OBSERVATIONS ON THE FISH POPULATION OF A LAKE CONTAMINATED BY RADIOACTIVE WASTES

LOUIS A. KRUMHOLZ
The American Museum of Natural History

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INTRODUCTION

In 1950, a cooperative program was established between the United States Atomic Energy Commission and the Tennessee Valley Authority for the investigation of the physical and biological effects of the dissemination of radioactive materials and wastes on the environment of the area occupied by and contiguous to the operations of the Commission at Oak Ridge, Tennessee. Despite the fact that the more hazardous liquid wastes from the Oak Ridge National Laboratory, which contained large concentrations of fission products and uranium, and low concentrations of transuranic elements, were placed in tanks, it was thought that seepage from the tanks and the routine disposal of low-level radioactive wastes into White Oak Creek might have a deleterious effect on the flora and fauna. In addition, if the organisms manifested a certain degree of tolerance, some economies in waste disposal might be accomplished.

Under this agreement, the Tennessee Valley Authority set up a program of study to determine what radioactive elements had accumulated in the biota of the stream, in which tissues they had accumulated, and what, if any, had been the effects of such accumulation on survival rates, on population balances, and on the various types of individual organisms. The study period extended from June, 1950, until July 1, 1953.

A preliminary outline for such an ecological survey of the White Oak Creek drainage area was reported by Higgins (1950). At that time he listed many studies which were intended to be carried out but which were not because of lack of time and/or personnel. In the final programming, the over-all study was divided into three main categories: botany, limnology, and fishery biology, as outlined by Krumholz (1954). Office space and laboratory facilities were provided by the Health Physics Division of the Oak Ridge National Laboratory.

In as much as this paper is concerned only with the ecology of the fishes of White Oak Lake, there is no need to elaborate on the other phases of the study. The scope of the program for fishery biology included (a) six semi-annual estimates of the size and composition of the fish population, followed by the eradication of the extant fish population by the use of rotenone in order to verify the results of the netting studies, (b) the dissection of fishes in an effort to establish the percentage composition, by weight, of the various tissues in the body, (c) the food habits of some fishes as determined by analyses of their stomach contents, (d) the accumulation and selective concentration of radiomaterials in individuals of the various species, and (e) radiochemical analyses of selected samples of tissues in order to determine the amounts and identity of the radioelements accumulated. In addition, some studies were carried out on other vertebrates, particularly on the migratory waterfowl and the muskrat. However, the findings on these other vertebrates are not reported here.

During the course of the study, the following numbers of plants and animals were collected and identified by members of the study group: 38 species of bryophytes, representatives of 93 genera of algae, 392 species of vascular plants, 253 species of invertebrates, and 228 species of vertebrate animals. No attempt was made to collect and identify the terrestrial insects. Even from this incomplete list of 523 plants and 481 animals, it is evident that there are a great many biological factors which contribute to the ecology of the area.

Such a vast array of flora and fauna, when coupled with the various edaphic, physical, and climatological factors, made it impossible, in the time allotted, to study all the biological groups in detail. For this reason, only those organisms and communities which were believed best to exemplify the over-all picture were selected for study. However, it is important to know the relationships between the aquatic plants and animals, because the microscopic flora and fauna frequently serve as food for the larger animals. A detailed study of these aquatic food chains could shed considerable light on the capability of one organism to concentrate different radionuclides selectively and perhaps pass them on to some predatory species. For instance, a benthic form, such as a larval chironomid, could selectively concentrate radiophosphorus to a fairly high degree. If, however, that radioelement was not in a suitable form to be assimilated by the fish that fed upon the larva, the radiophosphorus would not be accumulated in the tissues of the fish. Similarly, if the larva did not have the tendency to accumulate large quantitites of radiostrontium selectively and the fish did have that tendency, the fish, by consuming very large numbers of the larva and by utilizing all the radiostrontium ingested, could accumulate relatively large amounts of that element. If the radiostrontium were in such a form that both the larva and the fish that fed upon the larva could assimilate and selectively concentrate it, the over-all factor of selective accumulation might be very large.

Although food chains were not studied in detail, it is believed that sufficient information was obtained on which to base general assumptions regarding the effects of radioactive waste materials on the flora and fauna of a selected area, and to recognize the importance and necessity of a continuing program of research.

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The present paper is a revision of parts of the final report of the Ecological Survey of White Oak Creek, Roane County, Tennessee, conducted by the Tennessee Valley Authority for the United States Atomic Energy Commission under Contract No. AT(40-1)-221.

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I am indebted to Dr. Karl Z. Morgan, Director, Health Physics Division, Oak Ridge National Laboratory, for providing office space and laboratory facilities throughout the study period and also during the period of preparation of the final report. Dr. Morgan and his entire staff, especially Mrs. Venus I. Knobf and Messrs. H. H. Abee, W. A. Mills, and P. E. Brown, were most cooperative in assisting, guiding, and counseling the personnel of the study group at all times.

I sincerely appreciate the assistance of personnel of the Research and Medicine Division of the Atomic Energy Commission in Oak Ridge, Tennessee. I particularly wish to thank Dr. Edward McCrady, under whose guidance the initial phases of the study were planned, and Dr. C. S. Shoup, under whose guidance the study was continued until its termination.

DESCRIPTION OF THE AREA

White Oak Creek, a tributary to the Clinch River in Roane County, Tennessee, has a drainage area of 3850 acres. The topography is typical of the Ridge and Valley Province of the eastern part of the state. The underlying strata are principally limestones, dolomites, sandstones, shales, and siltstones of Cretaceous and Ordovician origin (Stockdale, 1951).

White Oak Creek rises from several sources located on the southeastern slope of Chestnut Ridge, and between Chestnut and Haw ridges. The main stream flows in a southwesterly direction across Bethel Valley over limestones of the Chicamauga group to Haw Gap just south of the site of the Oak Ridge National Laboratory. The stream flows through Haw Gap over the sandstones and shales of the Rome formation and enters Melton Valley where it crosses a region of Conasauga shale until it empties into the Clinch River at mile Cl. 20.8. Along its course, it receives several tributaries, the largest of which is Melton Branch. That branch rises in the eastern end of Melton Valley and empties into White Oak Creek just above the upper end of White Oak Lake (fig. 1).

White Oak Lake is an impoundment of the waters of White Oak Creek. The dam consists of a fill on a highway, 0.6 mile upstream from the mouth of the creek, which was in existence for some time before the lake was impounded. In 1941, the highway fill was raised to its present level by the Tennessee Valley Authority, and the present concrete culvert was installed (Smith, 1945). During the summer of 1943, a cofferdam of interlocking steel sheet piling was driven around the upstream side of the culvert, and the spillway was closed in October of that year. A vertical sliding gate, 4 feet by 6 feet, with a top elevation of 750 feet above mean sea level, is used to control the level of water in the lake. Another gate, 4 feet square, is fitted into the piling near its base and serves to drain the lake completely. Above the elevation of 750 feet, the water spills freely over the top of the piling. At full pool, the lake extends about a mile upstream from the face of the dam and has an area of 44.19 acres (Fry, 1953).

The lake was designed to serve as a delay in the water stream between the Laboratory and the Clinch River in order to permit decay of the short-lived radioisotopes, and as a holdup point in the case of Laboratory operations which lead to the discharge of unusual quantities of radioactive waste. In as much as one function of the lake was that it should serve as a final settling basin for waste effluents, it was rarely kept at full pool. Rather, the water level was maintained at an elevation of approximately 748 feet, at which level the lake has an area of 35.87 acres. For purposes of this study, that level and area were considered as normal.

When the lake was impounded, no attempt was made to clear any of the timber or brush from the ponded area. As a result, much of the upper end of the lake has become badly overgrown with willows and other woody plants; many dead trees, flooded out by the impounded water, either remain standing or have toppled over. Old barbed-wire fences are present in parts of the lake, along with an abundance of waterlogged debris which is scattered over much of the lake bottom. The presence of this sunken debris caused considerable difficulty in the setting and lifting of nets, in seining, and in other operations pertinent to the execution of an aquatic survey.

White Oak Creek receives the waste effluent from the Oak Ridge National Laboratory from a series of sources located at 2.34 and 3.0 miles above its mouth (Setter and Kochtitzky, 1950). The principal source of effluent is through the Settling Basin which empties through a weir box into the creek at a point about 2.54 miles above the Clinch River. The average volume of the effluent from the Settling Basin, based on figures compiled by the Chemical Separations Department, Operations Division, Oak Ridge National Laboratory, was approximately 650,000 gallons per 24-hour period during 1953, a decrease of about 11 per cent from that of 1952. In addition to the above-mentioned effluent, the daily output from the retention ponds for 1953 was about 17,000 gallons.

The waste effluent which enters White Oak Creek consists of a heterogeneous mixture of chemical wastes resulting from laboratory, pilot-plant, and full-scale operations. Some of these wastes are radioactive and some are not. Part of the radioactivity is due to fission products, uranium, and transuranic elements, and part to the induced radioactivity from the processing of various materials in preparation of isotopes. In addition to these industrial wastes, there is sewage effluent; the sewage has undergone primary treatment (sedimentation) and chlorination.

During the course of this study, extensive construction was under way on the Laboratory site. As a result, many denuded areas were formed, and these, coupled with the high annual rainfall, resulted in the carrying of considerable quantities of silt into the streams and ultimately into White Oak Lake. Consequently, the waters of the lake were almost constantly muddy during 1950, 1951, and 1952. As soon as it was feasible, the denuded areas were seeded and mulched, and during 1953 and the first part of 1954 the waters of the lake remained relatively clear.

