."

The analyses presented in Tables 31 and 32 indicate that in 1954 and 1957 drum were fairly well distributed among the three components of the lake and that enough hauls were made to detect at least 50 per cent population changes. The differences among drum populations in the various years of seining (populations based on catch per 100 yards of seine used) were slightly significant ($F = 2.62$, $d.f. = 5$ and 295); the difference between the drum population of 1954 and the smaller population of 1956 was slightly significant ($t = 2.57$, $d.f. = 52$). (The catch data in Table 34 show that the trend of the population of drum was downward after 1954.) The drum catch dropped to its lowest point in 1958. The decline was apparently related to the increased removal of drum in 1954 and 1955 (Table 34) and the scarcity of individuals of two year-classes in the lake in the 1956–1958 period. In 1954 and 1955, the drum fishery was largely dependent upon 4-, 5-, and 6-year-old fish (Fig. 17). By September

Table 34.—Population trends of freshwater drum at Lake Chautauqua as reflected in commercial seine hauls (made during September) and in total catch per acre of water (all fishing methods combined), 1951–1958.

Year	*Number of Hauls*	*Pounds Caught Per Estimated Acre Seined*	*Pounds Caught Per 100 Yards of Seine*			*Total Pounds Caught and Removed Per Acre of Water*
			Mean	Standard Error	Range of True Mean at 95 Per Cent Level	
1951	13		...		...	3.9
1952	24	54.9*	94.5*	±15.7*	62.6 to 126.4*	9.8
1953	47	†	79.7†	±15.2	49.0 to 110.4	9.7
1954	57	85.8	111.9	±17.4	77.1 to 146.7	20.6
1955	66	66.7	98.0	±14.3	69.4 to 126.6	17.7
1956	50	39.8	62.6	± 8.2	46.1 to 79.1	8.6
1957	43	52.1	78.0	±11.6	54.6 to 101.4	11.2
1958	48	40.2	57.0	± 7.5	41.9 to 72.1	8.3

*1951–1952 data were combined.
†Data for 1953 were not used because they were not considered representative; vegetation made seining difficult, and temporary regulations designed to protect waterfowl food plants prohibited seining in some areas.

of 1956, the fish of 5 years and older had evidently been reduced in numbers through fishing and natural mortality to the point where the presence of a large year-class was required to maintain a high population. In September of 1956, fish of the comparatively small 1953 year-class, as 4-year-olds, formed only a minor part of the drum catch (Fig. 17). The 1954 year-class was evidently larger than the 1953 year-class and in September, 1957, when regarded as 4 years old, it comprised an important part of the drum catch. However, the 1954 year-class was not large enough to compensate for the weak 1953 year-class, which was regarded as 5 years old in September, 1957 (Fig. 17). The lack of large year-classes in the lake accounted for the low drum population (as measured by the catch) in 1958. We doubt if there was sufficient removal of drum after 1955 to have had much effect on the size of the drum population in 1958. The population probably would have been low in 1958 even though there had been no fishing.

CHANNEL CATFISH: POPULATION CHANGES.—The catch of catfish per 100 yards of seine varied considerably from year to year (Table 35), and certain of the differences were found to be significant ($F = 8.66$, $d.f. = 5$ and 295). The catch data show that the population increased in size after 1953 and continued to be relatively large until 1958. The difference in catch between 1957 and 1958 was found to be significant ($t = 5.48$, $d.f. = 44$).

In 1955, the percentage of large catfish (20 inches or more in length) taken in the seine hauls dropped considerably (Table 35 and Fig. 20). The decrease in percentage of large individuals in the catch that year may have been caused by heavy removal of catfish in 1954 (Tables 5 and 35). It was accompanied by an increase in number of 3- and 4-year-old fish in the catch (Fig. 21). As Fig. 21 shows, the catch each year after 1954 was largely dependent upon 4-year-old fish. The sharp decline in the catch in 1958 was caused by the small size of the 1955 brood, then classified as 4 years old, and by heavy removal in previous years of 4-year-old and older fish. The number of catfish removed from the lake each year after 1953 was estimated to have been 35 to 50 per cent of the catfish of 13.0 inches or longer in the population (estimate based on data given in Table 35). The catfish population was no doubt affected by fishing. The fishing success that continued up to 1958 indicated that increased removal of fish may have contributed to spawning success and survival and provided space for young catfish entering the lake from the river.

During high-water periods, probably some channel catfish left the lake while others entered it. In the course of aging catfish, we noted that some of the fish had made poor growth in their early years, and we considered that such fish might have been recruited from the river. They were not very common in the collections, and we are of the opinion that a goodly percentage of the catfish that we caught were either spawned in the lake or were recruited from the river as very young fish.

Our collection of population data on catfish stopped after the 1958 season. Commercial trotline fishermen reported that the catch of legal-size catfish was "poor" in 1959, while commercial wing-net fishermen informed us that catfish were "fairly abundant" in 1960. The catch rates of pole-and-line fishermen, 1950–1959 (Table 35), offered no clear indication of either a decline or a recovery in the catfish population during the period of our study. However, the low pole-and-line catch rate for 1958 tends to confirm other low figures for 1958 (Table 35).

The estimated standing crop of channel catfish, or estimated catch per year per acre seined, was about 17 pounds in the 1954–1957 period. In Oklahoma, Houser (1960*a*:12) estimated the standing crop of channel catfish in Lake Lawtonka to be 10.9 pounds per acre; he contrasted this figure with 28.0 pounds per acre, the average standing crop of catfish (all ages) in 16 Oklahoma reservoirs. Sandoz (1960:141), also in Oklahoma, estimated standing crops of channel catfish to be 16.6 pounds per acre in Laughridge Pond and 19.0 pounds per acre in Mahan Pond. The high annual yields at Lake Chautauqua of 8.3 to 9.0 pounds of

Table 35.—Population trends of channel catfish at Lake Chautauqua as reflected in pole-and-line catch, in commercial seine hauls, and in total catch per acre of water (all fishing methods combined), 1950–1959.

Year	*Pole-and-Line Catch Per Fisherman-Day (Number of Fish)*	*Commercial Seine Hauls (September)*						*Total Pounds Caught and Removed Per Acre of Water*
		Number of Hauls	Per Cent of Catch Measuring 20.0 Inches or More Total Length	Pounds Caught Per Estimated Acre Seined	Pounds Caught Per 100 Yards of Seine			
					Mean	Standard Error	Range of True Mean at 95 Per Cent Level	
1950	0.12	..	..	..	..	..	..	4.7
1951	0.09	13	48.0	.	.	..	..	4.3
1952	0.09	24	50.0	9.1*	15.4*	±2.2*	10.9 to 19.9*	5.0
1953	0.06	47	39.1	†	9.3	±1.9	5.5 to 13.1	3.7
1954	0.07	57	46.1	18.3	25.0	±4.2	20.8 to 29.2	8.5
1955		66	23.6	12.6	17.3	±1.9	13.5 to 21.1	8.3
1956	0.08	50	16.5	22.6	35.4	±5.3	24.7 to 46.1	9.0
1957	0.07	43	16.6	13.8	20.3	±2.3	15.6 to 25.0	7.7
1958	0.04	48	15.2	4.6	6.6	±1.0	4.6 to 8.6	3.7
1959	0.06		...	..	..	..	..	2.9

*1951–1952 data were combined.
†Data for 1953 were not used because they were not considered representative; vegetation made seining difficult, and temporary regulations designed to protect waterfowl food plants prohibited seining in some areas.

usable-size catfish per acre, 1954–1956, as shown in Table 35, tended to confirm our estimates that Lake Chautauqua contained a large catfish population.

BIGMOUTH BUFFALO: POPULATION CHANGES.—In the years of our study, the sizes of the catch of bigmouth buffalo at Lake Chautauqua changed considerably (Table 36). Some of the changes in catch per 100 yards of seine were highly significant ($F=14.15$, $d.f. = 5$ and 295) and were probably caused for the most part by increased fish removals. The largest catches occurred in the years 1951–1952 combined and 1957. The difference in catch between these two periods was only slightly significant ($t=2.21$, $d.f.=39$). The population in 1951–1952 was composed mainly of members of the large 1948 year-class and a considerable number of older fish; the population in 1957 was dominated by the large 1953 year-class and contained very few older fish (Fig. 18). A scarcity of older fish in the collections after 1955 resulted from the removal of many of these fish and from natural mortality.

The drop in the catch (Table 36) from 215.7 pounds per 100 yards of seine (142.5 pounds per acre) in 1957 to 84.3 pounds per 100 yards of seine (60.5 pounds per acre) in 1958 was rather significant ($t = 4.04$, $d.f. = 44$). The large 1953 year-class first suffered fishing mortality in 1955 at the age of 3 years (Fig. 18). In our opinion, in that year large numbers of the smaller members (less than 15 inches) of the 1953 year-class that were caught and released died as a result of being bagged in the seine. On one haul in 1955, the senior author saw about 20,000 pounds of these undersize fish released. No individuals of a series of undersize buffalo that were tagged were ever retaken. From time to time during the seining period, dead members of this group of small fish were seen floating in the water. In 1956 and 1957, the 1953 year-class, as well as older year-classes, suffered heavy fishing mortality. The presence of large numbers of old fish in the population in the early years of our seining program (Fig. 18) demonstrates that the bigmouth buffalo is a long-lived fish. We believe that the decline in the bigmouth buffalo population in 1958 might have been minor had there been no fishing after 1954.

Table 36.—Population trends of bigmouth buffalo at Lake Chautauqua as reflected in commercial seine hauls (made during September) and in total catch per acre of water (all fishing methods combined), 1951–1958.

Year	*Number of Hauls*	*Per Cent of Fish Measuring 20.0 Inches or More Total Length*	*Pounds Caught Per Estimated Acre Seined*	*Pounds Caught Per 100 Yards of Seine*			*Total Pounds Caught and Removed Per Acre of Water*
				Mean	Standard Error	Range of True Mean at 95 Per Cent Level	
1951	13	53.5	. .	. .	. .	. .	38.4
1952	24	70.2	250.7*	444.5*	±99.1*	243.3 to 645.7*	52.5
1953	47	65.4	. †	75.6	±13.0	49.3 to 101.9	46.4
1954	57	69.3	91.9	125.3	±17.7	89.9 to 160.7	52.4
1955	66	46.8	58.1	74.4	± 8.4	57.6 to 91.2	45.3
1956	50	29.3	74.8	113.4	±15.3	82.6 to 144.2	40.0
1957	43	30.2	142.5	215.7	±29.7	155.7 to 275.7	53.8
1958	48	39.8	60.5	84.3	±13.1	58.0 to 110.6	32.6

*1951–1952 data were combined.
†Data for 1953 were not used because they were not considered representative; vegetation made seining difficult, and temporary regulations designed to protect waterfowl food plants prohibited seining in some areas.

GIZZARD SHAD: POPULATION CHANGES. —Because we found that sampling methods were selective for various sizes of gizzard shad, we have included in our population analysis of this species the catch data from each of the three methods we used: minnow seining, test-netting, and commercial seining (Table 37).

Minnow seine collections indicated that a great amount of variation occurred from year to year in the spawning success of the gizzard shad. For any one year-class, there appeared to be little or no relationship between its numbers as young-of-the-year in minnow seine collections and its numbers as adults in test-nets or commercial seines (Table 37). Both test-netting and commercial seining indicated that the adult shad population was quite small in the 1950–1952 period. In 1951–1952 combined, the catch of adult shad per estimated acre seined amounted to only 19.7 pounds; in 1957, the year in which the catch of adult shad reached its maximum, the catch was 88.5 pounds per acre. An analysis of variance of the commercial seine haul data (Table 37) indicated that significant differences ($F = 5.95$, $d.f. = 6$ and 317) existed in the number of pounds of adult shad caught per 100 yards of seine in the various years. The shad catch was significantly greater per 100 yards of seine in 1954 than in 1951 ($t = 4.02$, $d.f. = 26$). Similarly, the catch in 1957 was significantly greater than in 1954 ($t = 3.34$, $d.f. = 49$).

The fluctuations in the numerical size of the shad population (as reflected in the catch) were probably related to a number of factors. The large adult population of bigmouth buffalo in the 1951–1952 period (Table 36) may have competed with the adult shad population. Then, as the buffalo population was reduced in size through fishing and natural mortality, the adult shad population appeared to increase and may have partially filled the niche formerly occupied by the large buffalo population.

We believe that some of the adult shad in the population of Lake Chautauqua in 1957 and 1958 were recruited as adult fish from the Illinois River. Adult shad were seen entering the lake during periods of high water in 1957; we assumed these were river fish and not lake fish that were returning to the

Table 37.—Population trends of gizzard shad at Lake Chautauqua as reflected by minnow seining, test-netting, and commercial seining, 1950–1959.

Year	*Minnow Seine (Summer), Number of Young Caught Per Haul*	*Test-Net (Fall), Number of Fish Caught Per Net-Day*	*Commercial Seine Hauls (September)*				
			Number of Hauls	Pounds Caught Per Estimated Acre Seined	Pounds Caught Per 100 Yards of Seine		
					Mean	Standard Error	Range of True Mean at 95 Per Cent Level
1950	3.6	2.00		. .			.
1951	30.0	2.54	13	.	16.8	± 1.9	12.6 to 21.0
1952	9.2	3.22	24	19.7*	†	.	. .
1953	56.5	4.21	47		27.8	± 7.1	13.5 to 42.1
1954	500.0	5.13	57	47.4	62.6	±11.2	40.1 to 85.1
1955	5.8	3.31	66	34.7	48.3	± 7.2	33.9 to 62.7
1956	21.5	0.74	50	50.9	80.4	±11.1	58.1 to 102.7
1957	3.1	9.59	43	88.5	129.5	±28.6	71.7 to 187.3
1958	2.1	20.37	48	53.8	54.1	±10.3	33.4 to 74.8
1959	16.7	2.38					. .

*1951–1952 data were combined.
†1952 shad catch data were not separated by individual haul and could not therefore be used in determining the mean catch.

lake after having gone out to the river. Subadult shad were scarce in the fall test-net collections in 1956 (Table 37).