The climate is usually characterized by relatively mild winters and hot summers. The average annual rainfall is about 52 inches and is fairly evenly distributed over the year. During the course of the study, exceptional periods of drought, precipitation, and low temperature were recorded. The summer of 1950 was marked by unusually heavy rainfall which caused luxurious plant growth. The fall of 1950 was mild until the end of November, when the temperatures, accompanied by heavy snowfall, were the lowest recorded in 80 years. At that time, White Oak Lake became completely covered with ice, and that condition persisted for about four weeks. The cold weather continued well into the spring and the development of the spring flora was delayed until late April. The summer of 1951 was hot and dry, and the drought extended through July and August. During that period the vegetation suffered severely. The fall of 1951 was drier than normal, and the succeeding winter was much milder than the preceding one. There was no complete ice cover on White Oak Lake during that period. The summer of 1952 was drier and hotter than the preceding one, and the 1952 drought became one of the worst in local history. The fall was dry and the ensuing winter was mild. Again, there was no complete ice cover on White Oak Lake. The spring of 1953 was about normal, but by July the signs of a drought, even more serious than the one in 1952, were in evidence. From this summary of the climatic conditions, it is evident that the study was made during a period of generally adverse conditions; the lake was excessively turbid most of the time, and the summers and autumns were unusually hot and dry.

During the summer of 1950 the maximum depth of water in the lake (at full pool) was about 10.5 feet. However, while the study was in progress, the level of the lake fluctuated considerably. At some times it was as much as 4 feet below full pool, and at others there was more than 2 feet of water spilling over the top of the cofferdam. Heavy rains caused sudden rises in the pool level, and sometimes those increases amounted to as much as 3 feet in a few hours.

RADIOLOGICAL METHODS

All samples of tissues were prepared for radioassay in the laboratories of the Health Physics Division of the Oak Ridge National Laboratory by a modification of the nitric acid, wet-digestion method developed specifically for this program by Krumholz and Emmons (1953). Those samples represented different tissues from the various kinds of fishes, and any radioactivity in them was the direct result of the normal metabolic processes. The sizes of the samples differed considerably, but in all cases an effort was made to obtain enough tissue to yield reliable results.

During the study, more than 15,000 samples of fish tissue were prepared for radioassay and counted. Each sample was counted in duplicate for 20 minutes. All counting was done under the supervision of Mrs. Juanita C. Anderson in the counting-room facilities of the Health Physics Division on the second shelf of an end-window Geiger-Mueller counter (scale of 64) at a geometry of approximately 10 per cent, depending on the particular counter used. All data are listed as gross beta radioactivity in counts per minute per gram (fresh weight) of tissue. Thus, the numbers of disintegrations per minute per gram are approximately 10 times the numbers of counts. The values for the amounts of radioactivity present (counts per minute per gram) can be readily converted into microcuries by dividing by 2.22 times 10^5.

Radiochemical analyses of individual samples were performed by either Mr. A. H. Emmons or Mr. B. Kahn of the Health Physics Division. The more extensive radiochemical analyses were performed in the laboratories of the Analytical Chemistry Division under the supervision of Mr. C. L. Burros.

In some instances, decay and/or absorption curves were prepared from individual samples in an effort to determine the identity of the radionuclides present.

THE FISH POPULATION OF WHITE OAK LAKE, 1950–1953

ONE OF THE MOST ESSENTIAL PARTS of a study of any body of water is a rather accurate appraisal of the size and composition of the extant fish population. Other features to be considered are the age, rate of growth, and the condition of the fish as indicated by the relationship between the length and weight. In addition, observations on the success of reproduction, the ability of any species to maintain itself as an integral part of the population, food supply, and so on, frequently give clues to the general well-being of the population as a whole.

Several methods for estimating the size of the total fish population of a body of water have been developed during recent years. Most of these methods are based on the procedures devised by Petersen (1896). The salient features outlined by Petersen are: (a) the release of a number of marked fish into a body of water, (b) the recording of the numbers of fish caught during the period in question, and (c) noting the numbers of marked fish present among the total catch. From these data it is possible to estimate the size of the total population, P, from the following equation:

$$P = MC/R$$

in which M is the number of marked fish in the body of water, C is the total number of fish caught, and R is the number of marked fish recaptured.

One of the most widely used equations for estimating the size of a fish population is that devised by Schnabel (1938) in which

$$P = \Sigma(AB)/\Sigma(C)$$

where P is the estimate of the size of the population, A is the number of marked fish examined on any one day, B is the summation of the number of marked fish in the body of water at that time, and C is the summation of the number of recaptured marked fish. Schnabel used the method of maximum likelihood in averaging a series of estimates while the marking was in progress. Krumholz (1944) pointed out that it could be proved algebraically that the Schnabel equation yields estimates that are generally too high. However, when the ratio between the number of marked fish and the total population is small, and hence the numbers of recaptured marked fish is necessarily small in relation to the number of marked fish in the body of water, the equation is adequate for most estimates.

It has been shown by Ricker (1948) that such estimates are valid only if the following assumptions hold true: (1) that the marked fish suffer the same mortality as the unmarked ones; (2) that the marked fish do not lose their mark; (3) that the marked fish are as vulnerable to fishing as the unmarked ones; (4) that the marked fish become randomly mixed with the entire population; (5) that all of the marked fish are reported when caught; and (6) that there is only a negligible amount of recruitment to the catchable population during the period of time when the study is being carried on.

Even though White Oak Lake has received waste materials from the Oak Ridge National Laboratory during most of its existence, there is little reason to believe that the above-mentioned assumptions would be less likely to hold true for the fish population in that lake than in any other. For that matter, White Oak Lake would appear to lend itself more readily to such a study, because there was no exploitation of the fishery and, consequently, there could be no loss of marked fish through that channel. The only changes in the size and composition of the fish population of White Oak Lake were from natural causes which, in this case, would include the presence of excessive waste materials and/or siltation.

In an effort to obtain as complete data as possible, six semi-annual netting studies were made, beginning in the fall of 1950 and ending in the spring of 1953. Shortly after the completion of the last netting study, the lake was partially drained, treated with rotenone, and all the fish were killed and picked up in so far as possible.

MATERIALS AND METHODS

The kinds of fish present in White Oak Lake during the period of investigation that were captured in the nets were: the bluegill (*Lepomis m. macrochirus*), the largemouth bass (*Micropterus salmoides*), the black crappie (*Pomoxis nigro-maculatus*), the white crappie (*Pomoxis sparoides*), the carp (*Cyprinus carpio*), the goldfish (*Carassius auratus*), carp×goldfish hybrids, the yellow bullhead (*Ameiurus natalis*), the northern redhorse (*Moxostoma erythrurum*), and the gizzard shad (*Dorosoma cepedianum*). In addition, one common sucker (*Catostomus commersonni*) was caught in the spring of 1952. The only other kind of fish that was present in the lake during the study period, but which was not large enough to be retained in the nets, was a large population of the western mosquitofish (*Gambusia a. affinis*). Here it is important to note that there were no minnows present other than the carp and goldfish, as there were in the surrounding uncontaminated waters.

Hoop nets were used to catch the fish necessary for making the estimates of the fish population. Each net consisted of cotton webbing stretched over six wooden hoops of the following diameters from front to rear: 4½ feet, 4¼ feet, 4 feet, 3¾ feet, 3½ feet, and 3¼ feet, with throats or funnels on the first and third hoops. The first throat was finished with four strings which were attached to the inside of the second throat. The second throat was fingered and finished with two strings which in turn were attached to the tail rope at the rear of the net. The tail of the net was fitted with a drawstring so that fish, having entered the front of the net, could be worked towards the rear of the net and removed by loosening of the drawstring. Thus, when the tail rope was pulled tight, the throats would also be drawn tight and held up and away from the bottom and sides of the net. The entire net was 116 meshes long, the first 32 meshes being 1½-inch bar measure, and the last 84 being 1-inch bar measure.

Each net was fitted with a 50-foot lead fastened across the center of the first hoop, and a 20-foot wing attached on each side. Both wings and the lead were made of 1½-inch bar webbing and were fitted with floats and weights. Each wing, the lead, and the tail rope were tied to native sassafras poles so that the nets could be firmly placed in the lake bottom.

In the setting of the nets, the lead pole was worked firmly into the lake bottom near the shore. The lead was then stretched out into the lake, making an angle of about 45 degrees with the immediate shoreline, and the net placed in the desired location. Then the two wing poles were set in place, each making an angle of about 45 degrees with the lead. The hoops were then pulled tight, away from the lead and wing poles, and the tail pole was driven firmly into the lake bottom. Thus the net rested on the lake bottom but was held upright by the hoops and poles and was readily accessible to the fish.

A total of 14 different locations were used for setting nets as indicated on the accompanying map (fig. 1). Perhaps there were other locations where nets could have been set, but at most other sites the water was either too deep or too shallow to accommodate the nets properly, or there was so much brush and debris present that handling the nets would have been impracticable. The nets were generally set with the front facing downstream so that the fish, which usually work upstream near the shore, would enter them. No more than eight nor fewer than five nets were set in the lake at any one time. The nets were set at the various locations as indicated by the quality of the fishing and remained at any particular location only so long as the fishing was good.

Each net in the lake was lifted each day, and the fish were removed and placed in tubs of lake water in the boat. The net was reset, and the fish were taken to the central release station (fig. 1). There the fish were sorted to species, measured to fork and total length to the nearest millimeter, marked if necessary, and returned to the lake. The marking of the fish consisted in the excision of a fin at its base deeply enough so that the fin would not regenerate. The wounds caused by such marking usually healed within a week or so, leaving a clean scar. Accurate daily records were kept of all fish caught in the nets. If any fish caught in the nets was already marked, the length measurements were recorded, the mark was noted, and the fish was returned to the lake. Such marking continued for each species of fish during each of the six estimates, until it was believed that an adequate number had been marked. This period extended from two to five weeks, depending on the species involved and the quality of the fishing.

After the nets had remained in the lake for several days, they usually became so dirty that they did not fish efficiently. Accordingly, each net was removed from the lake whenever necessary and cleaned with a power spray of hot water. The nets were dried overnight before being reset.

Towards the latter part of each netting study, scale samples, length measurements, and weights were taken from representative samples of each species of fish to provide information on age and growth and on the relationship between length and weight. Age determinations were made on the scale-reading machine at the headquarters of the Fish and Game Branch of the Tennessee Valley Authority at Norris, Tennessee.

ESTIMATES OF THE FISH POPULATION

The most satisfactory way to make an estimate of the total fish population of any body of water is to obtain separate estimates for the individual species and to combine them into a total. It is usually not satisfactory to treat the different species together as a unit because of the selectivity of the gear, as some species of fish enter the nets more readily than others. For instance, it has been shown by Ricker (1948) in Indiana that the redear sunfish (*Lepomis microlophus*) is about 10 times as vulnerable to trapping as the very similar bluegill. Calculations show that if the data for the two species were treated as a unit, the result would be lower than the combined individual population estimates. Similarly, Krumholz (1944) showed that the individual estimates for the species in a population of mixed centrarchids was more than twice as great as an estimate that treated all fishes as one species.

Another factor to be considered is the selectivity of the gear for the fishes of different sizes. From the description of the nets used, it is obvious that the smaller individuals of each species could readily pass in and out through the meshes. Because of this escape of small fishes through the nets, the present study embraces estimates of only those fishes that had attained the following total lengths in millimeters: bluegills, black crappies, and white crappies, 100; carp, goldfish, bullheads, and redhorse, 150; and largemouth bass, 200. Although there is good evidence from previous collections of fish from the lake (Knobf, 1951) that the gizzard shad was very abundant, no estimates of the shad population were made because that species was taken so infrequently in the nets and because it is so delicate that it cannot withstand the handling necessary for the making of an estimate.

With the data at hand, an attempt was made to estimate the numbers of only those fish that were readily caught in the nets. Such an estimate includes the majority of the total weights of the species concerned. There is little need to compare the estimates arrived at by the use of the various equations derived by different workers in the field, and the equation derived by Schnabel (1938) is used throughout.

The six semi-annual estimates were handled individually and then compared as a group. The detailed derivation for each species is given only for those made during the first study, and only the figures of the final estimates of the last five studies are listed. The details of the six semi-annual studies follow:

1. First Fall Estimate: August 31 through October 6, 1950. Nets were set at stations 1 through 13 for varying periods of time, and a total of six nets were fished continuously. All fish caught through September 17 were marked by the excision of the left pectoral fin.

2. First Spring Estimate: March 21 through April 25, 1951, with the exception of two days, April 13 and 15. Six nets were fished continuously and were located for varying periods of time at stations 1 through 8, station 12, and station 14. All fish caught through April 7 were marked by the excision of the right pectoral fin.

3. Second Fall Estimate: September 25 through October 29, 1951. Seven nets were fished continuously during the period and

were set, at some time or another, at each of the 14 stations. All fish caught were marked by the excision of the left pelvic or ventral fin. The catches of black crappies were so large early in the study that only those caught through October 4 were marked. Conversely, in as much as only 11 largemouth bass were taken during the entire study, all of them were marked. All individuals of the other species caught through October 11 were marked.

4. SECOND SPRING ESTIMATE: March 17 through April 21, 1952. Seven nets were fished continuously and were rotated among the 14 stations. All fish were marked by the excision of the right pelvic or ventral fin. Such marking continued for black crappies through April 5, for redhorse through April 9, for white crappies through April 10, for bluegills through April 11, for bullheads and shad through April 21, for carp through April 15, and for largemouth bass through the entire period.

5. THIRD FALL ESTIMATE: September 22 through October 29, 1952. Seven nets were fished continuously and rotated among the 14 stations. After two weeks of consistently poor fishing, an additional net was set on October 6 and was reset in a different location every two days in an effort to find out whether or not the fish were congregating in one place. After two weeks of such sampling, the additional net was removed. All unmarked fish caught during the entire study were marked by the exicision of the left pectoral fin.

6. THIRD SPRING ESTIMATE: March 16 through April 20, 1953. Eight nets were used for 23 of the 35 days of the study and only seven nets for the remainder of the period. The individual nets were rotated for different periods of time among the 14 stations. All fish were marked by the excision of the dorsal fin, or an adequate part of it, at its base. The marking continued for black crappies through April 10, and for all other species through April 15.

Although many shad were caught and marked during the six studies, no estimates were made because of the extreme unlikelihood of recapture. In all estimates, the carp, goldfish, and goldfish×carp hybrids were considered as one species.

THE FIRST FALL POPULATION ESTIMATE

A total of 3356 fish were caught during the present study. Of those, 1992 were marked, and 355 of the marked fish were recaptured.

BLUEGILLS: A total of 1119 bluegills were examined, 508 were marked, and 70 of the marked fish were recaptured. The estimate of the size of the population, together with the data on the fish handled, marked, and recaptured, is listed in table 1. Each of the year classes, 1946, 1947, 1948, and 1949, was represented in the catch.

BLACK CRAPPIES: During this study, 760 individuals were caught, 386 were marked, and 73 of the marked fish were recaptured. The data for the numbers of fish examined, marked, and recaptured, together with the estimate of the size of the population, are listed in table 2. From these data it is apparent that the black crappie is about twice as vulnerable to hoop netting as the bluegill. Even though there were 508 marked bluegills in the lake as compared with 386 black crappies, there were only 70 bluegills recaptured, whereas 73 marked black crappies returned to the nets. The final estimate of the numbers of black crappies was a little less than half of that of the bluegills. Still, the black crappies, both marked and unmarked, although fewer in number than the bluegills, were taken with relatively greater frequency than the bluegills. Among the black crappies caught, the 1946, 1948, and 1949 year classes were represented.

WHITE CRAPPIES: Although a total of 98 white crappies were caught, only three of the 51 fish marked during the study were recaptured. Such a small number of recaptures can hardly be expected to yield a reliable estimate. However, the estimate of 1200 white crappies may have been a fair indication of their abundance. They were not so abundant as the black crappies in September, 1950, although there were three year classes, 1947, 1948, and 1949, represented. The data on the numbers of fish handled, marked, and recaptured, with the estimate of the size of the population, are listed in table 3.

LARGEMOUTH BASS: Largemouth bass are notoriously difficult to catch in hoop nets. Even in lakes where bass are known to be plentiful (Bennett, 1948), the take in hoop

TABLE 1

ESTIMATE OF THE SIZE OF THE BLUEGILL POPULATION OF WHITE OAK LAKE, SEPTEMBER, 1950

Date, 1950	(*A*) No. of Fish Examined	No. of Fish Marked	(*B*) No. Marked Already in Lake	Product	(*AB*) Sum of Products	No. of Returns	(*C*) Sum of Returns	Estimate of Population
Aug. 31	31	30	—	—	—	—	—	—
Sept. 1	17	17	30	510	510	—	—	—
2	20	20	47	940	1450	—	—	—
3	28	26	67	1876	3333	1	1	3333
4	30	28	93	2790	6123	1	2	3062
5	27	27	121	3267	9390	—	2	4695
6	17	16	148	2516	11906	1	3	3969
7	7	7	164	1148	13054	—	3	4351
8	20	20	171	3420	16474	—	3	5491
9	23	21	191	4393	20867	1	4	5217
10	44	43	212	9328	30195	1	5	6039
11	42	42	255	10710	40905	—	5	8181
12	45	41	297	13365	54270	4	9	6030
13	26	26	338	8788	63058	—	9	7006
14	21	19	364	7644	70702	2	11	6427
15	20	18	383	7669	78362	2	13	6028
16	12	12	401	4812	83174	—	13	6398
17	99	95	413	40887	124061	4	17	7298
18	93	—	508	47244	171305	7	24	7138
19	92	—	508	46736	218041	7	31	7034
20	65	—	508	33020	251061	8	39	6437
21	52	—	508	26416	277477	5	44	6306
22	33	—	508	16764	294241	3	47	6260
23	28	—	508	14224	308465	1	48	6426
24	39	—	508	19812	328277	5	53	6194
25	37	—	508	18796	347073	3	56	6198
26	23	—	508	11684	358757	—	56	6406
27	16	—	508	8128	366885	1	57	6437
28	19	—	508	9652	376537	—	57	6606
29	5	—	508	2540	379077	—	57	6650
30	12	—	508	6096	385173	2	59	6528
Oct. 1	30	—	508	15240	400413	3	62	6458
2	6	—	508	3048	403461	1	63	6404
3	13	—	508	6604	410065	3	66	6213
4	9	—	508	4372	414637	2	68	6098
5	13	—	508	6604	421241	2	70	6018
6	5	—	508	2540	423781	—	70	6054

nets is limited. In this study, 49 of the 71 bass caught were marked and released, and 16 of the marked fish were recaptured. Because of its predatory habits, the largemouth bass is seldom an abundant species in any population. However, the estimate of from 130 to 140 fish (about four fish per acre) is lower than expected for this region. Members of the 1945, 1946, 1947, 1948, and 1949 year classes were represented in the catch. The estimate of the size of the population and the numbers of fish handled, marked, and recaptured are listed in table 4.

Early in March, 1950, 200 adult largemouth bass were jaw-tagged and released in White Oak Lake by personnel of the Tennessee Valley Authority, Fish and Game Branch, who thereby had hoped to replenish the pop-

TABLE 2

ESTIMATE OF THE SIZE OF THE BLACK CRAPPIE POPULATION OF WHITE OAK LAKE, SEPTEMBER, 1950

Date, 1950	(*A*) No. of Fish Examined	No. of Fish Marked	(*B*) No. Marked Already in Lake	Product	(*AB*) Sum of Products	No. of Returns	(*C*) Sum of Returns	Estimate of Population
Aug. 31	28	28	—	—	—	—	—	—
Sept. 1	12	12	28	336	336	—	—	—
2	6	6	40	240	576	—	—	—
3	15	14	46	690	1266	1	1	1266
4	17	16	60	272	1538	1	2	769
5	25	25	76	1900	3438	—	2	1719
6	35	34	101	3535	6973	—	2	3487
7	23	23	135	3105	10078	—	2	5039
8	23	21	158	3634	13712	2	4	3428
9	31	30	179	5549	19261	1	5	3852
10	52	49	209	10868	30129	3	8	3766
11	35	35	258	9030	39159	—	8	4895
12	41	40	293	12013	51172	1	9	5686
13	22	20	333	7326	58498	2	11	5318
14	8	7	353	2024	60522	1	12	5044
15	6	4	360	2160	62682	2	14	4477
16	5	4	364	1820	64502	1	15	4300
17	20	18	368	7360	71862	2	17	4227
18	28	—	368	10108	82670	6	23	3594
19	20	—	368	7360	90030	4	27	3334
20	61	—	368	23546	113576	10	37	3070
21	17	—	368	6562	120138	2	39	3080
22	10	—	368	3860	123998	3	42	2952
23	20	—	368	7360	131358	2	44	2985
24	36	—	368	13896	145254	5	49	2964
25	46	—	368	17756	163010	7	56	2911
26	27	—	368	10422	173432	5	61	2843
27	5	—	368	1930	175362	—	61	2875
28	12	—	368	4632	179994	2	63	2857
29	7	—	368	2702	182696	2	65	2811
30	13	—	368	5018	187714	2	67	2802
Oct. 1	10	—	368	3860	191574	1	68	2817
2	5	—	368	1930	193504	1	69	2804
3	8	—	368	3088	196592	—	69	2849
4	3	—	368	1158	197750	—	69	2866
5	16	—	368	6176	203926	2	71	2872
6	12	—	368	4632	208558	2	73	2857

ulation. During the netting operations in September, 1950, only two of the tagged individuals were caught, and one of these was caught a second time. From this preliminary information it appears that the planting was unsuccessful.