Predation upon young shad by an extremely large adult crappie population that was present in the 1949–1951 period may have been partly responsible for small adult shad populations in 1951 and 1952. Jenkins (1953:53) reported a striking decrease in the young-of-the-year shad population in Grand Lake, Oklahoma, and thought the decrease might have been linked with the tremendous expansion of the white bass population in the lake. The increased removal of large channel catfish from Lake Chautauqua by commercial fishing reduced catfish predation upon adult shad after 1954 (many catfish 20.0 inches or more in length were observed to contain large shad). Winterkill resulting from sudden changes in temperature and in carbon dioxide tensions (Miller 1960:385–386; Powers, Shields, & Hickman 1939:259) may have been an important factor influencing the abundance of adult shad in the lake.

CARP: POPULATION CHANGES.—It was pointed out earlier in this paper that the commercial seine data could be used to detect only large changes in the carp population. Analysis of variance calculated for the catch of adult carp per 100 yards of seine used indicated that significant differences existed between the catches for various years (F=4.42, $d.f.$=5 and 295). The catch of adult carp in 1951–1952 combined and in 1954 was about 70 pounds per acre (Table 38). In 1957 and 1958, the catch of adult carp was a few pounds more per acre. No significant difference was detected for the carp on a catch-per-acre-seined basis between 1951 and 1952 combined and 1957 ($t = 0.52$, $d.f. = 39$). The catch of carp in 1955 was much lower than in 1954, and the difference was slightly significant ($t = 2.20$, $d.f. = 60$). The catch in 1957 was significantly higher than the catch in 1956 ($t = 3.52$, $d.f. = 45$). The carp catch in 1955 and 1956 appeared to be significantly lower than in other years of our study, and we have assumed that the adult population in 1955 and 1956 also was lower.

Carp taken in the seine hauls were notably smaller in 1955–1956 than in 1951–1954 (Table 38). The decrease in size was evidently related to fishing mortality or to movement of the larger

Table 38.—Population trends of carp at Lake Chautauqua as reflected in commercial seine hauls (made during September) and in total catch per acre of water (all fishing methods combined), 1951–1958.

Year	Number of Hauls	Average Weight of Fish in Pounds	Per Cent of Fish Measuring 20.0 Inches or More Total Length	Pounds Caught Per Estimated Acre Seined	Pounds Caught Per 100 Yards of Seine			Total Pounds Caught and Removed Per Acre of Water
					Mean	Standard Error	Range of True Mean at 95 Per Cent Level	
1951	13	6.19	61.6					22.6
1952	24	5.01	68.5	70.1*	118.0*	±24.0*	69.3 to 166.7*	14.8
1953	47	6.55	76.0	†	51.3	±13.1	24.8 to 77.8	7.1
1954	57	5.52	69.6	69.0	100.5	±34.3	31.9 to 169.1	16.9
1955	66	3.26	21.7	16.2	23.8	± 6.0	11.8 to 35.6	10.2
1956	50	3.29	23.3	12.1	19.8	± 8.0	3.7 to 35.9	8.5
1957	43	4.51	50.4	84.5	139.0	±33.0	72.3 to 205.7	24.2
1958	48	4.14	43.2	72.0	109.6	±29.7	49.9 to 169.3	21.0

*1951–1952 data were combined.
†Data for 1953 were not used because they were not considered representative; vegetation made seining difficult, and temporary regulations designed to protect waterfowl food plants prohibited seining in some areas.

fish out of the lake prior to the fall of 1955. We have been led to believe that both carp and gizzard shad moved in and out of Lake Chautauqua during periods in which the lake was connected with the river and that they remained in the lake when acceptable niches there were available to them.

CRAPPIES: POPULATION CHANGES.—In the period 1950–1954, we tagged 2,963 white crappies at Lake Chautauqua. From these tagged fish we obtained 61 returns, all of which were taken from the lake. The tagging study indicated that the white crappie population at Lake Chautauqua was not mobile and that the fish tended to remain in the lake, even though ample opportunity was afforded them to move out during periods of high water.

We also tagged 1,332 black crappies at Lake Chautauqua. Only 10 returns were obtained from these tagged fish. Eight of the returns were from fish recaptured in the lake, and two were from fish taken in the Illinois River. In a period of 121 days, one tagged black crappie (7.2 inches total length) left the lake and moved 35 miles up the Illinois River, where it was caught by an angler. The other tagged black crappie recovered in the river was caught in a commercial net 3 miles from the point of release in the lake 147 days after being tagged. The few returns we obtained indicated that the black crappie was more mobile than the white crappie.

The adult crappie population (both species) at Lake Chautauqua was estimated from tag returns to have been 100 pounds per acre in 1950 and 40 pounds per acre in 1951. Data from our fall netting studies (Table 39) indicate that in several years the population was probably as low as 10 or 15 pounds per acre. The large population of crappies in the fall of 1950 was composed mainly of 3-year-old fish from the large and dominant broods of both species spawned in 1948 (Fig. 25 and 26). The 1948 brood of white crappies was much larger than the 1948 brood of black crappies.

The aging studies presented earlier in this paper showed that very few white crappies in Lake Chautauqua lived to be more than 5 years of age. Comparison of data from spring angling (Fig. 24) with data from fall test-netting (Fig. 25) indicates that a high natural mortality of adult crappies oc-

Table 39.—Data relative to the crappie population at Lake Chautauqua, 1950–1959. The standing crop was estimated through tagging operations.

Year	*Number Caught by Anglers*	*Average Catch Per Fisherman-Day*	*Average Catch Per Hour*	*Number of Adults Caught Per Net-Day in Test-Nets*	*Estimated Standing Crop in Pounds Per Acre in Fall Period*	*Pounds Caught and Removed Per Acre by Anglers*
1950	10,096	1.0	0.19	36.2	100	0.8
1951	35,496	2.6	0.46	14.5	40	3.0
1952	18,422	1.5	0.26	18.9	..	2.3
1953	12,510	2.2	0.43	8.7*		1.6
1954	32,151	2.4	0.41	11.9		5.4
1955	16,622	1.5	0.36	4.4		2.1
1956	7,664	1.0	0.17	3.6*		1.2
1957	15,998	1.5	0.27	9.2		1.7
1958	4,110	0.5	0.09	12.7	.	0.4
1959	4,216	0.7	0.12	3.1*	..	0.3
Average	*15,729*	*1.5*	*0.28*	*12.3*		*1.9*

*Vegetation and low turbidity in this year reduced the efficiency of nets.

curred at Lake Chautauqua during the warm months of certain years. For example, fish of the 1955 year-class as 3-year-olds made up a large part of the anglers' catch of white crappies in the spring of 1958 (Fig. 24); at the end of the summer of 1958, fish of this year-class as 4-year-olds made up only a small part of the catch in test-nets (Fig. 25). Hansen (1951:249) suggested that heavy mortality in one or more broods of white crappies took place in the summer months of his study at Lake Decatur, Illinois.

The 1950 and 1951 test-netting, commercial seining, angling, and tagging data were of value in assessing the mortality of the large 1948 brood of white crappies. In the fall of 1950, the 1948 broods of crappies (both species), which had just completed their third summer of growth, dominated the net catches (Fig. 25 and 26); the estimated standing crop of the 1948 brood of white crappies was 70 pounds per acre. The entire adult crappie population (both species), as shown in Table 39, was estimated to average 100 pounds per acre. Test-net data showed that 74.1 per cent of the crappies were whites and 25.9 per cent were blacks.

In the fall of 1951, the estimated standing crop of all white crappies was 30 pounds per acre, while the estimated standing crop of the 4-year-old white crappies of the 1948 brood was 16 pounds per acre. In the fall of 1951, white crappies comprised 75.3 per cent of the crappie population and black crappies 24.7 per cent. We estimated that the 1948 brood of white crappies lost 60 to 75 per cent of their numbers during their third year of life. About 95 per cent of this loss was caused by natural mortality and about 5 per cent through fishing (sport and commercial).

Hansen (1951:249) found in two broods of white crappies at Lake Decatur a major decline in numbers when the fish were approximately 3 years old. At Clear Lake, in Minnesota, Scidmore (1955:1) found that the mortality of crappies (mainly black) was "rapid after the fourth year." At Lake Chautauqua, the high mortality rate among white crappies during their third year of life prevented us from even attempting to make estimates of the mortality rates for the smaller broods that occurred in the lake after the passing of the 1948 brood. The high mortality rate estimated above for the large 1948 brood during its third summer of life may apply also to the small broods; a scarcity of white crappies over 3 years of age was evident in the net collections after 1954 (Fig. 25).

The factors involved in the extended survival of an extremely large brood, like that of 1948, were not detected in our study. Scidmore (1955:1) found evidence that a drastic reduction in the size of the adult population of crappies (black) was related to the establishment of a dominant year-class. He noted that a dominant year-class was usually separated from the next dominant year-class by 2 or more years. Thompson (1941:209) believed that a 4- or 5-year cycle of size and abundance occurred in fish populations at Lake Senachwine, Illinois. He hypothesized that a large, new year-class of crappies appeared at Lake Senachwine after natural mortality had reduced the preceding dominant year-class to such a low level that its cannabalistic food requirements had little effect upon the survival of its own young.

As has been pointed out earlier in this paper, only one extremely large or dominant brood of crappies (both species) appeared in Lake Chautauqua during our study. The crappies at Lake Chautauqua in 13 years failed to show any tendency toward being cyclic in their abundance. The species composition data presented graphically in Fig. 30, which is based on creel census data, give evidence that the adult populations of crappies, bluegills, and yellow bass fluctuated widely. Each of these species at one time or another domi-

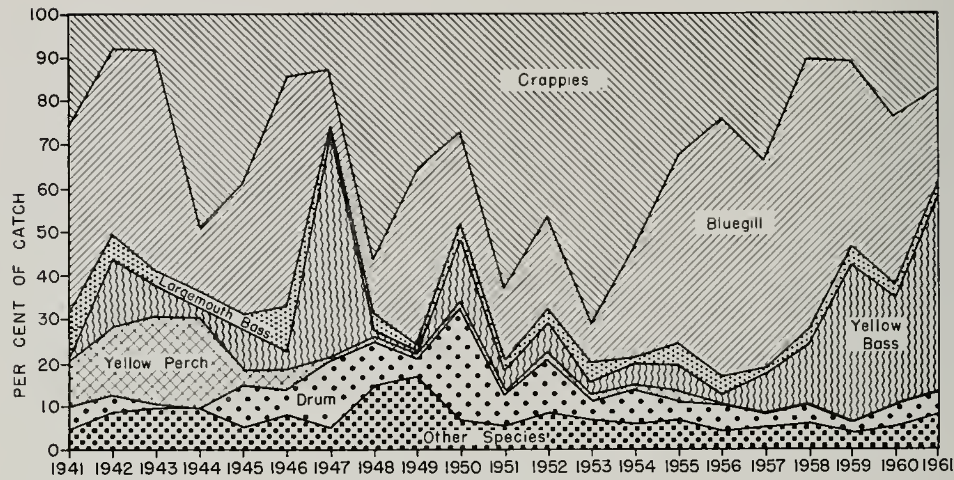


Fig. 30.—Species composition of fish in the anglers' catches at Lake Chautauqua, 1941–1961. The graph, which is based on numbers of fish, gives evidence that the adult populations of crappies, bluegills, and yellow bass fluctuated widely in the 21-year period.

nated the catch. Fishing conditions undoubtedly had some effect on the species composition shown in the graph; however, anglers at the lake usually fished for the species that were abundant, and upon this basis we believe that the graph gives a fairly accurate picture of the natural fluctuations in abundance of the sport fishes of catchable sizes.

BLUEGILL AND YELLOW BASS: POPULATION CHANGES. — The catch data presented in Table 40 indicate that the adult bluegill population of Lake Chautauqua was larger in the 1954–1959 period than at any other time during the study. During much of this period of high bluegill population, the crappie and yellow bass populations were comparatively low (Fig. 30). Over most of this period, the yellow bass population was evidently increasing in size and in 1961 it was large enough to dominate the anglers' catch.

WHITE BASS: POPULATION CHANGES.—The tagging studies at Lake Chautauqua indicated that the white bass population was quite mobile. During pe-

Table 40.—Data relative to the anglers' catch of bluegills at Lake Chautauqua in the period 1950–1959.

Year	*Number Caught*	*Average Catch Per Fisherman-Day*	*Average Catch Per Hour*	*Average Weight in Pounds*	*Pounds Caught and Removed Per Acre of Water*
1950	7,626	0.7	0.14	0.27	0.6
1951	9,335	0.7	0.12	0.31	0.8
1952	8,316	0.7	0.12	0.37	0.9
1953	1,680	0.3	0.06	0.37	0.2
1954	15,787	1.2	0.20	0.37	1.6
1955	21,838	2.0	0.36	0.37	2.3
1956	18,892	2.4	0.43	0.40	2.1
1957	22,220	2.1	0.38	0.40	2.5
1958	23,408	2.8	0.50	0.26	1.7
1959	15,526	2.4	0.43	0.23	1.0
Average	*14,463*	*1.5*	*0.27*	*0.34*	*1.4*

riods of high water, large numbers of white bass moved out of Lake Chautauqua into the Illinois River. Of 605 white bass tagged and released in Lake Chautauqua, 31 were recovered. Only 12 of the tag returns were from fish recaptured in the lake. The other returns were from fish collected in the Illinois River and in other waters connected with the river. One tagged white bass moved out of the lake into the Illinois River and thence up Spoon River, a distance of 20 miles, within 8 days. A similar observation was recorded by Barber (1952:115) on a white bass tagged and released in the Kentucky River. This fish moved 20 miles from its point of release in 13 days.

The short life span and limited spawning success of the white bass in Lake Chautauqua made the species of varying importance as a predator during our investigation. This fish was probably of some importance as a predator on young gizzard shad and to a lesser extent on other forage species in 1950–1952 and 1954–1956. (Only limited food studies were made.) It is doubtful if the species was abundant enough in other years to have had much effect as a predatory species.