CARP: The most abundant species from the standpoint of total weight in the fish population of White Oak Lake, as shown by this first study, is the carp. It is usually not difficult to trap carp, and the accompanying estimate is believed to be reasonably accurate. Eight hundred and twenty-nine carp were caught, 718 were marked, and 46 of the marked fish were recaptured. The data on which the estimate was based are listed in table 5. Individuals of the 1946, 1947, 1948, and 1949 year classes were represented in the catch.

TABLE 3

ESTIMATE OF THE SIZE OF THE WHITE CRAPPIE POPULATION OF WHITE OAK LAKE, SEPTEMBER, 1950

Date, 1950	(*A*) No. of Fish Examined	No. of Fish Marked	(*B*) No. Already Marked in Lake	Product	(*AB*) Sum of Products	No. of Returns	(*C*) Sum of Returns	Estimate of Population
Aug. 31	3	3	—	—	—	—	—	—
Sept. 1	2	2	3	6	6	—	—	—
2	2	1[a]	5	10	16	1	1	16
3	1	1	5	5	21	—	1	21
4	4	4	6	24	45	—	1	45
5	5	5	10	50	95	—	1	95
6	5	5	15	75	170	—	1	170
7	2	2	20	40	210	—	1	210
8	6	6	22	132	342	—	1	342
9	2	2	28	56	398	—	1	398
10	7	7	30	210	608	—	1	608
11	6	6	36	216	824	—	1	824
12	7	7	43	301	1125	—	1	1125
13	4	4	47	148	1273	—	1	1273
14	1	1	48	48	1321	—	1	1321
15	1	1	49	49	1370	—	1	1370
16	—	—	49	—	1370	—	1	1370
17	2	2	51	102	1472	—	1	1472
18	2	—	51	102	1574	1	2	787
19	3	—	51	153	1727	—	2	864
20	5	—	51	255	1982	—	2	991
21	2	—	51	102	2084	—	2	1042
22	1	—	51	51	2135	—	2	1068
23	1	—	51	51	2186	—	2	1093
24	4	—	51	204	2390	—	2	1198
25	6	—	51	306	2696	—	2	1348
26	1	—	51	51	2747	—	2	1374
27	1	—	51	51	2798	—	2	1399
28	—	—	51	—	2798	—	2	1399
29	1	—	51	51	2849	—	2	1425
30	—	—	51	—	2849	—	2	1425
Oct. 1	1	—	51	51	2900	—	2	1500
2	7	—	51	357	3257	—	2	1629
3	2	—	51	102	3359	—	2	1679
4	1	—	51	51	3410	1	3	1137
5	—	—	51	—	3410	—	3	1137
6	—	—	51	—	3410	—	3	1137

[a] On September 2 the marked fish recaptured in the net was accidentally killed. Accordingly it was removed from the number of fish already marked in the lake.

More carp were marked during the study than any other species. For some unknown reason the catch of carp was relatively high during the first 10 days of the study, and then it fell off markedly.

Carp have frequently been accused of crowding out the more desirable species from lakes in various parts of the United States. The evidence in support of this statement is apparently sound and is largely based on the ecology of the carp. In feeding, the carp roils the water to a considerable extent and the fishes which feed by sight, notably the centrarchids, are automatically placed under a

TABLE 4

ESTIMATE OF THE SIZE OF THE LARGEMOUTH BASS POPULATION OF WHITE OAK LAKE, SEPTEMBER, 1950

Date, 1950	(*A*) No. of Fish Examined	No. of Fish Marked	(*B*) No. Already Marked in Lake	Product	(*AB*) Sum of Products	No. of Returns	(*C*) Sum of Returns	Estimate of Population
Aug. 31	4	4	—	—	—	—	—	—
Sept. 1	2	2	4	8	8	—	—	—
2	2	2	6	12	20	—	—	—
3	6	6	8	48	68	—	—	—
4	7	7	14	98	166	—	—	—
5	4	4	21	84	250	—	—	—
6	10	10	25	250	500	—	—	—
7	5	3	35	175	675	2	2	338
8	2	2	38	76	751	—	2	376
9	4	2	40	160	911	2	4	228
10	2	1	42	84	995	1	5	199
11	5	2	43	215	1210	3	8	151
12	—	—	45	—	1210	—	8	151
13	3	2	45	135	1345	1	9	149
14	3	1	47	141	1486	2	11	135
15	1	1	48	48	1534	—	11	139
16	—	—	49	—	1534	—	11	139
17	—	—	49	—	1534	—	11	139
18	1	—	49	49	1583	1	12	132
19	—	—	49	—	1583	—	12	132
20	—	—	49	—	1583	—	12	132
21	1	—	49	49	1632	—	12	136
22	—	—	49	—	1632	—	12	136
23	—	—	49	—	1632	—	12	136
24	3	—	49	147	1779	1	13	137
25	—	—	49	—	1779	—	13	137
26	1	—	49	49	1828	—	13	141
27	1	—	49	49	1877	1	14	134
28	—	—	49	—	1877	—	14	134
29	—	—	49	—	1877	—	14	134
30	—	—	49	—	1877	—	14	134
Oct. 1	1	—	49	49	1926	1	15	128
2	2	—	49	98	2024	—	15	135
3	—	—	49	—	2024	—	15	135
4	—	—	49	—	2024	—	15	135
5	—	—	49	—	2024	—	15	135
6	1	—	49	49	2073	1	16	130

handicap. Such a roiling of the water has been shown to have caused a deposit of as much as 8 inches of silt over the lake bottom adjacent to areas where carp were abundant but which were protected from them (Threinen and Helm, 1954). Furthermore, the carp attacks the beginning of the food chain and thus competes directly with the small centrarchids, but under conditions which are advantageous to the carp. The carp has been accused of uprooting aquatic vegetation (Tryon, 1954), and it may be that the presence of large numbers of carp is one of the primary reasons for the virtual absence of rooted aquatic plants in White Oak Lake.

The carp grows very rapidly, often reaching lengths of 10 inches or more during the first summer of life. In growing so rapidly,

TABLE 5

Estimate of the Size of the Carp Population of White Oak Lake, September, 1950

Date, 1950	(*A*) No. of Fish Examined	No. of Fish Marked	(*B*) No. Marked Already in Lake	Product	(*AB*) Sum of Products	No. of Returns	(*C*) Sum of Returns	Estimate of Population
Aug. 31	173	173	—	—	—	—	—	—
Sept. 1	128	126	173	22144	22144	1	1	22144
2	125	119	299	37375	59519	6	7	8503
3	68	68	418	28424	87943	—	7	12563
4	48	47	486	23328	111271	1	8	13909
5	19	17	533	10127	121398	2	10	12140
6	32	31	550	17600	138998	1	11	12636
7	26	25	581	15106	154104	1	12	12842
8	52	49	606	31512	185616	3	15	12374
9	19	19	655	12445	198061	—	15	13204
10	11	10	674	7381	205442	1	16	12840
11	12	12	684	8208	213650	—	16	13353
12	6	5	696	4176	217826	1	17	12813
13	4	4	701	2804	220630	—	17	12978
14	3	2	705	2115	222745	1	18	12735
15	6	4	707	4242	226987	2	20	11349
16	5	3	711	3555	230542	2	22	10479
17	5	5	714	3570	234112	—	22	10641
18	3	—	719	2157	236269	1	23	10273
19	8	—	719	5752	242021	2	25	9681
20	4	—	719	2876	244897	—	25	9796
21	9	—	719	6471	251368	1	26	9668
22	9	—	719	6471	257839	3	29	8891
23	7	—	719	5033	262872	3	32	8215
24	11	—	719	7909	270781	6	38	7126
25	7	—	718[a]	5026	275807	—	38	7258
26	12	—	718	8618	284423	3	41	6937
27	3	—	718	2154	286577	3	44	6513
28	5	—	718	3590	290167	1	45	6448
29	1	—	718	718	290885	—	45	6464
30	2	—	718	1436	292321	—	45	6496
Oct. 1	1	—	718	718	293039	—	45	6512
2	1	—	718	718	293757	—	45	6528
3	2	—	718	1436	295193	1	46	6417
4	1	—	718	718	295911	—	46	6433
5	—	—	718	—	295911	—	46	6433
6	2	—	718	1436	297346	—	46	6464

[a] On the previous day one of the marked fish caught in the net was dead. Accordingly it was removed from the number of marked fish in the lake.

this species does not afford forage for any of the piscivorous species for a very long period of time. The carp broadcasts its eggs when spawning and spawns over a wide area. Although it provides no care for its eggs or young, the extremely large numbers of eggs deposited virtually assure the success of the brood. The tremendous amount of activity which accompanies the spawning act of the carp makes spawning for other species that may be in the vicinity a rather precarious undertaking.