GROWTH AND CONDITON OF FISHES

The data presented in preceding sections of this paper indicate that the sizes of the populations of the abundant fishes in Lake Chautauqua varied from year to year during the period of our study. The variations apparently were related to several factors involving the fish: (i) natural mortality, (ii) mortality due to fishing, (iii) spawning success, (iv) absence or presence of large or dominant year-classes, (v) recruitment of individuals from the Illinois River and escape of individuals from the lake to the river, (vi) competition between species, and (vii) growth.

Factors Affecting Growth and Condition

In this section, water levels and vegetation, population density, and fish removal are considered as possible factors affecting year-to-year changes in the growth and condition of the abundant species of fish at Lake Chautauqua.

WATER LEVELS AND VEGETATION.—The most apparent abiotic factor affecting the ecology of Lake Chautauqua during the years of our study was the fluctuating water level caused by overflowing of the Illinois River into the lake during periods of high river stages. During the 1950–1959 period, the normal pool stage of the lake was 435.0 feet above mean sea level (5.0 feet on the graphs in Fig. 31). The Illinois River overflowed into Lake Chautauqua when the river reached a stage of about 437.5 feet on the gauge at the lake (7.5 feet on the graphs in Fig. 31). The graphs show that fluctuations of river stages had no effect on the water levels of the lake until the stage of 437.5 feet was reached. At this stage and higher, the lake levels fluctuated with the river. The number of days each year in the months of June, July, and August that water levels were 437.5 feet or higher are given in Table 41. These numbers closely approximated the length of time during each summer of the investigation that the river was connected with the lake and that high water levels existed in the lake. Our measure of the effect water levels had on growth and condition of fishes was based on the number of days the lake stage was 437.5 feet or higher (Table 41).

At Lake Chautauqua, low water levels in summer were associated with abundant growth of sago pondweed, which, in turn, was associated with low turbidity. Estimates made of the abundance of sago pondweed in the lake in the months of June, July, and August are given in Table 41. Sago pondweed began to appear in the lake in May and continued to be present until late October or early November, if water levels remained low and stable. During our investigation, heavy growths of sago pondweed occurred in the lake in the summers of 1953, 1956, and 1959. Those were the only years in which water levels remained low from June through August (Table 41). Jackson & Starrett (1959:161–163) found that turbidity in the lake was lower when vegetation was abundant than when it was absent. We may assume that lower turbidities occurred in the summer months of 1953, 1956, and 1959 than in the other years of the program. In those years the vegetation provided a habitat for a large population of Tendipedidae larvae and other insects that are eaten by fish.

Water levels were considered by us as a density-independent factor affecting the condition and growth of bluegills, crappies, and possibly other species of fish in Lake Chautauqua. During growing seasons in which vegetation abounded throughout the lake, crappies and bluegills were found in our seining operations to be well distributed in the lake.

In years in which vegetation was scarce or absent as a result of high water levels in summer, we took very few bluegills and crappies in our September seine hauls. Test-netting indi-

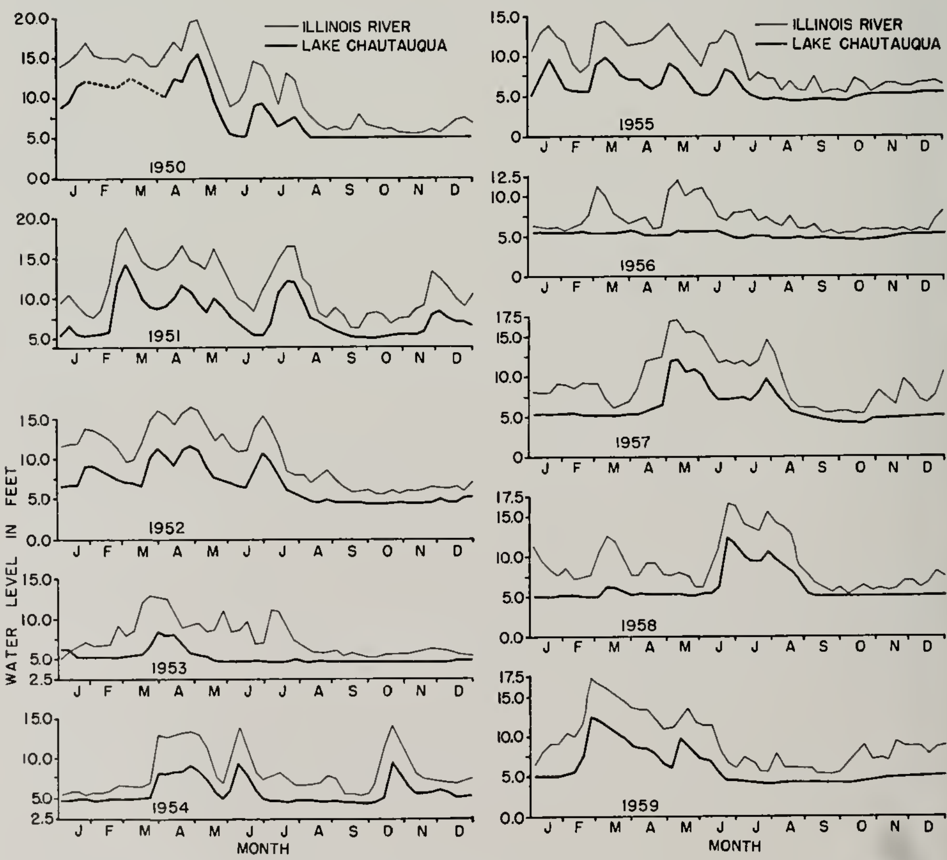


Fig. 31.—The water levels or stages of the Illinois River and of Lake Chautauqua, 1950–1959. Pool stage at Lake Chautauqua during the growing season was 435.0 feet above mean sea level, or 5.0 feet as shown on the graphs. The river overflowed into the lake at a stage of about 437.5 feet above mean sea level. The graphs (except part of the graph for 1950) were based on weekly summaries of water level data. They show the fluctuations that occurred in water levels and the effects of the river stages on water levels at Lake Chautauqua. The broken line in the graph for 1950 represents estimated levels during a short period in which no readings were taken.

cated that these species were in areas of the lake in which stumps and other suitable habitat were present. The amount of vegetation (or the absence of it) appeared to us to control the amount of suitable space available to bluegills and crappies, and therefore probably the carrying capacity of the lake for these species.

Table 41.—Number of days each year, 1950 through 1959, in which lake level elevation was 437.5 feet above mean sea level or higher, and the maximum elevation attained during the months of June, July, and August at Lake Chautauqua; also, the abundance of sago pondweed. At the stage of 437.5 feet, the lake was connected with the Illinois River.*

Year	*Number of Days at 437.5 Feet or Higher*	*Maximum Lake Level Elevation in Feet (Above Mean Sea Level)*	*Abundance of Sago Pondweed*†
1950	26	440.5	Absent
1951	32	442.1	Absent
1952	23	441.0	Absent to sparse
1953	0	434.8	Abundant
1954	15	439.7	Sparse to abundant
1955	12	438.6	Moderate
1956	0	435.1	Abundant
1957	28	440.3	Absent to moderate
1958	64	442.7	Absent to sparse
1959	1	437.5	Abundant

*The normal pool stage of Lake Chautauqua is 435.0 feet above mean sea level.
†Abundance was determined as described in Jackson & Starrett 1959:157; the terms *abundant* and *heavy* are equivalent.

In a growing season in which the water levels were low and the vegetation was abundant, the carrying capacity of the lake was probably much higher for bluegills, crappies, and possibly other fishes, than in a growing season in which water levels were high or fluctuating and the vegetation was scarce or absent.

POPULATION DENSITY AND FISH REMOVAL.—Some fisheries biologists have recognized population density as an important factor in the growth rate of fishes (Hile 1936:253–262 and others).

Hile (1936:262) reported that the growth rates of four separate populations of cisco in Wisconsin were determined primarily by the densities of the populations rather than by the basic productive capacities of the waters occupied by the fish (the slowest growth in the most densely populated lake).

Pirognikoff (1927:17) reported that the growth rate of the Siberian dace in Lake Chani (West Siberia) had been retarded considerably in a comparatively short period and stated that A. I. Beresovsky, Manager of the Siberian Ichthyological Laboratory, attributed the retarded growth to a decline in fishing activity and the resulting overpopulation of the lake. Pirognikoff stated further that Beresovsky considered intensified fishing activity as a radical measure for correcting the situation.

Willer (1929:672–675), working in Germany, reported that the growth of trout was influenced by "space-factors" (Raumfaktors). Hile & Deason (1934:236) attributed slow growth of whitefish in a Wisconsin lake to density of the fish population. They stated: "The crowding may impede growth through the creation of intense competition for food or through the operation of a 'space-factor.'"

Raitt (1939:78) observed close agreement between variations in growth rate and the degree of brood density of haddock in the North Sea—the smaller the brood the faster its rate of growth. Similarly, Bückmann (1939:26) found that in the German Bight the growth rate of the plaice was inversely proportional to the density of the stock of fish on the grounds. In Japan, Yoshihara (1952:59–60) investigated carp growth in nine ponds and found poor growth in ponds having dense populations.

Some investigators have reported a lack of inverse relationship between growth rate and population density of fish.

Hickling (1946:406–407) found that haddock stock on the Porcupine Bank (about 120 miles west of Ireland) after 4 years of no fishing in World War II was five times as dense as in the best years immediately before the war. The brood of 1942, existing under comparatively crowded conditions, grew no less rapidly than that of 1938; all the haddock examined were in excellent condition.

Le Cren (1949:258), in England, reported "no marked general increase in growth rate" in a population of perch at Lake Windermere after the population had been "severely reduced" by 8 years of trap fishery. He noted, however, that the mean lengths of the age groups of fish caught in the traps had shown significant variations from year to year and that the mean lengths were "somewhat greater" at the end of the 8 years than at the beginning.

Kawanabe (1958:178), in his studies of the "Ayu" in the River Ukawa, Japan, found that its growth was better in a dense population than in a thin one, and he concluded that "population density influences the growth of the fish, but it does so through the definite social structure peculiar to a species."

Concerning marine fish populations, Hjort (1932:5) wrote: "We may . . . safely conclude that the hypothesis of an inverse ratio between the number of individuals in a given population and the growth of these individuals is by no means of *universal* application."

Part of the concept of modern-day management of fish in warmwater lakes and ponds is based upon the hypothesis that an inverse ratio exists between the density of a population and the growth rates of individuals in that population, and that therefore growth rates can be increased by reducing the density through removal of individuals from the population.

Beckman (1941 and 1943) found an increase in the growth rates of rock bass in a Michigan lake after the fish population had been reduced through application of poison to one basin of the lake. In Alabama, Swingle, Prather, & Lawrence (1953) tried improving the growth rates of fish populations in overcrowded ponds by applying rotenone to parts of the ponds. Bennett (1954*a*: 251) reported maintaining relatively rapid growth of largemouth bass over a 10-year period at Ridge Lake, Illinois, by culling out the small bass and reducing the bluegill population during draining operations in alternate years.

Ricker & Gottschalk (1941:382) in Indiana and Rose & Moen (1953:104) in Iowa reported improved angling and increases in populations of game fish in warmwater lakes after populations of coarse fish in the lakes had been reduced with seines. Moyle, Kuehn, & Burrows (1950:163), who studied lakes from which some rough fish had been removed annually for 25 years, concluded: "In general, rough fish appear to have little effect on the total poundage of game fish in southern Minnesota lakes." In a later paper, Moyle & Clothier (1959:183–184) suggested that the decline in carp in Lake Traverse, Minnesota, might be related to the increase that occurred in crappies and bullheads in that lake.

In Massachusetts, Grice (1958:108) found that fyke netting of panfish and other nongame fish increased the growth rates of the species being thinned, but that it failed to improve the populations of game fish; where "removal was intensive, growth rates of panfish increased markedly." Lambou & Stern (1959:54–55) found that soon after removal of rough fishes from a lake they studied in Louisiana the sunfish population became overcrowded, and a decrease occurred in the average weight of sunfish in the creel.

Scidmore & Woods (1961:12, 18) reported that even with almost continuous efforts to remove carp from Clear Lake, Minnesota, "the carp population recovered quite rapidly with a shift in population structure toward greater numbers of young fish." These writers concluded from their studies on several Minnesota lakes that no direct relationship could be found between the amount of rough fish removal and subsequent improvement in panfish populations.

Our Lake Chautauqua study, as discussed in the section below, "Growth and Condition Data," revealed either that (i) an intensive program of fish removal had little effect on population density or that (ii) growth and condition of the fish were influenced by more factors than population density. At the end of 4 or 5 years of our study, the growth and condition of bluegills, crappies, freshwater drum, and bigmouth buffalo showed improvement. Such improvement could, at that time, have been correlated with the increased removal of commercial fishes from the lake. By continuing the study over a longer period, we found that the improvement in growth and condition that was evident early in the study tended to be lost. Perhaps a more intensive removal program would have had a measurable effect upon the growth and condition of fishes in the lake. However, the program apparently was intensive enough to reduce the average lengths of bigmouth buffalo, freshwater drum, carp, and channel catfish taken in commercial seines.

Successful reproduction of certain fishes, particularly carp, bigmouth buffalo, gizzard shad, bluegill, and yellow bass, may have offset population reductions resulting from fish removal. Also, the lake probably recruited additional stocks of fish from the river during high water levels.

The annual yields of sport fish were approximately the same at the end of our fish removal program as at the beginning. Apparently the commercial removal of fishes did not greatly benefit or harm the sport fishery at the lake.

Growth and Condition Data

From length and age data in Tables 1, 9, 15, 18, 21, and 24, we derived indices of growth (as described on page 8) for each of six species of fish abundant at Lake Chautauqua in the years of our study. From data collected in the fall months, we derived indices of condition (C) or average annual fall condition factors (as described on page 7) for each of eight species, the six referred to above and two others (Table 42).

BLUEGILL: GROWTH AND CONDITION DATA.—The year-to-year variations that occurred in the average lengths of 3-, 4-, and 5-year-old bluegills in Lake Chautauqua are shown in Fig. 32 and Table 9. The indices of growth based on data in Table 9 are expressed graphically in Fig. 33.

The average lengths of 3-year-old bluegills tended to vary more from year to year than did the average lengths of older bluegills (Table 9 and Fig. 32). Fish of the three age-groups (3-, 4-, and 5-year) made better growth

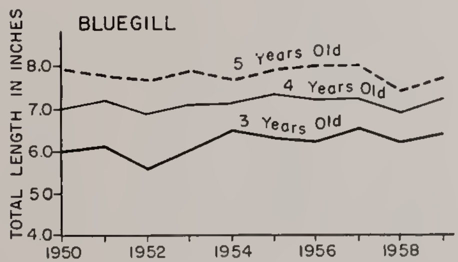


Fig. 32.—Year-to-year variations in growth rates (as indicated by length) of 3-, 4-, and 5-year-old bluegills at Lake Chautauqua, 1950–1959 (data from Table 9).

(as shown by average lengths) during the 1953–1957 period than during the preceding 3-year period or the following year, 1958. Although most of this period of good growth coincided with years of heavy removal of commercial fishes and shad from Lake Chautauqua (Table 5), we believe that commercial fish removal was not an important factor in the growth of bluegills in the lake. Our conclusion is supported by knowledge that the heaviest removal of commercial species and shad from the lake came in 1957, the year before a marked drop in bluegill growth rate occurred. If the heavy removal of commercial species and shad had been responsible for good bluegill growth in the 1953–1957 period, then good growth should have continued through 1958.

The period of good bluegill growth appears to have coincided with the pe-

Table 42.—Average annual fall condition (C) factors of the bluegill, white crappie, black crappie, carp, channel catfish, gizzard shad, bigmouth buffalo, and freshwater drum at Lake Chautauqua, 1950–1959.

Year	*Bluegill*		*White Crappie*		*Black Crappie*		*Carp*	
	Number of Fish	C Factor	Number of Fish	C Factor	Number of Fish	C Factor	Number of Fish	C Factor
1950	464	8.02	2,243	4.91	750	5.50	0	. . .
1951	53	8.35	1,183	5.13	161	5.68	307	5.39
1952	72	9.59	629	5.34	487	5.85	163	5.31
1953	137	9.37	503	5.80	138	6.32	167	5.12
1954	620	9.11	375	5.63	353	5.87	136	4.90
1955	218	10.03	147	5.60	259	6.27	241	4.72
1956	221	9.86	329	5.70	271	6.41	345	4.74
1957	299	8.38	405	5.03	196	5.54	387	4.82
1958	81	7.59	553	5.02	270	5.61	349	4.65
1959	248	8.49	264	5.48	238	5.90	0	. . .
Average or total	*2,413*	*8.88*	*6,631*	*5.36*	*3,123*	*5.90*	*2,095*	*4.96*

Table 42.—Continued

Year	*Channel Catfish*		*Gizzard Shad*		*Bigmouth Buffalo*		*Freshwater Drum*	
	Number of Fish	C Factor	Number of Fish	C Factor	Number of Fish	C Factor	Number of Fish	C Factor
1950	0	. . .	61	3.47	0	. . .	0	. . .
1951	90	3.45	0	. . .	292	6.44	358	4.98
1952	0	. . .	53	3.42	228	6.40	162	5.07
1953	160	3.43	140	2.75	208	6.22	341	5.26
1954	115	3.16	62	3.03	279	6.24	306	5.00
1955	306	3.28	118	3.38	274	6.40	392	4.52
1956	321	3.37	122	3.39	356	6.47	394	4.44
1957	316	3.14	257	3.23	426	6.64	370	4.64
1958	284	3.20	198	3.12	368	6.41	394	4.30
1959	0	. . .	0	. . .	0	. . .	0	. . .
Average or total	*1,592*	*3.29*	*1,011*	*3.22*	*2,431*	*6.40*	*2,717*	*4.78*

riod of largest catches per acre (and presumably of largest populations) of adult bluegills (Fig. 33). The occurrence of good growth with comparatively large populations of bluegills was

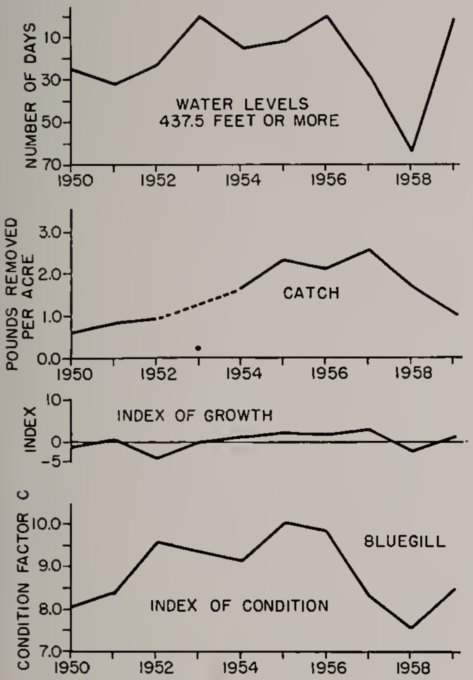


Fig. 33.—Trend in water levels at Lake Chautauqua (number of days water levels were at least 437.5 feet above mean sea level in June, July, and August, Table 41) and trends in population sizes (as reflected by anglers' catch, Table 40), indices of growth, and indices of fall condition (C) of bluegills at Lake Chautauqua, 1950–1959. The trend in the indices of condition was quite similar to the trend in water levels. Part of the curve representing catch is broken to indicate deviation from actual 1953 data (shown by a dot), which were considered inadequate and atypical.

believed by us to have been related to some density-independent factor that raised the lake's carrying capacity for bluegills. The factor involved here was, in our opinion, water levels. The best bluegill growth occurred in years (other than 1957) in which the water was low (and therefore relatively stable and low in turbidity) during the summer months (Fig. 33); even in 1957 the water was low, stable, and clear long enough to permit moderate growth of vegetation in some places (Table 41). The sharp decline that occurred in growth of bluegills in 1958 was, in our opinion, a result of continued high water levels (and consequent high turbidity) during the growing season of that year. A slight negative correlation was found to exist between high water levels and growth index of bluegills ($r = -0.46$).

During the years 1953–1956, in which no, or only a few, days of high water levels occurred, the turbidity was comparatively low, and vegetative growth was moderate to abundant; vegetation provided cover, and, directly or indirectly, suitable space and food for fish. These conditions evidently were favorable to the growth of bluegills. Patriarche (1953:249), in discussing poor growth of bluegills in Lake Wappapello, Missouri, stated, "Presumably the lack of vegetation, unstable water levels, and competition for food curtail the insect and plant food supply upon which the bluegill depends."

The average annual fall condition factors of bluegills (Table 42) tended to follow a trend similar to that of the growth index (Fig. 33). Fall condition, like growth, declined sharply in 1958. We believe that, during the time of our study, water levels were the principal factor affecting fall condition, as well as growth. Condition values were lower in autumns following summers of high water levels than in autumns following summers of low water levels. The correlation coefficient of $r = -0.81$ indicated a rather highly significant negative relationship between high water levels of Lake Chautauqua and high average fall condition factors of the bluegill.

White Crappie: Growth and Condition Data.—The annual variations that occurred in the growth patterns of 2-, 3-, and 4-year-old white crappies in the years 1950–1959 at Lake Chautauqua are reflected in the average lengths of the fish in these age-classes (Table

15 and Fig. 34). The 2-year-old white crappies of 1950–1952 had smaller average lengths than the 2-year-olds of any other year of our study. The 2-year-old fish of 1953 showed a drastic increase in growth rate (as measured by average length in the fall), and 2-year-old fish continued to show good growth rates each year through 1959. The improved growth rates probably were related to the comparatively small populations of crappies present in the lake after 1952.

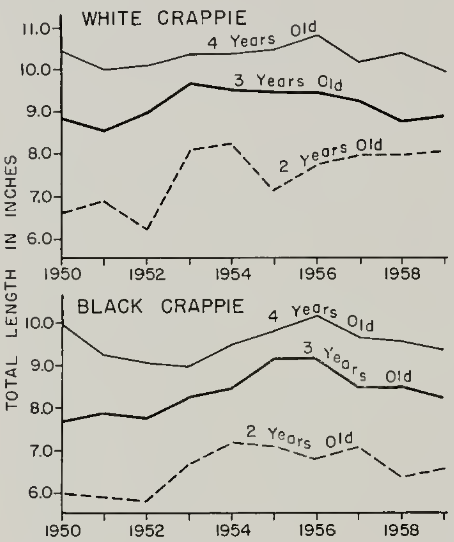


Fig. 34.—Year-to-year variations in growth rates (as indicated by length) of 2-, 3-, and 4-year-old white crappies and black crappies at Lake Chautauqua, 1950–1959 (data from Table 15 and Table 18).

The average lengths of the 3- and 4-year-old white crappies varied less from year to year than the average lengths of the 2-year-olds. After 1956, the average lengths of the 3- and 4-year-old fish declined slightly. By 1958 and 1959, the average lengths of fish of these ages had dropped to about where they had been in 1950 and 1951. The length data given here on the 3- and 4-year-old white crappies indicate that the increased removal of commercial fishes had no apparent beneficial effect on growth of these crappies.

We did not find that any correlation ($r=-0.16$) existed between the growth indices of 3- and 4-year-old white crappies and the Lake Chautauqua water levels (Fig. 35). The calculated correlation coefficient may be misleading, since more than one age-group was involved in the computation. In 1953, a year of low water levels, the 2-, 3-, and 4-year-old fish showed increases in average lengths (Fig. 34). In 1956, a year of low water levels, the 2- and 4-year-old fish showed increases in average

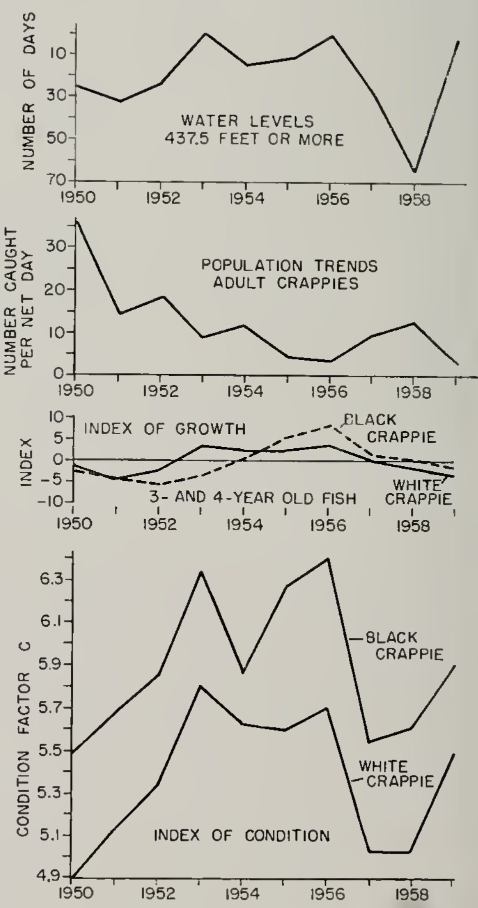


Fig. 35.—Trend in water levels at Lake Chautauqua (number of days water levels were at least 437.5 feet above mean sea level in June, July, and August, Table 41) and trends in population sizes (as reflected by test-netting, Table 39), indices of growth, and indices of fall condition (C) of white crappies and black crappies at Lake Chautauqua, 1950–1959.

lengths. In 1958, a year of high water levels, the 3-year-old fish showed a drop in average length. Both the 2- and 3-year-old fish showed increased average lengths in 1959, a year of low water levels. The 4-year-old fish showed a decrease in average length in that year; this decrease may have been caused at least partially by the small size of these fish as 3-year-olds in the previous year. The importance of the density-independent factor, water levels, on the white crappies of Lake Chautauqua is developed further in the following discussion on condition.

The average fall condition factor (C) of the white crappies of Lake Chautauqua ranged from a low of 4.91 in 1950 to a high of 5.80 in 1953 (Table 42). The 1950–1959 data indicate that a rather close negative correlation existed between high summer water levels and average fall condition factors of these crappies ($r=-0.79$). The graphs shown in Fig. 35 indicate that in an autumn following a summer of low water levels the average condition factor was high and in an autumn following a summer of high and fluctuating water levels the average condition factor was low. We believe that water levels acted as a density-independent factor that affected the Lake Chautauqua carrying capacity for fishes, such as crappies and bluegills, that feed by sight and tend to remain close to cover.

The low average condition of white crappies in the fall of 1950 demonstrated the effect of lowered carrying capacity (created by high water levels the previous summer) combined with high population density. In the summers of 1957 and 1958, water levels of Lake Chautauqua were high, and the carrying capacity of the lake was consequently reduced. In these years, the population density of white crappies was comparatively low, and, although the fall condition of the fish was low in both years, it was not so low as it had been in 1950, when the population density of crappies was high.

Increased removal of commercial fish apparently had no effect upon the average fall condition factor of white crappies, inasmuch as this factor was low in 1958, the year following an extensive removal of commercial fish, the largest removal of the entire research program (Table 2).

BLACK CRAPPIE: GROWTH AND CONDITION DATA.—The annual growth patterns of 2-, 3-, and 4-year-old black crappies are presented with those of the white crappies in Fig. 34. The 3- and 4-year-old black crappies showed more variation in growth rates than did white crappies of the same age-groups. The large and dominant 1948 brood of crappies, together with high water levels, seems to have had more effect on growth of the black crappies than it did on growth of the whites. In the fall of 1950, the dominant brood, which was then classified as 3 years of age, had the smallest average length recorded during the study for black crappies of that age (Table 18). As might have been expected, fish of the 1948 brood had a low average length as 4-year-olds in 1951. In 1953, the black crappies of the 1950 brood made poor growth, as shown by their average lengths in the fall as 4-year-olds, whereas fish of most other age-groups of both species showed marked improvement in their growth rates. Possibly fish of the 1948 broods of both species were still present in sufficient numbers in 1953 to affect the growth of black crappies of the 1950 brood. The poor growth of black crappies in the period 1950–1952 was probably related to the large numbers of crappies in the population at that time and to high water levels. Three- and 4-year-old black crappies showed improvement in growth in the years 1954–1956 (Fig. 34 and Table 18).