Bullheads: Bullheads are relatively easy to trap and frequently return to the same

TABLE 6

ESTIMATE OF THE SIZE OF THE BULLHEAD POPULATION OF WHITE OAK LAKE, SEPTEMBER, 1950

Date, 1950	(A) No. of Fish Examined	No. of Fish Marked	(B) No. Marked Already in Lake	Product	(AB) Sum of Products	No. of Returns	(C) Sum of Returns	Estimate of Population
Aug. 31	37	37	—	—	—	—	—	—
Sept. 1	53	43	37	1961	1961	10	10	196
2	22	9	80	1760	3721	13	23	162
3	9	5	89	801	4522	4	27	167
4	15	9	94	1410	5932	6	33	180
5	42	20	103	4326	10258	22	55	187
6	16	6	123	1968	12226	10	65	188
7	13	8	129	1677	13903	5	70	199
8	17	9	137	2329	16232	8	78	208
9	9	6	146	1314	17546	3	81	217
10	5	1	152	760	18306	4	85	215
11	4	4	153	612	18918	—	85	223
12	1	1	157	157	19075	—	85	225
13	3	2	158	474	19549	1	86	227
14	6	4	160	960	20509	2	88	233
15	—	—	164	—	20509	—	88	233
16	5	1	164	820	21329	4	92	232
17	10	2	165	1650	22979	8	100	230
18	7	—	167	1169	24148	5	105	230
19	5	—	167	835	24983	3	108	231
20	3	—	167	501	25484	1	109	234
21	—	—	167	—	25484	—	109	234
22	2	—	167	334	25818	1	110	235
23	—	—	167	—	25818	—	110	235
24	3	—	167	501	26319	2	112	235
25	8	—	167	1336	27655	2	114	243
26	2	—	167	334	27989	—	114	246
27	—	—	167	—	27989	—	114	246
28	1	—	167	167	28156	—	114	247
29	—	—	167	—	28156	—	114	247
30	—	—	167	—	28156	—	114	247
Oct. 1	5	—	167	835	28991	1	115	252
2	—	—	167	—	28991	—	115	252
3	—	—	167	—	28991	—	115	252
4	2	—	167	334	29325	1	116	253
5	—	—	167	—	29325	—	116	253
6	1	—	167	167	29492	—	116	254

net time after time. A total of 306 bullheads were caught, 167 were marked, and 116 of the marked fish were recaptured. One of the marked fish was taken in four different nets for a total of six times. The data on the bullheads caught, marked, and recaptured, together with the estimate of the size of the population, are listed in table 6.

REDHORSE: A total of 173 redhorse were caught during this study. Of these fish, 113 were marked and returned to the lake, and 31 of the marked fish were recaptured. These data, together with the population estimate, are listed in table 7. Only the 1948 year class was represented among the fish caught.

TOTAL FISHES: An estimate of 13,050 individuals was obtained by combining the data and treating all fish as one species. However, as mentioned above, such a procedure is invalid and tends to yield an estimate that

TABLE 7

ESTIMATE OF THE SIZE OF THE POPULATION OF REDHORSE IN WHITE OAK LAKE, SEPTEMBER, 1950

Date, 1950	(*A*) No. of Fish Examined	No. of Fish Marked	(*B*) No. Marked Already in Lake	Product	(*AB*) Sum of Products	No. of Returns	(*C*) Sum of Returns	Estimate of Population
Aug. 31	15	15	—	—	—	—	—	—
Sept. 1	10	10	15	150	150	—	—	—
2	9	9	25	225	375	—	—	—
3	14	12	34	476	851	2	2	426
4	6	6	46	276	1127	—	2	564
5	8	6	52	416	1543	2	4	386
6	12	10	58	696	2239	2	6	373
7	9	9	68	612	2851	—	6	475
8	11	10	77	847	3698	1	7	528
9	7	7	87	609	4307	—	7	615
10	4	—	94	376	4683	4	11	426
11	7	5	94	658	5341	2	13	411
12	9	6	99	891	6232	2	15	415
13	5	3	105	525	6757	2	17	397
14	1	1	108	108	6865	—	17	404
15	1	1	109	109	6974	—	17	410
16	2	2	110	220	7194	—	17	423
17	1	1	112	112	7306	—	17	430
18	3	—	113	339	7645	1	18	425
19	1	—	113	113	7758	—	18	431
20	3	—	113	339	8097	1	19	426
21	4	—	113	452	8549	2	21	407
22	3	—	113	339	8888	2	23	386
23	3	—	113	339	9227	1	24	384
24	2	—	113	226	9453	—	24	394
25	3	—	113	339	9792	2	26	377
26	4	—	113	452	10244	3	29	353
27	3	—	113	339	10583	1	30	353
28	2	—	113	226	10809	—	30	360
29	1	—	113	113	10922	—	30	364
30	—	—	113	—	10922	—	30	364
Oct. 1	2	—	113	226	11148	—	30	372
2	2	—	113	226	11374	1	31	367
3	3	—	113	339	11713	—	31	378
4	—	—	113	—	11713	—	31	378
5	—	—	113	—	11713	—	31	378
6	—	—	113	—	11713	—	31	378

is considerably lower than the additive total obtained by treating the species separately and then combining the totals. When the following individual estimates (bluegill, 6100; black crappie, 2850; white crappie, 1200; largemouth bass, 135; carp, 6450; bullhead, 250; and redhorse, 375) are added, an estimate of 17,360 individuals is obtained. It is believed that this latter estimate gives a better and more accurate picture of the size and composition of the fish population of White Oak Lake in September, 1950. The latter estimate is approximately one-third (31.9%) higher than the former one.

THE FIRST SPRING POPULATION ESTIMATE

During this study, a total of 4073 fish were caught in the nets. Of these, 1884 were marked and returned to the lake, and 623 of the marked fish were recaptured.

BLUEGILLS: There were 1611 bluegills caught during this study; 625 of them were marked and returned to the lake, and 140 of the marked fish were recaptured. From these data it was estimated that there were about 5600 bluegills of a greater length than about 4 inches in the lake at that time. As in the study during the fall of 1950, there were representatives of the 1946, 1947, 1948, and 1949 year classes in the catch.

The estimate of 5600 bluegills in the spring of 1951 indicates that there was a loss in numbers of about 8 per cent from the 6100 estimated to have been present in the previous fall.

BLACK CRAPPIES: A total of 1462 black crappies were caught during this study. Approximately half (742) of these fish were marked, and 342 of the marked fish were recaptured. Here, again, as in the preceding study, it is indicated that the black crappie is about twice as vulnerable to hoop netting as the bluegill. Of the 625 marked bluegills in the lake, only 140 (22.4%) were recaptured, whereas there were 342 (46.1%) of the 742 marked black crappies recaptured. From these data it was estimated that there were about 2200 black crappies of a greater length than about 4 inches in the lake in the spring of 1951. That estimate indicates that there was a loss in numbers of about 22.8 per cent from the estimated 2850 black crappies of the fall of 1950.

An examination of the length-frequency distributions of the catches, which are discussed in detail below, indicates that the over-winter loss was traceable primarily to the virtual absence of the 1946 year class in the spring catch. No members of this year class were caught in subsequent studies, and it is believed that that group disappeared from the lake over the winter. The disappearance of the 1946 year class was partially compensated for by the increase in the numbers of the 1950 year class in the spring catch. Only four individuals of the 1950 year class were taken in the fall study, whereas 172 individuals of that year class were caught during the spring study. Those fish had obviously grown enough during the winter months to be retained more readily by the nets.

WHITE CRAPPIES: There were 345 white crappies caught during the spring of 1951. Of these fish, 129 were marked, and 100 of the marked fish were recaptured. From these data it was estimated that the spring population of white crappies consisted of only about 340 individuals.

A comparison of the estimate for the spring with that of the preceding fall indicates that there was a decline of about 70 per cent in numbers over the winter. Here, however, it should be mentioned that the estimate for the fall is perhaps not so reliable as that for the spring because of the very few recaptures during the fall study; in the fall there were only three recaptures, whereas in the spring there were 100. In the spring, the ratio of black crappies to white crappies in the total catch was 4.2 to 1, while during the study of the preceding fall that ratio was 7.8 to 1. It may be that the white crappie is less vulnerable to hoop netting in the fall than it is in the spring, or it may be that the habits of the two species differ considerably from one season to another.

LARGEMOUTH BASS: Only five largemouth bass were caught in the nets. All five of those fish were marked, and one fish was recaptured. No estimate was made from these meager data. All the bass caught were large, weighing at least 2 pounds each, and none of the smaller individuals caught the preceding fall nor any of the tagged fish released in March, 1950, were caught.

CARP: As in the estimate made during the fall of 1950, the carp was the most abundant fish in the lake from the standpoint of total weight. Although the spring estimate indicated that there were fewer carp than bluegills, the average weight of the carp was considerably greater than that of the bluegills.

Only slightly more than half as many carp were caught in the spring of 1951 as in the fall of 1950. The reason for such a drop in the catch is not obvious. However, the percentage of marked fish recaptured during the spring (6.6%) was almost the same as that of the fall (6.4%), and the spring estimate is believed to be as reliable as the one made in the fall. There were 482 carp caught in the spring study; of these 289 were marked, and 19 of the marked fish were recaptured. From these data it was estimated that there were 4830 carp in White Oak Lake in the spring of 1951.

The average size of the carp in the spring catch was smaller than that in the fall. The spring catch consisted primarily of fish of the 1948 and the 1949 year classes, whereas the fall catch was comprised, in a large part, of members of the 1946 and the 1947 year classes. The difference in the two estimates indicates that there was an over-winter loss in numbers of about 25 per cent.

BULLHEADS: During the study only 103 bullheads were caught. Of these, 63 were marked, and 11 marked fish were recaptured. Here, the estimated population for the bullheads in the spring was about half again as large as the fall estimate. The most apparent reason for such an increase was the greater relative abundance of small bullheads in the spring catch. Fish of a shorter length than 8 inches made up only about 16 per cent of the catch in the fall, whereas in the spring fish of that size made up about 35 per cent.

REDHORSE: Only 65 redhorse were caught, of which 31 were marked, and 10 of the marked fish were recaptured. The estimate of about 145 fish based on these data is not reliable. However, when compared with the estimate of the previous fall, there is an indication of a loss of about 62 per cent of the population.