After 1956, the average lengths of the 3- and 4-year-old crappies of both species declined. The 2-year-old black crappies exhibited a growth pattern quite similar to that of white crappies of the same age. After 1952, 2-year-olds of both species continued to show increases in average length (Fig. 34). The relatively small number of 2-year-old crappies after 1952, coupled with years of low water levels, evidently favored the growth of crappies in their second summer of life.

As shown by condition factors (Table 42), the black crappie at Lake Chautauqua in the years of our study was a plumper fish than the white crappie. The two species made similar year-to-year changes in plumpness or condition (Fig. 35).

Like the white crappie, the black crappie had fall condition values that were negatively correlated with high water levels ($r = -0.73$). The relationship between water levels and average fall condition factors (Fig. 34) discussed above for the white crappie is applicable to the black crappie.

Channel Catfish: Growth and Condition Data.—The year-to-year variations that occurred in the average lengths attained by 4-, 5-, and 6-year-old channel catfish of Lake Chautauqua are shown in Fig. 36 and Table 21. Each year, 1953–1956, the 4-year-old channel catfish showed increases in average length, but in the following 2-year period they showed decreases. The period of good growth coincided with a period of summers of comparatively low water levels (Table 41). We believe that during this period the carrying capacity of the lake for catfish increased as a result of the low water levels. During part of this period, the size of the catfish population (as determined by the catch per acre seined) was relatively high (Table 35); normally the large population would have had an adverse effect on growth of the fish if the carrying capacity of the lake had not been increased. Part of this period of good growth rates of 4-year-old catfish was in the years of increased removal of catfish and other fish (Fig. 37 and Table 5). However, had removal of fish been the principal factor involved here, growth rates of 4-year-old fish should have continued to be good through 1957 and 1958 (instead of decreasing in 1957 and 1958), since 1956 and 1957 were years of extensive removal of fish, including catfish.

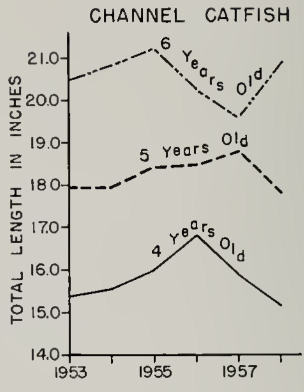


Fig. 36.—Year-to-year variations in growth rates (as indicated by length) of 4-, 5-, and 6-year-old channel catfish at Lake Chautauqua, 1953–1958 (data from Table 21).

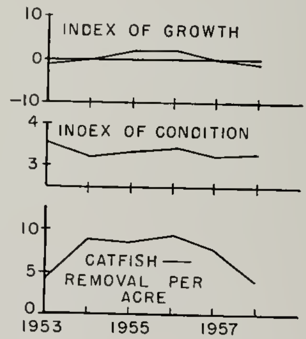


Fig. 37.—Patterns of growth and fall condition (C) of channel catfish in Lake Chautauqua and number of pounds of catfish removed per acre from the lake, 1953–1958 (fish removal data from Table 35).

The 5-year-old channel catfish followed a pattern of average lengths similar to the pattern followed by the 4-year-olds except in 1957, when an increase rather than a decrease in average length occurred (Fig. 36). The increase in 1957 was made by 5-year-old fish of the 1953 year-class and may be explained in part, at least, by the unusually good average length of individuals of this year-class as 4-year-old fish in 1956. In 1958, fish of the 1953 year-class as 6-year-olds were larger than fish of the 1952 year-class were in 1957; the 4- and 5-year-old fish were smaller in 1958 than in 1957. We cannot explain why the average length of the 6-year-old fish dropped in 1956 while the average lengths of the 4- and the 5-year-olds showed increases.

The indices of growth of 4-, 5-, and 6-year-old channel catfish (Fig. 37) showed a slight negative correlation with the high water levels of Lake Chautauqua ($r = -0.47$).

Only very slight variations occurred from year to year in the average fall condition factors of channel catfish (Table 42 and Fig. 37). The small changes that occurred in condition indicated a slight negative correlation with high water levels ($r = -0.39$). Finnell & Jenkins (1954:20–21) and Buck (1956:46) found that turbidity retarded the growth of channel catfish in Oklahoma. At Lake Chautauqua, the relatively clear waters during the growing seasons in years of low water evidently had some beneficial effect on condition and growth of channel catfish.

GIZZARD SHAD· CONDITION DATA.—The average fall condition factors for gizzard shad at Lake Chautauqua, as determined from length and weight data collected in September and early October, 1950 and 1952–1958, showed little variation, except in 2 years of low condition factors, 1953 and 1954 (Table 42). The increased removal of fish during the 1954–1957 period (Table 5) apparently had no desirable effect on the average fall condition of shad; the condition values were lower in 1956, 1957, and 1958 than in 1950 and 1952 (Table 42). The increase in abundance of adult shad after 1953 apparently had some effect upon the condition of the shad, since average fall condition factors after that year were not as high as they had been in 1950 and 1952 when the adult populations, as measured by the catch, were small (Table 37).

The fluctuations in average condition factors of gizzard shad in the autumns of 1950–1958 showed no significant correlation with the high water levels of the respective preceding summers ($r = +0.10$). The low condition value in the fall of 1953 followed a summer of low water levels (Table 41). This low condition value was possibly related to the large brood of bigmouth buffalo spawned in 1953.

BIGMOUTH BUFFALO: GROWTH AND CONDITION DATA.—The average lengths that the 4-, 5-, and 6-year-old buffalo at Lake Chautauqua attained in the period 1951–1958 are shown in Fig. 38 and Table 24. Other than in 1953 and 1954, the year-to-year trends in average

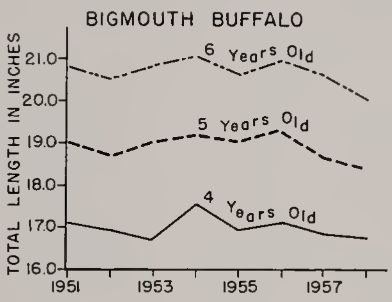


Fig. 38.—Year-to-year variations in growth rates (as indicated by length) of 4-, 5-, and 6-year-old bigmouth buffalo at Lake Chautauqua, 1951–1958 (data from Table 24).

length of individuals in the three age-groups were quite similar. The decline in average length of the 4-year-old fish in 1953 may have resulted from competition with the large population of buffalo spawned in that year.

The variations that occurred from year to year in average length of the buffalo were small. The average lengths, other than length of the 4-year-old fish in 1953, tended to be greater in the 1953–1956 period than at any other time in the study except possibly 1951 (Table 24). With few exceptions, the years of good growth of buffalo (as measured by average length in the fall) coincided with years in which the summer water levels were low (Tables 24 and 41 and Fig. 38). The range in the indices of growth was minor (—2.6 to

+2.0). The increased removal of fish during the investigation apparently did not increase the growth rate of bigmouth buffalo; the average length of buffalo was slightly less in 1958 than at the beginning of the removal program in 1951 (Fig. 38 and Table 24).

The variations that occurred in the average fall condition factors for bigmouth buffalo (Table 42) were quite small but were more pronounced than those noted for the indices of growth. The lowest average fall condition factors for the bigmouth buffalo, as for the gizzard shad, occurred in 1953 and 1954. From 1951 through 1958, high summer water levels seemed to have a minor effect on the average fall condition factors ($r = +0.30$). After 1954, the C factors for buffalo increased slightly each year until 1958, when the factor dropped to 6.41, a figure close to that calculated for the year 1955. If the increased removal of buffalo and other fishes had been responsible for the slightly higher condition values in the years 1955–1957, then the C value should have been high in 1958, since more fish were removed from Lake Chautauqua in 1957 than in any other year during the program (Table 5).

Freshwater Drum: Growth and Condition Data.—The average lengths of the 3-, 4-, and 5-year-old drum at Lake Chautauqua varied only slightly from year to year in the 1951–1954 period (Fig. 39 and Table 1). In 1955, declines occurred in the average lengths of fish of all three age-groups—sharp declines in the 3- and 4-year-old fish. In the following year, average lengths of the 3- and 4-year-old fish increased to about the levels of the years before 1955. The average length of the 5-year-old fish in 1956 was slightly less than the average length of this age-group in 1955. The decrease in average length of this age-group in 1956 may have been a result of the small size of the individuals the preceding year as 4-year-olds. In 1957, all three age-groups increased in average length. The 4-year-old fish of 1957 were larger than those of any previous year. In that year the 3- and 5-year-olds were approximately as large as in any earlier year. In 1958, the 3-year-olds were larger than in any other year of the study. The 4- and 5-year-olds were much smaller than in 1957.

The sharp decline that occurred in average length of drum individuals in 1955 followed the year of the largest removal of drum (73,197 pounds, Table 5) during the entire fish removal program. Another decline in average length of drum occurred in 1958, a year after the largest removal of fish (all of the species combined). The population density of drum (as indicated by catch per 100 yards of seine) was at its lowest in 1958 (Table 34). Water levels did not seem to have any noticeable effect on growth rates. The factors affecting the growth rates of the drum at Lake Chautauqua were not apparent to us.

The average fall condition factor of freshwater drum at Lake Chautauqua was at its highest in 1953 (Fig. 40 and Table 42). In 1954, the condition factor dropped to approximately its level in 1951. Then, in 1955, the condition factor made a sharp decline and did not recover to the 1954 level during the 1955–1958 period.

In 1955 and subsequent years, fish buyers in Chicago reported back to us that the flesh of some of the drum from Lake Chautauqua was "hard-meated"

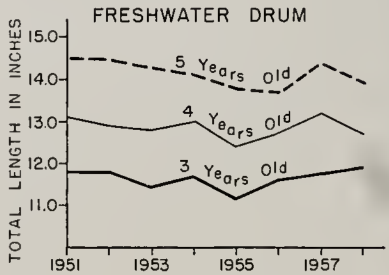


Fig. 39.—Year-to-year variations in growth rates (as indicated by length) of 3-, 4-, and 5-year-old freshwater drum at Lake Chautauqua, 1951–1958 (data from Table 1).

(rubbery). This condition affected the sale of drum from the lake, and the local wholesale undressed price dropped from about 8 cents to 3.5 cents a pound. Prior to 1955, we had never received a complaint regarding the flesh of drum from Lake Chautauqua. The low average fall condition factor of drum in the 1956–1958 period occurred during the years the population density of drum (as estimated by catch per 100 yards of seine) was relatively low. The poor condition of drum in the 1956–1958 period occurred during and following the time of the most extensive removal of fish (all kinds) from the lake. At Lake Winnebago, Wisconsin, Wirth (1958:32) observed an improvement in the condition of drum following a drastic reduction of drum stocks—"little improvement" in the first 3 years of a removal program but "a decided change" in the next 2 years.

In most years of our study, we found little relationship between water levels of Lake Chautauqua and average fall condition factors of the freshwater drum in the lake (Tables 41 and 42). This finding is not surprising, since, according to Langlois (1954:262), adult drum can find their food by taste and smell. Possibly at Lake Chautauqua, high turbidity resulting from high water and the absence of vegetation would not seriously interfere with feeding.

One factor that possibly affected the condition of drum was the increase in abundance of carp, gizzard shad, and bluegill that occurred after 1952, following the extensive removal of buffalo. The effect of the increase in abundance of these species cannot be proved.

Another factor that may have affected the condition of drum in Lake Chautauqua was a change in abundance of food. This change may have affected the condition of carp, also. The effect of this change is developed for both carp and drum in the following paragraphs.

CARP: CONDITION DATA.—After 1953, the average fall condition factors of drum and carp followed rather similar downward trends (Fig. 40). These species were the only ones studied that exhibited such trends in condition after 1953. We suspect that the condition of both species was affected by the same factor or factors. As suggested above, the decline in condition may have been caused by a change in abundance of food.

Since 1956, commercial fishermen have complained that a large percentage of the carp caught in the Illinois River were too small for commercial sale. The predominance of small carp has damaged the Illinois River commercial fishery. In 1957, we began to study the growth rate of carp in the river. We found this growth rate to be relatively poor for the middle and upper reaches of the Illinois. Small size and low condition of the Illinois River carp, we found, were related to this poor growth rate. A decrease in the general

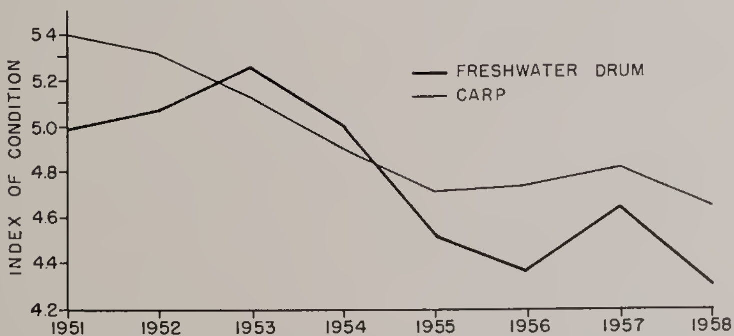


Fig. 40.—Average fall condition (C) factors of carp and freshwater drum at Lake Chautauqua, September, 1951–1958.

well-being of carp in the river was paralleled by a decline in the condition of carp and drum in Lake Chautauqua.

Paloumpis & Starrett (1960:422–424) reported that the population of fingernail clams (Sphaeriidae) in lower Quiver Lake (part of the Illinois River) dropped from 1,115 individuals per square foot in 1952 to 54 per square foot in 1953 and to 0 in 1954. The snail population in lower Quiver Lake also declined in this period. Fingernail clams virtually disappeared from Lake Chautauqua after 1954. In a recent study (unpublished), Starrett & Paloumpis found that the principal foods available to carp in the middle Illinois River were Tubificidae worms, filamentous algae, Entomostraca, phytoplankton, and, to a limited extent, insect larvae.

Forbes & Richardson (1920:106) considered carp as "omnivorous feeders, taking principally vegetable matter, but insect larvae, crustaceans and mollusks, and other small aquatic animals as well." Moen (1953:675) found in his detailed study of the food habits of carp in Iowa lakes that aquatic insect larvae, small crustaceans, and snails formed the bulk of the animal foods consumed during the summer periods. Richardson (1928:471) considered the increase of small Sphaeriidae (fingernail clams) that occurred in the Illinois River as a result of pollution as beneficial to the "coarse fish" by affording them a greater supply of food. We believe that the fingernail clams in the Illinois River formerly furnished an important source of food for carp and that with the virtual disappearance of the fingernail clams in the river in about 1953 the growth of the carp in that river was affected adversely.

We have hesitated even to conjecture that the decline in condition of carp and drum in Lake Chautauqua was related to the reduced fingernail clam population in that lake, as may have been the case with the growth of carp in the Illinois River. Darnell (1958:381) reviewed the literature on the food habits of drum and stated that "the smallest individuals feed upon entomostracans. These are followed by aquatic insects, and the large drums feed chiefly upon clams and snails, supplemented by crayfish and other materials." Darnell examined four drum from Lake Pontchartrain, Louisiana, that contained food and found that about 73 per cent of the stomach contents consisted of clams, 11 per cent mud crabs, 10 per cent undetermined organic material, and 6 per cent amphipods. He also found traces of blue crabs, gastropods, hydroids, and leaves and twigs of vascular plants. Dendy (1946:117–118), who studied the food habits of drum in Norris Reservoir, Tennessee, reported that when mollusks were not available drum substituted fish for the mollusks that were normally part of their diet.

Two detailed food habits studies, one by Daiber (1952:38) on Lake Erie and the other by Moen (1955:593) on four Iowa lakes, indicated that insect larvae, crustaceans, and fish comprised the bulk of the food taken by drum. Mollusks were available to the drum in Lake Erie, but Daiber (1952:39) found no evidence that they were used for food by the drum. Moen (1955:591) reported that mollusks (Gastropoda) formed only about 3 per cent of the total volume of food in the stomachs of the drum collected from the four Iowa lakes. Fingernail clams were present in the lakes, but Moen found none in the stomachs of the drum.

No detailed food habits study was made of drum at Lake Chautauqua; the few stomachs of drum collected from this lake after 1954 and examined by us contained insect larvae and fish. Benthic studies made at Lake Chautauqua by Paloumpis & Starrett (1960:417) indicated that each year in the period 1952–1956 the lake supported a large population of dipterous larvae. Small-size fish that might have served as forage for drum occurred abundantly each summer during the study. The insect larvae should have been abundant enough to furnish an adequate food supply for carp. However, in spite of the abundance of food in the lake, other than mollusks, the condition of carp and drum declined. In 1957 (Fig. 40), the C values of these species showed some improvement and then declined again. At Quiver Lake, there was a temporary increase in the fingernail clam population in 1957 (Paloumpis & Starrett 1960:425). Bottom fauna studies were not conducted on Lake Chautauqua in 1957. Possibly the fingernail clam population increased that year in Lake Chautauqua as well as in Quiver Lake. Whether an increase in the clam population might have been related to the 1957 increase in the condition values of carp and drum can only be speculated.

The literature reviewed above on the food habits of drum indicates that there is a conflict of opinions among biologists as to the importance of Mollusca in the diet of the drum. In the event that even small quantities of Mollusca are a nutritional requirement in the diet of carp and drum, then the decrease in the Mollusca population that occurred in Lake Chautauqua in the years of our study could have had an adverse effect on the condition values of these fishes in the lake.

EFFECTS OF FISH REMOVAL ON FISHING

The effects of an intensive fish removal program on the growth and condition (C) of fish and on the size of fish populations at Lake Chautauqua have been discussed in the preceding sections. The effects that increased intensity of commercial fishing had on commercial and sport fishing are presented below.

Effect on Commercial Fishing

The possible effects that the increased fish removal had on size of commercial species are discussed in another section, "Growth and Condition Data." The changes that occurred from year to year in the mean weights of the four principal commercial species are given in Table 43. The decreases in the weights of these species occurred concurrently with the increased fishing pressure and are quite apparent. In some species, decreases in size and weight would eventually have occurred because of natural mortality and lack of dominant year-classes; in other species, decreases were caused by fishing.

Table 43.—Mean weights (pounds) of commercial fishes caught in commercial seine hauls in September at Lake Chautauqua, 1951–1958.

Year	*Channel Catfish*	*Bigmouth Buffalo*	*Freshwater Drum*	*Carp*
1951	2.9	7.4	1.3	6.2
1952	3.4	8.0	1.4	5.0
1953	3.2	6.5	1.3	6.6
1954	3.0	6.9	1.5	5.5
1955	2.3	6.0	1.1	3.4
1956	2.3	5.0	0.9	3.3
1957	1.9	4.9	1.1	4.5
1958	1.8	5.0	0.9	4.1
Average	*2.6*	*6.2*	*1.2*	*4.8*

In 1952, 728 pounds of fish were caught per 100 yards of seine employed in the relatively unexploited waters of Lake Chautauqua, and, even though the fishing effort was greatly increased after 1952, fishermen were still able in 1957 to catch 623 pounds of fish per 100 yards of seine. However, the species composition of the catch changed considerably during this period, as indicated in Table 44. The most important changes in composition were in buffalofishes and gizzard shad. Apparently adult shad occupied the habitat earlier used by the buffalo population, which suffered a higher fishing mortality rate than other species during the program (Table 5). In order to maintain a high yield in the later years, particularly for buffalofishes, commercial fishermen had to nearly double the fishing effort that they had exerted on the lake with seines

Table 44.—Pounds of fish caught and removed from Lake Chautauqua with commer-
bigmouth), freshwater drum, channel catfish, and gizzard shad, are given number of pounds

Year	*Yards of Seine Employed (Cumulative)*	*Carp*		*Buffalofishes*		*Freshwater Drum*	
		Pounds Caught	Per Cent of Catch	Pounds Caught	Per Cent of Catch	Pounds Caught	Per Cent of Catch
1951	14,200	22,653	26.8	49,831	58.8	7,797	9.2
1952	23,400	21,436	12.6	107,885	63.3	26,738	15.7
1953	34,500	15,072	17.4	25,115	29.1	30,943	35.8
1954	49,650	49,139	22.1	65,489	29.4	61,163	27.5
1955	56,250	12,819	8.6	46,039	30.8	52,790	35.3
1956	46,080	8,499	6.0	52,359	37.3	27,825	19.8
1957	42,680	58,893	22.1	99,287	37.3	36,281	13.7
1958	43,450	46,673	30.7	39,257	25.9	26,014	17.1
Total or per cent of catch	*310,210*	*235,184*	*18.5*	*485,262*	*38.1*	*269,551*	*21.2*

*Less than 0.1 per cent of catch.

in 1952. Even though the commercial fishermen had to increase their effort, the fishing continued to remain as a profitable operation for them. We believe that the decline in the commercial fishery was caused by the increased fishing pressure on the lake by roundup fishing and by seining.

Individual wing-net fishing seemed to have little or no effect on the buffalo fishery prior to 1951. We believe that it would have been possible to maintain a population of large buffalo in Lake Chautauqua if fishing had been limited to individual wing-net fishing. The present study indicates that, because of the great variation in the strength of annual broods, a buffalo population could be overfished within a few years. Restoration of an overexploited population would depend upon one or both of two possibilities: (i) the production of a large brood such as that of 1953, many members of which survived to be recruited into the adult fish population of Lake Chautauqua

Table 45.—Average numbers of fish caught per fisherman-day and pounds removed per acre by anglers each year at Lake Chautauqua, 1950–1959.

Kind of Fish	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*	*1958*	*1959*
Crappies	0.96	2.59	1.51	2.20	2.41	1.53	0.97	1.52	0.50	0.66
Bluegill	0.73	0.68	0.68	0.30	1.18	2.02	2.39	2.11	2.83	2.43
Yellow bass	0.50	0.19	0.23	0.08	0.24	0.28	0.08	0.38	0.16	2.05
Largemouth bass	0.13	0.08	0.10	0.13	0.04	0.22	0.17	0.07	0.14	0.24
Freshwater drum	0.90	0.31	0.41	0.16	0.34	0.26	0.25	0.15	0.20	0.14
Channel catfish	0.11	0.09	0.09	0.06	0.07	0.07	0.08	0.07	0.04	0.06
Other kinds	0.18	0.17	0.23	0.18	0.24	0.28	0.09	0.16	0.69	0.20
Total	*3.51*	*4.11*	*3.25*	*3.11*	*4.52*	*4.66*	*4.03*	*4.46*	*4.56*	*5.78*
Crappies and bluegill combined	1.69	3.27	2.19	2.50	3.59	3.55	3.36	3.63	3.33	3.09
Estimated pounds per acre removed by anglers	5.0	6.2	6.1	2.6	10.2	6.5	4.4	6.0	4.0	3.7

cial seines in September, 1951–1958. For each of five kinds, carp, buffalofishes (mainly
and per cent of total catch. Data for other kinds are combined.

Channel Catfish		*Gizzard Shad*		*Others*		*Total*
Pounds Caught	Per Cent of Catch	Pounds Caught	Per Cent of Catch	Pounds Caught	Per Cent of Catch	
1,353	1.6	2,400	2.8	651	0.8	84,685
4,346	2.5	10,000	5.9	0	. .	170,405
3,638	4.2	11,650	13.5	8	*	86,426
13,038	5.8	33,755	15.2	96	*	222,680
9,997	6.7	27,521	18.4	241	0.2	149,407
15,822	11.3	35,660	25.4	236	0.2	140,401
9,584	3.6	61,670	23.2	340	0.1	266,055
2,967	2.0	34,865	23.0	2,019	1.3	151,795
60,745	*4.8*	*217,521*	*17.1*	*3,591*	*0.3*	*1,271,854*

in 1956, and (ii) recruitment of fish from the river.

Effect on Sport Fishing

The best sport fishing at Lake Chautauqua occurred in 1954 (Table 45), when anglers removed 10.2 pounds (estimated) of fish per acre. The poorest fishing was in 1953, when anglers caught only 2.6 pounds (estimated) per acre. Fishing effort was higher in 1959 than in any other year; however, good fishing did not continue throughout the summer, as was indicated by the small number of pounds per acre removed by anglers in that year (Table 45).

Changes in composition of the sport fishery catch were indicated earlier in the section "Population Dynamics." The changes in the sport fish populations were thought to have been natural fluctuations of abundance. The catch per unit of effort (per fisherman-day) was slightly better for most years after 1954 than for most years before. However, the yield in pounds per acre did not increase; it was higher in the period 1950–1954 than in the period 1955–1959. We believe that, at Lake Chautauqua, commercial fishing had no lasting measurable effect on sport fishing.

DISCUSSION

A few old Illinois River fishermen are still left who recall the so-called "good old days" of fishing in the river and its floodplain lakes. Many of the floodplain areas have been drained and now produce corn instead of fish. The old-timers remember how they or their fathers, fishing in the open pockets of the heavy beds of "moss" with long cane poles and tandem spinners, caught bass for the market. They remember that the water was deeper in the lakes during the summer months than it is today.

Quiver Lake, which lies adjacent to Lake Chautauqua, was a popular fishing lake many years ago. Kofoid (1903: 244) studied the biology of Quiver Lake back in the 1890's and recorded the following observations about the vegetation of the lake during that period:

> The vegetation is a very important and much more constant factor in the environment of Quiver Lake than it is in that of the river. In its maximum development reached in the summers of 1894 and 1895 it fills . . . the lake from shore to shore with a closely matted growth, the only open places being an interrupted and tortuous channel through which the waters of Quiver Creek . . . make their way to the river. The vegetation in the body of the lake consists in the main of *Ceratophyllum,* with an admixture of *Elodea* and *Potamogeton* toward the margins. Along the east-

ern shore, and toward the upper end of the lake where springy shores and sandy bottom are to be found, the vegetation partakes more of the permanent littoral character. Here rushes, sedges, arrowleaf, and the aquatic *Cruciferae* and *Umbelliferae* appear among the *Potamogetons* and other floating plants. In the northern area, especially along its western shore, where more alluvium is found, water-lilies, pickerel-weed, and the lotus abound, and the *Potamogetons* are more abundant . . . . The "wild celery" (*Vallisneria spiralis*) is sparingly present in the channel of the eastern arm of the lake, while in the tributary bottom-lands above are aquatic meadows of wild rice and other water-loving grasses, rushes, and sedges.

In years of higher water . . . , such as the four following 1895, the vegetation differs from that of low-water years more in quantity than in kind. The main body of the lake and a considerable portion of both arms are freed to a greater or less extent from their vegetation, a border of varying width remaining near the shores, and scattered clumps dotting the lake here and there in the broad stretches of open water.

Today Quiver Lake is devoid of aquatic plants. The formerly deep basin of the lake has been filled in with 4- to 8-foot deposits of silt. Turbid water at depths of over 3 feet and a soft, flocculent bottom prevent the establishment of aquatic plants in the lake. Conditions in Quiver Lake are duplicated in many of the other floodplain lakes of the Illinois River; that is, in the past 35 years siltation has greatly changed the ecology of these lakes.

In the late 1930's Bellrose (1941:237–245) became aware of the changes occurring in the waterfowl habitat of the Illinois River valley. He proposed two methods for managing the floodplain lakes for waterfowl. These methods are extremely important here since they relate directly to habitat changes that affect the fishery.

The first of the methods (Method A) that Bellrose (1941:274) proposed contained the following provisions:

The water levels should be lowered sufficiently by July 1 to leave at least 30 per cent of the area in mud flats, allowing such moist-soil plants as nutgrasses, water hemp or pigweed, various smartweeds, teal grass, wild and Japanese millets and rice cut-grass —all good duck food plants—to develop on the mud flats. These plants usually appear by natural means, without the necessity of sowing. However, if they have not occurred on the grounds in a number of years, it is advisable to sow the mud flats with Japanese millet seed and tubers of chufa. Chufa might well replace other less valuable nutgrasses, which produce no tubers and which are the more abundant of the species in the Illinois River valley.