TOTAL FISHES: Addition of the individual estimates (for bluegills, 5600; black crappies, 2200; white crappies, 340; largemouth bass, no estimate; carp, 4830; bullheads, 390; and redhorse, 145) yields a total of 13,505 fish in the population exclusive of the largemouth bass. A comparison of this estimate with that of the preceding fall indicates that there was an over-winter loss of about 3720 fish (22%).

During the winter of 1950–1951, there was a heavy mortality of gizzard shad in White Oak Lake. The fish were of much the same size, from 13 to 15 inches in total length, and were all of the same year class so far as is known. It is believed that the mortality was a natural one and that the fish had lived out their normal life span. At the time of the mortality it was estimated that between 3000 and 4000 fish died, and it is believed that that year class virtually disappeared from the lake at that time.

THE SECOND FALL POPULATION ESTIMATE

A total of 5767 fish were caught during this study. Of these fish, 2409 were marked and returned to the lake, and 643 of the marked fish were recaptured.

BLUEGILLS: During the five-week period, 1902 bluegills were caught, 615 were marked, and 41 marked fish were recaptured. From these data it was estimated that there were about 22,000 bluegills of a greater length than 4 inches in the lake at the time. This estimate represents a four-fold increase in the size of the population from that of the previous spring and nearly as great an increase over that of the preceding fall. The bluegill population consisted primarily of members of the 1948, 1949, and 1950 year classes; individuals of the 1946 and 1947 year classes were relatively scarce.

BLACK CRAPPIES: A total of 2857 black crappies were taken in the nets; of these, 1140 were marked, and 467 of the marked fish were recaptured. From these data it was estimated that there were about 5100 black crappies present that were large enough to be retained by the nets. That estimate represents a greater than two-fold increase over the spring estimate and nearly a doubling of the size of the population from the preceding fall. Representatives of four year classes, 1948, 1949, 1950, and 1951, were present in the catch.

WHITE CRAPPIES: There were 154 white crappies taken in the nets during the fall of 1951. Sixty-four of these fish were marked, and 16 of the marked fish were recaptured. An estimate based on these data indicates that there were about 450 white crappies in White Oak Lake in October, 1951, an increase of about 17 per cent over the estimate of 375 for the previous spring. In contrast to both the black crappies and bluegills, where there were increases in the populations from October, 1950, to October, 1951, there was a decrease of more than 60 per cent in the estimated size of the white crappie population of October, 1950.

LARGEMOUTH BASS: During this study there were only 11 largemouth bass taken in the nets. All these fish were marked, but none of the marked fish was recaptured. Thus no estimate of the size of the population could be made. This catch did not include any of the tagged fish released in the lake in March, 1950. Most of the bass taken were thin and emaciated. It may be that the extreme turbidity of the lake water made it virtually impossible for the bass to obtain enough food to maintain a healthy population.

CARP: A total of 264 carp were taken during this study; 203 were marked, and 12 of the marked fish were recaptured. Again, as in the spring of 1951, there were only slightly more than half as many carp caught as in the immediately preceding study. However, the percentage of marked fish recaptured remained about the same for all three studies.

From the data at hand it was estimated that there were about 2250 carp in the population. That estimate represents a decrease of about 47 per cent from the 4825 carp estimated to have been present the previous spring, which in turn represented a decrease of about 25 per cent from the 6450 individuals estimated to have been present in the fall of 1950.

BULLHEADS: There were 347 bullheads taken in this study, 255 were marked, and 54 of the marked fish were recaptured. The size of the population was estimated to be about 875 fish, a more than two-fold increase over the 390 bullheads estimated to have been present the previous spring, and an increase of three and one-half times over the estimate of the preceding fall.

REDHORSE: During this study 133 redhorse were caught, 64 were marked, and 51 marked fish were recaptured. It was estimated that there were about 115 individuals in the population. If the first three estimates of the size of the redhorse population are accurate, it is an indication that there has been a rather steady decline in the size of the redhorse population since the first estimate was made in October, 1950.

GIZZARD SHAD: A total of 99 gizzard shad were taken in the nets during this study. Of those, 57 were marked and returned to the lake, and two of the marked fish were recaptured. However, no estimate of the size of the gizzard shad population was made.

TOTAL FISHES: The estimate of the size of the total fish population of White Oak Lake in the fall of 1951, arrived at by addition of the individual estimates, follows: bluegills, 22,000; black crappies, 5100; white crappies, 450; largemouth bass, no estimate; carp, 2550; bullheads, 875; and redhorse, 115; for a total of 31,090 fishes large enough to be retained by the nets.

This second fall estimate indicates that there was a 78 per cent increase in numbers of fish over the estimate of the previous fall, and an increase of 130 per cent over the estimate of the immediately preceding spring.

THE SECOND SPRING POPULATION ESTIMATE

During the second spring study there were 5635 fish caught in the nets, 2953 fish marked and released, and 1566 marked fish recaptured.

BLUEGILLS: During the five-week period, 1697 bluegills were taken in the nets, 1050 were marked and released, and 176 marked fish were recaptured. From these data it was estimated that there were about 6500 bluegills in the population. This figure represents a decrease of the size of the bluegill population to less than one-third that estimated to have been present in October, 1951. However, it is an increase of about 16 per cent over the 5600 bluegills figured to have been present in May, 1951.

BLACK CRAPPIES: There were 3353 black crappies caught, 1466 marked, and 1307 marked fish recaptured. Here, as in each of the three previous studies, it is readily apparent that the black crappie is considerably more vulnerable to hoop netting than the bluegill. It was estimated that there were about 2700 black crappies in the lake. This estimate represents a decrease to about half of the size of the population of the previous fall, but indicates that there was about a 25 per cent increase over the 2200 black crappies estimated to have been present in May, 1951.

WHITE CRAPPIES: Only 65 white crappies were present in the total catch during this study. Of those, 35 were marked, and 29 of the marked fish were recaught. An estimate based on these data indicated that there were only about 50 white crappies in the lake in May, 1952, a decided decrease from any of the previous estimates. Such a decided decrease may be an indication that the species was disappearing from the population.

LARGEMOUTH BASS: During this study there were 15 largemouth bass taken, all of which were marked, and three of the marked fish were recaptured. No estimate of the size of the bass population was made. However, the bass caught during this study were generally in much better condition than those caught the preceding October. It may be that this change in condition was traceable to the relative clearness of the water during the few months immediately preceding the study which had afforded the fish a better opportunity for feeding.

CARP: In this study there were only 167 carp caught. Of these, 146 were marked, but only four of the marked fish were recaptured. Similarly, as in the autumn of 1951, there were only slightly more than half as many carp caught as during the study which immediately preceded it. However, in this study the percentage of marked fish fell off considerably. From these meager data it was estimated that there were about 3100 carp present in the lake. That figure represents an increase of about 20 per cent over the estimate of 2550 for the autumn of 1951, but also represents a decrease of more than 25 per cent from the 4825 individuals estimated to have been present in May, 1951.

BULLHEADS: There were 98 bullheads caught, 70 marked, and 12 marked fish were recaptured. The size of the bullhead population was estimated to be about 350 fish, a decrease to less than half of the number figured to have been present in October, 1951. However, it represents only a slight decrease from the 390 individuals present in May, 1951.

REDHORSE: Seventy-three redhorse were caught in the nets, 43 were marked, and 29 of the marked fish were recaptured. It was estimated that there were only about 75 redhorse in the lake in May, 1952. This is a further indication that this species may be gradually disappearing from the population.

GIZZARD SHAD: A total of 167 shad, of which 128 were marked and released, and six of the marked fish were recaptured, were handled during the study. No estimate of the size of the shad population was made.

TOTAL FISHES: The estimate of the size of the total fish population obtained by adding the individual estimates is: bluegills, 6500; black crappies, 2700; white crappies, 50; largemouth bass, no estimate; carp, 3100; bullheads, 350; and redhorse, 75; for a total fish population of 12,275 individuals.

This is the smallest estimate of the size of the fish population made so far, and represents a decrease of about 60 per cent from the estimate made six months earlier. The cause for such a tremendous over-winter mortality is not immediately obvious. Certainly, the winter was not nearly so severe as the preceding one, and no other untoward incidents were known to have occurred which might have led to such a decrease in the population.

THE THIRD FALL POPULATION ESTIMATE

During the third fall netting study, only 1611 fish were caught in the nets. Of those fish, 1453 were marked and released, and 115 of the marked fish were recaptured. The total catch was about 72 per cent lower than that for the preceding spring, and there is no apparent reason for the catch's being so low. Each of the catches during the four previous studies were large enough to serve as bases on which to estimate the size and composition of the population. There were no noticeable catastrophes to the total fish population nor to any segment of it, and it was assumed that the population present in the spring of 1952 was still extant. For some reason, however, the fish avoided the nets. It may be that the protracted period of heat and drought affected the movements of the fish. Also, it may be that the lake became overpopulated with stunted fish too small to be retained in the nets. Even so, it was expected that many of the larger fish which comprised a large segment of the population in the spring would still be present in the fall.

BLUEGILLS: During the 37-day netting period only 336 bluegills were caught in the nets. Of those, 322 were marked and returned to the lake, but no marked fish were recaptured. Thus there could be no estimate made of the size of the population. However, because more than 300 marked fish were in the lake and none of them were recaptured, it is believed that there was a relatively large bluegill population present. The recapture of a relatively large portion of such a few marked fish would have been an indication that there were only a small number of fish present or that the population had not been randomly sampled. The same gear that had been used in the previous studies was still in use, and the nets were set in the same locations.

BLACK CRAPPIES: A total of 935 black crappies were caught, 841 were marked and released, and 77 of the marked fish were recaptured. From these data it was estimated that there were about 5075 black crappies in the lake. That estimate represents about a 50 per cent increase over that of the immediately preceding spring, and was almost identical with that of the autumn of 1951.

WHITE CRAPPIES: There were only three white crappies caught during this study, and no estimate of the size of the population was made. Such a small catch corroborates the belief that this species was gradually disappearing from the lake. However, the small take was in line with the decreased catches for the other species.