In order to make the seeds, tubers or rootstocks of the moist-soil plants available to waterfowl, it is necessary to flood the beds in the fall months. Springs, streams, pumps and natural rises in the Illinois River are used in conjunction with dams . . . and levees to flood such areas.

The second method (Method B) that Bellrose (1941:274–275) proposed included the following:

Water levels should be maintained as nearly constant as possible at a depth of 2 to 3 feet. This creates a habitat suitable for such submerged and floating aquatic plants as longleaf, sago and bushy pondweeds and coontail. As a result of the water level created by the Peoria navigation dam, bodies of water between Peoria and Henry appear to be best adapted to this type of management.

According to Bellrose (personal communication, July 9, 1963), since 1941, siltation has occurred to such an extent that most Illinois River valley lakes have undergone serious deterioration as aquatic plant habitats. The bottoms of these lakes have become increasingly flocculent and soft, so that important duck food plants, such as coontail, longleaf pondweed, bushy pondweed (*Najas guadalupensis*), and wild celery (*Vallisneria spiralis*), can no longer, in the presence of wave action, remain attached to the bottom. Moreover, turbidity from wave action reduces the penetration of sunlight to such a degree that plants cannot thrive. Sago pondweed is able to attach itself to the soft bottom in the silt-laden lakes, provided the water level is stable and the water depth is not much more than 3 feet, as is the case in many parts of Lake Chautauqua. Low & Bellrose (1944:10, 14) found that in the Illinois River valley sago pondweed yielded only 10.6 cc of seed per square meter in 1941 and 1942 and that it ranked only 24th in seed production among the aquatic plants in those lakes. Bellrose does not now recommend management Method B in a lake that does not have a firm bottom.

Bellrose's Method A is the most effective technique used today in the Illinois River valley for managing a floodplain lake for the benefit of ducks. If the Illinois River does not overflow and flood the river basin during the summer months, an excellent stand of food plants for ducks is almost certain to develop in the basin by fall. Since the basins of most of the floodplain lakes of the Illinois River valley have become filled in with silt until they are nearly level, the type of drawdown called for under Bellrose's Method A exposes much of the lake bottom to the air. The remaining water is too shallow for the survival of sport fishes. We believe that effective management of an Illinois River floodplain lake for both ducks and fish is virtually impossible.

From 1950 through 1959, Lake Chautauqua was primarily managed under Bellrose's Method B, whereby the water was held as nearly as possible at a stable depth of 2 to 3 feet (435.0 feet above mean sea level). In those years, production of duck food plants was limited largely to sago pondweed, for reasons given above. In early fall, the sago pondweed, when present (1953, 1956, and 1959), was used principally by baldpates (*Anas americana*). Some blue-winged teals (*Anas discors*) and coots (*Fulica americana*) also fed on sago in early fall. By the time the large flight of mallards (*Anas platyrhynchos*) arrived in late October and November, the sago was gone, except for scattered seeds on the lake bottom.

Because of siltation, the basin of Lake Chautauqua is now so nearly level that use of the Method A management plan would be possible in years of low water levels. This plan would involve draining much of the lake basin during the summer to permit the growth (on exposed areas) of moist-soil plants: planted Japanese millet and volunteer native plants. In the autumn, the lake basin would be reflooded by water pumped from the river and diverted from Quiver Creek, or, in some years, by natural flooding from the Illinois River. If Method A were used, the lake would have very limited use for fish; in the opinion of Frank C. Bellrose of the Illinois Natural History Survey (personal communication May 14, 1964), the lake would have increased value for ducks.

If the lake were to be managed for fish, the summer water level should be equivalent to the 1950 level of 435.0 feet or slightly higher so that most of the lake would be 2 to 4 feet deep. Sedimentation surveys at 10-year intervals would show the extent of storage loss for each decade and allow a revision of the base level to compensate for the loss in storage. The river should be permitted to flow into the lake at a level of 437.5 feet or slightly higher.

In the years of our study, the density-independent factor that includes all phenomena associated with or influenced by stable or varying water levels was considered to be the single most important factor affecting the dynamics of the fish populations of Lake Chautauqua. In our opinion, if the river were kept out of the lake, and the water could be held at a normal pool level for a period of about 5 years, the populations of some of the fishes would become overabundant and the yield of both the sport and commercial fishes would decline. For nearly 40 years, the senior author has been somewhat familiar with the fishing at Spring Lake (Tazewell County), near Lake Chautauqua. Since Spring Lake was isolated from the Illinois River in about 1910, it has produced mainly small sunfish. According to old-timers, prior to 1910 the fishing in Spring Lake was excellent, and the fish were of sizes attractive to fishermen.

Many facets of fish population dynamics involved with fluctuations of water levels in river and lake and with connections between river and lake are not clearly understood. However, the good growth rates and the apparent lack of overpopulation of the fishes in

Lake Chautauqua during the period of our study made us realize that the density-independent factor, water levels, was probably the principal factor acting upon the fish population of this floodplain lake. Lack of regularity of fluctuations was characteristic of Lake Chautauqua during our investigation. In one year, high water came in May and the following year it came in June and July. In another year, water was low and stable throughout the entire growing season. The water levels affected such diverse needs of fish as food, cover, space, and spawning. Stable water levels favored the growth of sago pondweed, which provided cover for the fish and growing space for the periphyton on which many fish fed. Fluctuating water levels undoubtedly had an important effect upon the spawning success of some fish species. For example, several nests of largemouth bass were found stranded by a 1-foot drop in water level. Possibly in some years large numbers of carp eggs were destroyed by receding waters. Richardson (1913:402–403) recorded the destruction of large numbers of carp fry as a result of the drying up of spawning grounds near Havana. The largest broods of carp and bigmouth buffalo produced in Lake Chautauqua during the course of our study occurred in 1953, a year of low and stable water levels during late spring and summer; however, when similar water level conditions existed in 1956, no large survival of spawns of carp and bigmouth buffalo occurred.

Because, during periods of high water, fish could enter or leave Lake Chautauqua, possibly the sizes of some fish populations were changed during such periods. We found some evidence that carp and gizzard shad made population adjustments in periods of high water.

The influx of biogenic salts into Lake Chautauqua from the Illinois River was not measured in the period of our study, but probably the river contributed such nutrients to the lake. Waterfowl contributed nutrients in the form of excreta. The exposure and reflooding of portions of the lake bottom undoubtedly were beneficial in making certain nutrients available. At normal pool stage, most of the lake water was within the calculated euphotic zone, which represented depths of 41.0 to 53.5 inches in the growing season of 1953 (Jackson & Starrett 1959:159). In such a situation, the growth of bottom microflora, which served as food for macrobenthic organisms and fish, was possibly stimulated.

Stroud (1948:93–94) concluded from his studies at Norris Reservoir, Tennessee, that "The present long-term cycle of water-level fluctuation is beneficial to the fish population as a whole resulting, as it apparently does, in periodic increases in the food supply and subsequent improvement in growth rates." Wood (1951), Bennett (1954*b*), Hulsey (1957), and others have considered water levels as an important factor affecting fish populations.

The commercial seine hauls made in Lake Chautauqua in September of each year, 1951–1958, were at approximately the same water levels. In years of low water levels during the growing season, sago pondweed was abundant and in such years crappies and bluegills were taken in considerable numbers in the seine hauls. In years of high water levels during the growing season, sago pondweed was either sparse or absent, and only a few crappies and bluegills were caught in the commercial seines. We have concluded from the seining and netting operations that in seasons in which sago pondweed was sparse or absent the crappie and bluegill populations were concentrated in the stump-filled semipermanent shoreline habitats, while in seasons in which sago flourished crappies and bluegills were widely distributed. We believe that the density-independent factor, water levels, actually changed the carrying capacity of the lake through bringing about changes in turbidity, food supply, vegetation, and suitable space.

We believe that the commercial fish removal program in Lake Chautauqua in the years of our study might have had a measurable effect upon the sport fishery had it not been for the fluctuating water levels, successful reproduction of fishes in the lake, and recruitment of fishes from the Illinois River.

We believe that the principal benefit resulting from the increased fish removal program at Lake Chautauqua was in the economic gains to the participating commercial fishermen and in the utilization of the fish as food for man, food that otherwise would have been lost.

SUMMARY

1.—Lake Chautauqua is located near Havana, in Mason County, Illinois. It is a restored 3,562-acre lateral-levee reservoir, shallow and subject to flooding by the Illinois River.

2.—A biological investigation was conducted on the fishes of this lake over a 10-year period, 1950–1959. The present paper is concerned principally with the various fishes and their relative abundance in Lake Chautauqua, their biology, the dynamics of their populations, and the effects of commercial fishing on them. Sedimentation, turbidity, chemical, and bottom fauna studies were made in conjunction with the fishery investigation.

3.—Field data were obtained on the fishery by creel censusing, commercial wing-net fishing, commercial seining, test-net fishing (1-inch-square-mesh wing nets), minnow seining, use of rotenone, and electrofishing. During the investigation, 52,214 fish were weighed and measured. In addition, 12,814 small fish were measured; 23,812 fish were aged.

4.—Prior to 1951, fishing pressure on the lake was comparatively light. Up to that year, commercial fishing was restricted to the use of individual wing nets. The estimated annual yield from the lake (all fishes) in the period 1942–1949 ranged from 12 to 45 pounds per acre (48.4 pounds per acre in 1950). To increase the yield, supervised commercial seining was carried on at the lake in September of each year, 1951–1958. Roundup fishing with wing nets, started at the lake in 1952, helped to increase the yield. In the 1951–1958 period, the annual yield of all fishes ranged from 73.1 to 121.0 pounds per acre. During the 10-year period of the study, 2,991,131 pounds or 839.7 pounds per acre were removed. Buffalofishes (mainly bigmouth buffalo) comprised 49.1 per cent of the weight of fishes removed from the lake.

5.—Sixty-four species of fish were collected from the lake. At least 30 of these species were either rare or rare-occasional, 21 species ranged from occasional to common, and only 13 species occurred abundantly. The abundant species were bigmouth buffalo, gizzard shad, carp, freshwater drum, bluegill, white crappie, black crappie, yellow bass, channel catfish, shortnose gar, emerald shiner, spottail shiner, and brook silverside.

6.—The growth rates of 14 species of fish at Lake Chautauqua were determined. Growth rates of most of the species studied compared favorably with growth rates of these species in other waters. A few species had excellent growth rates. Lack of stunted fish indicated that the fish populations in the lake were not overcrowded. In some species, the population was dominated for several years by one or two year-classes.

7.—Most of the catch of freshwater drum in the commercial seine hauls was composed of 3-, 4-, and 5-year-old fish. Very few drum in the catch were more than 6 years old.

8.—During the investigation, only two dominant year-classes of adult bigmouth buffalo were observed, those of 1948 and 1953. The increased removal of bigmouth buffalo changed the buffalo population in 4 years from one con-

taining a high percentage of old, large fish to one of predominantly young, small fish.

9.—One large carp spawn was observed during the study, that of 1953. Apparently, after September, 1956, carp were recruited into the lake from the river.

10.—Five-year-old and older fish dominated the catch of channel catfish in the commercial seine hauls in 1953 and 1954. After 1954, the commercial fishery of this species was dependent mainly upon 4-year-olds. Apparently, the change in this fishery was caused by the increased removal of catfish.

11.—The bluegill population in most years of the study was composed of several broods, of which one brood had better representation than the others. The minnow seine hauls indicated that bluegills spawned with varying degrees of success; the success of several year-classes of bluegills varied considerably in later life. Apparently, many of the fish of a large and dominant brood of bluegills died from natural causes during their sixth summer of life (as 5-year-old fish).

12.—One large and dominant brood of white crappies was observed during the study. Natural mortality of white crappies was high in the fourth summer of life (as 3-year-old fish). In most years, black crappies were less abundant than white crappies.

13.—The strength of the year-classes of yellow bass observed during the study varied considerably.

14.—Only two year-classes of white bass observed in the lake during the study were of even moderate size. Tagging studies indicated that a large percentage of white bass over 1 year old moved out of the lake in periods of high water.

15.—Controlled commercial seining appeared to be the best method available to obtain population data on the abundant large fish in the lake. Population analysis was based on 348 completed seine hauls. Large variations occurred in catch from haul to haul. These variations were believed to have been related to (i) uneven distribution or concentration of fishes in the lake, (ii) movement of fishes within the lake, and (iii) accidental loss of fish from the seines. Tremendous variations in catch occurred among the seine hauls made in a given section of the lake (three sections). Statistical analysis indicated that impractical numbers of seine hauls were required to detect 10 per cent changes in population of the most numerous fish species. In the study, enough hauls were made to detect 40 to 50 per cent changes in the populations of buffalofishes, drum, and channel catfish, but only more drastic changes in the populations of carp.

16.—After the areas covered in seine hauls were found to be roughly circular, calculations were made of the number of pounds of fish caught per acre seined.

17.—Data from both tagging and test-netting were used in estimating the size of crappie populations.

18.—The standing crop of all species of fish at Lake Chautauqua was estimated to be about 500 pounds per acre in the 1951–1952 period. In 1957, the estimated standing crop of usable-size fish of four commercial kinds and gizzard shad was not far below the 1951–1952 estimate for these species. However, the species composition had changed. Populations of shad and of undersized carp had increased in size since the earlier period.

19.—The population of freshwater drum showed a downward trend after 1954. This trend was apparently associated with increased removal of drum and the scarcity of members of two year-classes.

20.—In 1955, the percentage of large channel catfish (fish of 20 inches or more total length) taken in the seine hauls dropped considerably; the catch showed an increase in the number of 3- and 4-year-old fish. In 1958, a sharp decline occurred in the catch of catfish;

the decline was believed caused by the small size of the 1955 brood and by heavy removal in previous years of 4-year-old and older fish.