LARGEMOUTH BASS: Only six largemouth bass were caught during this study. This small number also corresponds to the decrease in catch for the other species. However, sufficient numbers of bass on which to base an estimate had not been taken since the first netting study.

CARP: In as much as only 31 carp were caught and marked, and none of the marked fish were recaptured, there was no basis on which to make an estimate. Many of the carp taken in the nets carried lesions which sometimes penetrated the scales of the fish. The cause of such lesions is not known.

BULLHEADS: There were 155 bullheads taken in the nets, 134 were marked, and 21 marked bullheads were recaptured. The size of the bullhead population was estimated to have been about 490 fish, an increase of about 40 per cent over the immediately preceding estimate, and a decrease of 44 per cent from the estimate from the autumn of 1951.

REDHORSE: Of the 54 redhorse caught, 36 were marked, and 16 of the marked fish were recaught. It was estimated that there were about 55 redhorse present in the lake. This estimate lends credence to the previous assumption that this species was gradually but steadily disappearing from the lake.

GIZZARD SHAD: A total of 93 gizzard shad, of which 80 were marked and one marked fish was recaptured, were handled during this study. No estimate of the size of the population was made.

TOTAL FISHES: The lack of information on the abundance of two of the most numerous species of fish, the carp and the bluegill, precludes any total estimate of the population.

THE THIRD SPRING POPULATION ESTIMATE

A total of 2777 fish were caught in the nets during this study. Of these fish, 1834 were marked and returned to the lake, and 524 of the marked fish were recaptured. Although that total catch is considerably greater than that for the fall study of 1952, it was not so large as any of the first four estimates.

BLUEGILLS: Only 707 bluegills were taken in the nets, 622 were marked, and 48 of the marked fish were recaptured. From these data it was estimated that there were about 4750 bluegills in the lake. That estimate represents a decrease of about 25 per cent from the 6500 individuals estimated to have been present in the spring of 1952.

BLACK CRAPPIES: A total of 1409 black crappies were caught, 833 were marked, and 411 marked fish were recaptured. It was estimated that there were only about 1800 black crappies present in the lake that were large enough to be retained in the nets. This latest estimate represents an over-winter loss to only about one-third of the population estimated to have been present the preceding fall. Such a loss in numbers is certainly considerably greater than can be attributed to normal over-winter mortality, but the cause for the decreased size of the population is not obvious.

WHITE CRAPPIES: Only 15 white crappies were caught, six were marked, and marked fish were recaptured nine times. From these data it was estimated that the entire population of white crappies consisted of the six fish that were marked and released. Here again is evidence that this species was disappearing from the lake.

LARGEMOUTH BASS: Only four individuals were caught and marked, and none of the marked fish was retaken. No estimate of the size of the population was made.

CARP: A total of 289 carp were caught, 146 were marked, and 15 marked fish were recaptured. From these data it was estimated that there were about 1700 carp in the lake. However, this estimate is believed to be inaccurate. During the netting operations, an infection of near-epidemic proportions was noticed among the carp population. It was similar to the one noticed the preceding fall but was much more prevalent. The infection caused the formation of large ulcerous lesions which involved the scales, skin, flesh, and, in some instances, the viscera. More than one-fourth of the carp taken in the nets were dead, and nearly all the fish handled were infected. If the sampling was representative, the epidemic involved a majority of the carp in the lake, and many of the fish died. The cause of the infection is unknown.

BULLHEADS: There were 62 bullheads caught, 47 marked, and 10 marked fish recaptured during this study. From these data it was estimated that there were about 150 bullheads in the lake. Here, as with the black crappies, there was a decrease in the population to about one-third of the size estimated to have been present the previous fall.

REDHORSE: Only 51 redhorse were caught during this study. Twenty-three of those were marked, and marked fish were recaptured 26 times. From these data it was estimated that the entire population of redhorse consisted of about 25 fish. If this estimate is accurate, it is further evidence that this species was gradually disappearing from the population.

GIZZARD SHAD: There were 231 gizzard shad taken in the nets. This number is greater than the combined totals for the previous five studies. Even though no estimate of the size of the population was made, 153 shad were marked, and five of the marked fish were recaptured.

TOTAL FISHES: In as much as the estimate of the size of the population of carp, which has been one of the most abundant fishes in the lake, is believed to be in error, any estimate of the size of the total fish population would also be in error.

From the data on the length-frequency distribution and on the length-weight relationship of the various species of fish gathered during the netting studies, and from the data on which the estimates of the size and composition of the fish population were based, estimates were made of the total weights for each species and for the population as a whole. These estimates of the size, composition, and weights for each of the six semiannual netting studies are listed in table 8.

The estimates from the netting studies (table 8) indicated that, in general, the fish population exhibited fluctuations in number and weight that are within the expected range. The total weight of the population, as well as for each species, decreased during the winter months, and that lost weight was usually regained during the ensuing summer. Also there was good evidence that two species of fish were gradually disappearing from the lake. Another aspect of the studies revealed that the black crappie was more than twice as vulnerable to hoop netting as the bluegill.

For some unknown reason, the nets did not fish as efficiently during the last two netting periods as they did during the first four. Hence the reliability of the last two estimates for all species, with the possible exception of those of the black crappie and the bullhead, is questionable. The last two estimates of the size of the black crappie population were believed to be as accurate as any, because those

TABLE 8

ESTIMATES OF NUMBERS AND WEIGHTS (IN POUNDS) OF EACH SPECIES OF FISH LARGE ENOUGH TO BE TAKEN IN NETS DURING EACH OF SIX SEMI-ANNUAL NETTING STUDIES, WITH ESTIMATES OF TOTAL WEIGHT OF FISH, WHITE OAK LAKE, 1950–1953
(No estimates were made for the shad.)

Kind of Fish	Fall, 1950		Spring, 1951		Fall, 1951		Spring, 1952		Fall, 1952		Spring, 1953	
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Bluegills	6050	602	5600	639	22000	2106	6500	788	—	—	4740	611
Black crappies	2860	451	2200	254	5100	865	2700	516	5075	1117	1810	410
White crappies	1140	180	375	43	450	76	50	12	—	—	6	2
Largemouth bass	130	250	11	20	—	—	—	—	—	—	—	—
Carp	6450	3450	4825	1549	2550	1790	3100	2062	—	—	1700	1552
Bullheads	250	188	390	192	875	371	350	141	488	211	161	83
Redhorse	375	375	145	145	115	115	75	78	55	60	28	34
Total	17255	5136	13546	2842	31190	5323	12775	3597	5618	1388	8445	2692

fish were caught, marked, and recaptured in numbers comparable to those of any of the previous studies and, furthermore, the estimates appeared to be more or less in line with the others. In the final netting study it was believed that the estimates for the numbers of white crappies and redhorse were fairly reliable, in as much as both species were thought to have been disappearing from the lake. In all the other estimates during the last two netting studies, with the possible exception of the estimate for bullheads in the fall of 1952, too few marked fish were recaptured to yield reliable results.

In these estimates, although there was no reason to believe that the criteria for valid population estimates set forth by Ricker (1948) did not obtain, too few fish were caught to serve as a basis for making the estimates. Also, although Krumholz (1944) found that the fin-clipping method yielded fairly accurate results when checked against those from a rotenone study, he failed to interpret his data correctly, and based his findings on a fallacious estimate.

The Rotenone Study

In order to check the validity of the estimates of the size and composition of the fish population as shown by the netting studies, White Oak Lake was treated with rotenone shortly after the completion of the last study. The use of this plant alkaloid in the eradication of fish populations has been adequately described elsewhere by Krumholz (1948a) and others. When all the fish in the lake had been killed and recovered, and on the assumption that all the fish marked during the last netting study were present at the time, it was possible to determine the completeness of the recovery of dead fish from the lake, and from those data to estimate rather accurately the actual size and composition of the total fish population.

Immediately following the termination of the last netting study, White Oak Lake was partially drained in order to facilitate the treatment with rotenone. The water level was lowered almost to the 745-foot contour level (fig. 1), and, as a result, the lake had a maximum depth of slightly more than 5 feet and an area of less than 20 acres.

On April 27, 1953, with the assistance of personnel of the Tennessee Valley Authority, Fish and Game Branch, from Norris and Paris, Tennessee, parts of White Oak Creek and Melton Branch, and the whole of White Oak Lake were treated with a total of 25 gallons of emulsifiable rotenone (5%). The rotenone was first put in the streams leading into the lake and was then applied in a crisscross pattern over the entire surface of the lake down to the dam. As soon as the application of the rotenone was completed, the gate in the dam was closed to prevent the escape of the alkaloid into the stream below. During the time when the fish were being picked up, the gate in the dam was opened at intervals so that the water level in the lake would not become too high. As the outlet gate was screened, there was little chance that any of the dead fish would float out of the lake.

As the fish died, many of them floated to or remained at the surface of the lake where they were picked up and carried to the dock. There they were sorted to species and examined for marks from the netting studies. In addition, scale samples, weights, and length measurements were taken from representative samples of each species. However, the majority of the fish sank to the bottom as they died and did not rise to the surface again until they became bloated. In that condition, they were unfit for use in supplying accurate data on lengths and weights (Krumholz, 1950b). Thus, all the data on lengths and weights were gathered on April 27 and 28. After April 28, the fish were merely sorted to species and grouped according to lengths.

The collection of dead fish continued through the week of April 27, and by May 2 the fish that remained in the lake were in such an advanced stage of decomposition that they could not be handled easily. Accordingly the lake level was lowered, and most of the dead fish that had washed ashore were left stranded along the beach well above the water's edge. Under such conditions, the fish were readily examined for marks and grouped according to species and lengths. All fish that were picked up were buried in a deep excavation which was well away from the shoreline on the north side of the lake.

During the period when the fish were being picked up, a large number of birds, particularly turkey vultures (*Cathartes aura*), along with smaller numbers of black vultures (*Coragyps atratus*), great blue herons (*Ardea herodias*), belted kingfishers (*Megaceryle a. alcyon*), and green herons (*Butorides v. virescens*), were seen eating the dead fish. Early on the morning of April 30, 43 vultures were observed eating fish along the north shore of the lake. The numbers of fish eaten by these birds is unknown. In addition to the birds, raccoons (*Procyon l. lotor*) visited the area each night and ate some of the dead fish, and it is believed that other animals, as well, took advantage of the readily available food.