21.—Increased fishing pressure on the lake reduced the size (weight) of the bigmouth buffalo population below the size of the population of 1951–1952. The bigmouth buffalo population in the 1951–1952 period was composed mainly of members of the large 1948 year-class and a considerable number of older fish; the population in 1957 was dominated by the large 1953 year-class and contained very few older fish.

22.—The catch of gizzard shad per estimated acre seined in the 1951–1952 period was 19.7 pounds, whereas in 1957 the catch was 88.5 pounds per acre seined. Increases in the shad population appeared to be associated with decreases in the bigmouth buffalo population.

23.—Twenty-one years of creel-census data indicated that the adult populations of crappies (both species), bluegills, and yellow bass in Lake Chautauqua fluctuated widely.

24.—At the end of 4 or 5 years of the investigation, improvements in the growth and condition of bluegills, crappies, freshwater drum, and bigmouth buffalo could have been correlated with the increased removal of commercial fishes. When the investigation was continued, the early improvements apparently were lost. Successful reproduction, recruitment of fish from the river, and water levels tended to offset any measureable benefits resulting from the increased removal of fish.

25.—Water levels were considered as a density-independent factor affecting the condition and growth of bluegills, crappies, and possibly certain other species.

26.—After 1953, the average fall condition factors of carp and drum followed rather similar downward trends. Other species of fish studied did not follow such trends in condition. The declines in condition of carp and drum may have been related to the scarcity of fingernail clams in the lake after 1953.

27.—In the past 35 years, siltation has greatly changed the ecology of many of the floodplain lakes of the Illinois River. For management of the fishery, sedimentation surveys of Lake Chautauqua should be made every 10 years and the summer pool stage of the lake increased to compensate for any loss of storage capacity caused by siltation.

28.—The density-independent factor, water levels, was probably the single most important factor affecting the dynamics of the fish population of Lake Chautauqua.

29.—The principal benefit resulting from the increased fish-removal program at Lake Chautauqua was in economic gains to the participating commerical fishermen and in the utilization of the fish as food for man, food that otherwise would have been lost.

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Page numbers in italic type indicate principal references. Fish species having names of more than one word are listed with the words in normal rather than inverted order: for example, *Bigmouth buffalo* rather than *Buffalo, bigmouth.* Cross references are given only if believed necessary. Because *Angler(s), Anglers' catch(es),* and *Angling* are in close proximity in the index, no reference from one to the other is given; however, after *Angler(s),* reference is given to *sport fishermen.*

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LENGTH-WEIGHT RELATIONSHIP DATA

FOR 11 SPECIES OF FISH IN LAKE CHAUTAUQUA

S U P P L E M E N T A R Y T A B L E S

FOR

A BIOLOGICAL INVESTIGATION OF THE

FISHES OF LAKE CHAUTAUQUA, ILLINOIS

by William C. Starrett and Arnold W. Fritz

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These tables are referred to on page 7 in the section entitled "Calculations."

Supplementary Table 1.--Average and range of calculated weights (at various lengths) of 2,651 bluegills taken at Lake Chautauqua, Illinois (fall months, 1950-1959).

Total Length in Inches	Calculated Average Weight in Pounds*	Range of Annual Calculated Weights in Pounds
5.0	0.10	0.08 to 0.11
5.5	0.14	0.11 to 0.16
6.0	0.18	0.16 to 0.21
6.5	0.24	0.21 to 0.27
7.0	0.31	0.27 to 0.34
7.5	0.38	0.34 to 0.43
8.0	0.48	0.42 to 0.54
8.5	0.58	0.52 to 0.61
9.0	0.70	0.70 to 0.75

*Average calculated log W = -1.31249 + 3.31026 (log L).

Supplementary Table 2.--Average and range of calculated weights (at various lengths) of 7,739 white crappies taken at Lake Chautauqua, Illinois (September and early October, 1950-1959).

Total Length in Inches	Calculated Average Weight in Pounds*	Range of Annual Calculated Weights in Pounds
6.0	0.10	0.09 to 0.11
6.5	0.13	0.11 to 0.14
7.0	0.17	0.15 to 0.19
7.5	0.21	0.19 to 0.24
8.0	0.26	0.24 to 0.29
8.5	0.32	0.30 to 0.35
9.0	0.39	0.36 to 0.42
9.5	0.46	0.44 to 0.50
10.0	0.55	0.52 to 0.60
10.5	0.64	0.61 to 0.71
11.0	0.75	0.71 to 0.83
11.5	0.86	0.82 to 0.96
12.0	0.99	0.94 to 1.01

*Average calculated log W = -1.53658 + 3.27432 (log L).

Supplementary Table 3.--Average and range of calculated weights (at various lengths) of 3,985 black crappies taken at Lake Chautauqua, Illinois (September and early October, 1950-1959).

Total Length in Inches	Calculated Average Weight in Pounds*	Range of Annual Calculated Weights in Pounds
5.5	0.09	0.08 to 0.09
6.0	0.12	0.10 to 0.13
6.5	0.15	0.13 to 0.16
7.0	0.19	0.17 to 0.22
7.5	0.24	0.22 to 0.27
8.0	0.29	0.27 to 0.32
8.5	0.36	0.34 to 0.39
9.0	0.43	0.41 to 0.46
9.5	0.51	0.49 to 0.55
10.0	0.60	0.57 to 0.65
10.5	0.70	0.67 to 0.76
11.0	0.81	0.78 to 0.88
11.5	0.94	0.85 to 0.96

*Average calculated log W = -1.42138 + 3.19958 (log L).

Supplementary Table 4.--Average and range of calculated weights (at various lengths) of 2,091 yellow bass taken at Lake Chautauqua, Illinois (spring months 1950-1954 and 1957-1959).

Total Length in Inches	Calculated Average Weight in Pounds*	Range of Annual Calculated Weights in Pounds
6.5	0.14	0.11 to 0.16
7.0	0.17	0.14 to 0.20
7.5	0.21	0.18 to 0.24
8.0	0.26	0.23 to 0.29
8.5	0.32	0.29 to 0.35
9.0	0.38	0.35 to 0.41
9.5	0.45	0.41 to 0.48
10.0	0.53	0.48 to 0.56
10.5	0.62	0.56 to 0.65
11.0	0.71	0.65 to 0.75
11.5	0.82	0.74 to 0.85

*Average calculated log W = -2.42004 + 3.14296 (log L).

Supplementary Table 5.--Calculated weights (at various lengths) of 582 largemouth bass taken in the spring and fall months at Lake Chautauqua, Illinois (1950-1959).

Total Length in Inches	Calculated Weight in Pounds*	Number of Fish
6.0	0.11	4
6.5	0.14	13
7.0	0.18	8
7.5	0.22	17
8.0	0.27	22
8.5	0.32	34
9.0	0.38	40
9.5	0.45	47
10.0	0.53	61
10.5	0.62	38
11.0	0.71	55
11.5	0.81	32
12.0	0.93	42
12.5	1.05	20
13.0	1.19	26
13.5	1.33	34
14.0	1.49	17
14.5	1.66	19
15.0	1.84	12
15.5	2.04	6
16.0	2.25	7
16.5	2.47	5
17.0	2.71	8
17.5	2.96	3
18.0	3.23	5
18.5	3.51	3
19.0	3.81	2
19.5	4.12	1
20.0	4.46	1

*Average calculated $\log W = -2.34869 + 3.07281 (\log L)$.

Supplementary Table 6.--Calculated weights (at various lengths) of 1,094 white bass taken in the spring and fall months at Lake Chautauqua, Illinois (1950-1959).

Total Length in Inches	Calculated Weight in Pounds*	Number of Fish
4.5	0.03	1
5.0	0.05	18
5.5	0.07	90
6.0	0.09	89
6.5	0.11	42
7.0	0.15	33
7.5	0.18	24
8.0	0.23	39
8.5	0.28	21
9.0	0.34	4
9.5	0.41	1
10.0	0.48	14
10.5	0.57	51
11.0	0.66	99
11.5	0.77	136
12.0	0.88	118
12.5	1.01	68
13.0	1.15	70
13.5	1.31	59
14.0	1.48	48
14.5	1.66	36
15.0	1.86	17
15.5	2.07	9
16.0	2.30	7

*Average calculated $\log W = -2.34869 + 3.07281 (\log L)$.

Supplementary Table 7.--Average and range of calculated weights (at various lengths) of 2,882 freshwater drum taken at Lake Chautauqua, Illinois (September, 1951-1958).

Total Length in Inches	Calculated Average Weight in Pounds*	Range of Annual Calculated Weights in Pounds
9.0	0.34	0.31 to 0.36
9.5	0.40	0.36 to 0.43
10.0	0.47	0.42 to 0.50
10.5	0.54	0.49 to 0.59
11.0	0.63	0.56 to 0.68
11.5	0.72	0.64 to 0.78
12.0	0.82	0.73 to 0.88
12.5	0.92	0.82 to 1.00
13.0	1.04	0.92 to 1.13
13.5	1.17	1.03 to 1.26
14.0	1.30	1.15 to 1.41
14.5	1.45	1.28 to 1.58
15.0	1.60	1.41 to 1.75
15.5	1.77	1.55 to 1.94
16.0	1.95	1.69 to 2.14
16.5	2.14	1.84 to 2.35
17.0	2.34	1.99 to 2.57
17.5	2.56	2.16 to 2.82
18.0	2.79	2.79 to 3.00

*Average calculated $\log W = -2.36175 + 2.98633 (\log L)$.

Supplementary Table 8.--Average and range of calculated weights (at various lengths) of 2,471 bigmouth buffalo taken at Lake Chautauqua, Illinois (September, 1951--1958).

Total Length in Inches	Calculated Average Weight in Pounds*	Range of Annual Calculated Weights in Pounds
16.0	2.46	2.39 to 2.57
16.5	2.72	2.65 to 2.84
17.0	3.00	2.92 to 3.12
17.5	3.29	3.20 to 3.4~~2~~3
18.0	3.61	3.51 to 3.75
18.5	3.94	3.84 to 4.10
19.0	4.30	4.19 to 4.47
19.5	4.68	4.56 to 4.86
20.0	5.08	4.96 to 5.27
20.5	5.51	5.36 to 5.71
21.0	5.96	5.78 to 6.17
21.5	6.43	6.22 to 6.66
22.0	6.93	6.69 to 7.18
22.5	7.45	7.18 to 7.72
23.0	8.00	7.69 to 8.28
23.5	8.58	8.23 to 8.88
24.0	9.19	8.79 to 9.50
24.5	9.83	9.38 to 10.16
25.0	10.50	9.99 to 10.84
25.5	11.20	10.64 to 11.59
26.0	11.92	11.31 to 12.31

*Average calculated log W = -3.52421 + 3.25141 (log L).

Supplementary Table 9.--Average and range of calculated weights (at various lengths) of 2,481 channel catfish taken at Lake Chautauqua, Illinois (September, 1951-1958).

Total Length in Inches	Calculated Average Weight in Pounds*	Range of Annual Calculated Weights in Pounds
12.0	0.49	0.47 to 0.50
12.5	0.57	0.55 to 0.60
13.0	0.65	0.63 to 0.68
13.5	0.74	0.71 to 0.77
14.0	0.84	0.81 to 0.87
14.5	0.95	0.92 to 1.00
15.0	1.07	1.03 to 1.14
15.5	1.19	1.16 to 1.25
16.0	1.33	1.29 to 1.38
16.5	1.48	1.44 to 1.53
17.0	1.64	1.60 to 1.69
17.5	1.81	1.77 to 1.87
18.0	1.99	1.95 to 2.06
18.5	2.19	2.13 to 2.27
19.0	2.40	2.33 to 2.49
19.5	2.63	2.54 to 2.72
20.0	2.87	2.77 to 2.97
20.5	3.12	3.01 to 3.24
21.0	3.39	3.26 to 3.53
21.5	3.68	3.53 to 3.82
22.0	3.98	3.81 to 4.15
22.5	4.30	4.10 to 4.49
23.0	4.64	4.42 to 4.85
23.5	4.99	4.75 to 5.23
24.0	5.37	5.09 to 5.68
24.5	5.76	5.46 to 6.05
25.0	6.18	5.84 to 6.50
25.5	6.61	6.31 to 6.96
26.0	7.07	6.73 to 7.45
26.5	7.56	7.18 to 7.99
27.0	8.05	7.62 to 8.51
27.5	8.57	8.10 to 9.07
28.0	9.12	8.60 to 9.66

*Average calculated $\log W = -3.01994 + 3.44126 (\log L)$.

Supplementary Table 10.--Average and range of calculated weights (at various lengths) of 2,479 carp taken at Lake Chautauqua, Illinois (September. 1951-1958).

Total Length in Inches	Calculated Average Weight in Pounds*	Range of Annual Calculated Weights in Pounds
15.0	1.67	1.57 to 1.74
15.5	1.84	1.73 to 1.92
16.0	2.03	1.91 to 2.11
16.5	2.23	2.05 to 2.34
17.0	2.44	2.29 to 2.57
17.5	2.67	2.50 to 2.82
18.0	2.91	2.73 to 3.09
18.5	3.16	2.96 to 3.37
19.0	3.43	3.21 to 3.67
19.5	3.71	3.47 to 3.99
20.0	4.01	3.75 to 4.32
20.5	4.33	4.04 to 4.68
21.0	4.66	4.35 to 5.06
21.5	5.00	4.67 to 5.45
22.0	5.37	5.00 to 5.87
22.5	5.75	5.35 to 6.31
23.0	6.14	5.72 to 6.77
23.5	6.56	6.11 to 7.25
24.0	7.00	6.50 to 7.75
24.5	7.45	6.90 to 8.28
25.0	7.92	7.31 to 8.84
25.5	8.42	7.74 to 9.42
26.0	8.93	8.18 to 10.02
26.5	9.47	8.64 to 10.65
27.0	10.02	9.12 to 11.31
27.5	10.60	9.62 to 11.99
28.0	11.19	10.13 to 12.71

*Average calculated log W = -3.36498 + 3.05012 (log L).