During the rotenone study, a total of 255,261 fish, which weighed 23,226 pounds, were recovered from the lake. The numbers of fish, together with the weight in pounds, for each species of fish follow:

Kind of Fish	Number	Weight in Pounds
Gizzard shad	210,938	13,893
Bluegills	30,814	757
Carp	8,872	7,536
Black crappies	3,398	277
Bullheads	768	240
Largemouth bass	448	465
Redhorse	23	58

No white crappies were found in the lake following the treatment with rotenone.

Because of the tremendous numbers of fish involved, no attempt was made to inspect each of the gizzard shad for marks. However, of the 1675 fish, exclusive of the shad and white crappies, marked during the netting study in the spring of 1953, a total of 1001 were recovered, as indicated by the data in table 9.

TABLE 9

NUMBERS OF FISH MARKED DURING LAST SEMI-ANNUAL NETTING STUDY, WITH NUMBERS AND PERCENTAGES OF FISH RECOVERED DURING ROTENONE STUDY, APRIL, 1953

Kind of Fish	No. Marked	No. Re-covered	Per-centage Re-covered
Bluegills	622	412	66.2
Carp	146	3	2.1
Black crappies	833	532	63.9
Bullheads	47	33	70.2
Largemouth bass	4	4	100.0
Redhorse	23	17	73.9
Total	1675	1001	59.8

The small number of marked carp recovered was not considered an accurate indication of the actual recovery of that species from the lake, because most of the individuals of that species that were marked during the study were badly infected, and a good many of them probably died shortly after having been marked. Furthermore, it has been stated previously that about one-quarter of the carp found in the nets were dead. Thus it seems reasonable to discard the data on the recovery of marked carp in any attempt to estimate the size of the total population. The numbers of marked bluegills, black crappies, largemouth bass, bullheads, and redhorse that were recovered were believed to indicate accurately the completeness of recovery of fishes of those species from the lake. An average of the recovery of the marked fish for those species is approximately 65 per cent, and that figure is used, for want of a better one, in the estimates for the carp and shad.

If each of the figures for the actual numbers and weights for each species of fish recovered from White Oak Lake were multiplied by an appropriate factor to compensate for the incomplete recovery of marked fish, the estimated size and composition of the fish population would be increased to the following values:

Kind of Fish	Number	Weight in Pounds
Gizzard shad	324,423	21,367
Bluegills	46,560	1,144
Carp	13,645	11,590
Black crappies	5,318	434
Bullheads	1,094	342
Largemouth bass	448	465
Redhorse	31	78
Total	391,519	35,420

As mentioned above, White Oak Lake, at normal pool level, had an area of about 36 acres. Thus the actual number of fish picked up following the treatment with rotenone amounted to about 7100 fish per acre, which weighed 646.3 pounds, and the estimated total, based on the recovery of marked fish, was about 10,875 fish per acre, which weighed 984 pounds. The estimates of numbers and weights for each species of fish are:

Kind of Fish	Number	Weight in Pounds
Gizzard shad	9,012	593.5
Bluegills	1,293	31.8
Carp	379	321.9
Black crappies	148	12.1
Bullheads	30	9.5
Largemouth bass	12	12.9
Redhorse	1	2.2
Total	10,875	983.9

Although these data indicate the total numbers and weights of the different kinds of fishes present in White Oak Lake in April, 1953, they include fishes of all sizes and as such are not comparable to the data from the netting studies. It is stated above that the nets were selective for size, because the meshes were large enough to allow the small fishes to escape. The revised figures for the size and composition of the fish population include only those fish that were large enough to have been retained in the nets, as follows:

Kind of Fish	Number	Weight in Pounds
Gizzard shad	1,427	830.5
Bluegills	25,738	956.5
Carp	13,645	11,950.0
Black crappies	2,334	396.1
Bullheads	642	325.5
Largemouth bass	305	455.7
Redhorse	31	78.0
Total	44,122	14,632.3

The following is a tabulation of the fishes that were too small to have been retained in the nets:

Kind of Fish	Number	Weight in Pounds
Gizzard shad	332,996	20,536.5
Bluegills	20,822	187.5
Carp	—	—
Black crappies	2,984	37.9
Bullheads	452	16.5
Largemouth bass	143	9.3
Redhorse	—	—
Total	347,397	20,787.7

From these data it is evident that the fish small enough to pass through the meshes of the nets during the netting studies made up the great majority (88.73%) of the number of fish in the total population as estimated from the rotenone study. However, those small fish made up only slightly more than half (58.69%) of the total recovered weight. Here it should be emphasized that the gizzard shad were not included in any of the semi-annual netting estimates, and those that were recovered during the rotenone study consisted primarily (99.56%) of members of the 1952 year class which were too small to be caught in the nets. Furthermore, the gizzard shad made up 92.98 per cent of the total numbers and 98.79 per cent of the total weight of small fish recovered during the rotenone study. Thus if only the other six species of fish are considered, an analysis of the data indicates that nearly two-thirds (63.63%) of all the dead fish recovered were large enough to be held in the nets, and those fish made up 98.21 per cent of the total weight.

AGE AND GROWTH OF FISHES

In any study that is concerned with the ecology of a fish population it is essential to know the ages of the individual fishes at different sizes and their growth from year to year. The rate of growth, the age at first maturity, and the length of the life span reflect the well-being of the population. The information on age and growth of fishes in White Oak Lake was obtained from analyses of scales and from length frequencies as manifested by the different year classes at different seasons of the year.

The scale method for age determination has been adequately described by Van Oosten (1923, 1929) and others. Briefly, the scale method is based on two principles: (1) each year an annulus is laid down on the scale surface, usually during the late winter or early spring, and (2) the number of scales on any fish remains constant throughout life, and each scale increases in size proportional to the growth of the fish.

The distribution of the various length frequencies for any species of fish may be of considerable value in a determination of the age composition of the entire population. Here the different modes in the length-frequency curve may be an indication of the presence of different year classes. Such distribution curves are particularly useful in an analysis of the growth pattern for rapidly growing species. However, the data for length-frequency distribution alone are oftentimes insufficient, and the scale method must be used for verification.

Scale Readings

During the course of the study, 1896 samples of fish scales were read and analyzed for information on age and growth. These samples were collected during each of the netting studies and the rotenone study. In addition, scale samples were taken from all the fish dissected in the laboratory. Each of the scaled fishes that were large enough to be caught in the nets were represented as follows: black crappies, 765; bluegills, 591; gizzard shad, 188; white crappies, 108; largemouth bass, 92; carp, 78; and redhorse, 74. The data for each species are considered separately.

Black Crappie

The calculated lengths attained by the black crappies of different ages at the time of annulus formation are listed in table 10. In this group it is evident that there was an apparent decrease in the calculated growth as it was determined from successively older groups of individuals (Lee's phenomenon). One of the possible explanations for this phenomenon among ciscoes (*Leucichthys*) given by Hile (1936) was that the more slowly growing fish survived longer than the more rapidly growing individuals. Thus the early growth, as calculated from the slowly growing survivors of the older age groups, would naturally be small. In fish displaying only one annulus, the average total length was 90.5 mm., whereas in those with two, three, and four annuli, the average lengths were 82.2, 81.2, and 80.0 mm., respectively. The same phenomenon generally holds true for the fish that had two or more annuli. It must be remembered, however, that those fish with one annulus were not necessarily all members of the same year class, because fish one year old were caught during each of the sampling periods. Thus the data are a composite of all year classes of black crappies in the lake at the time when they had only one annulus. The same holds true for the other age groups.

TABLE 10

Average Total Lengths, with Minima and Maxima, at Time of Annulus Formation of Black Crappies of Different Ages, Calculated from Scale Readings, White Oak Lake, 1950–1953

	No. of Annuli			
	1	2	3	4
One Annulus				
Minimum	49			
Average	90.5			
Maximum	143			
Two Annuli				
Minimum	35	100		
Average	82.2	160.8		
Maximum	136	211		
Three Annuli				
Minimum	41	126	171	
Average	81.2	141.9	193.4	
Maximum	108	203	251	
Four Annuli				
Minimum	79	111	231	291
Average	80.0	126.0	238.0	303.0
Maximum	81	141	245	315

The actual measured lengths of the different year classes of black crappies collected during the six netting periods, which were predominant in the lake during the study, are listed in table 11. An analysis of these data indicates that the fish of the 1951 year class were larger, on the average, at the end of their first summer of life (fall of 1951) than those of either the 1950 or 1952 year classes. In addition, that same group had a greater average length at the end of their second summer of life (fall of 1952) than those of the 1949, 1950, or 1952 year classes. This rapid growth of the 1951 year class is readily explained by the fact that the size of that year class was considerably smaller than any other brood of black crappies hatched during the study period. In contrast, the 1952 brood was the most abundant year class observed during the study and consequently was of the smallest average size at the end of the first summer of life. Thus it is apparent that the size of any brood is one of the principal factors which control the growth of the individual members of that brood.

TABLE 11

AVERAGE MEASURED TOTAL LENGTHS, WITH MINIMA AND MAXIMA, AT TIME OF COLLECTION OF BLACK CRAPPIES OF THE DIFFERENT YEAR CLASSES, WHITE OAK LAKE, 1950–1953

	Fall, 1950	Spring, 1951	Fall, 1951	Spring, 1952	Fall, 1952	Spring, 1953
1949 year class						
Minimum	131	147	178	189	194	198
Average	152.2	158.1	195.0	199.8	205.6	210.0
Maximum	175	178	212	216	235	235
1950 year class						
Minimum	96	103	151	152	176	179
Average	105.2	111.2	170.6	174.9	193.9	195.5
Maximum	111	117	185	197	257	228
1951 year class						
Minimum			105	107	156	168
Average			123.3	125.7	173.8	174.6
Maximum			141	144	187	189
1952 year class						
Minimum					76	93
Average					101.4	113.3
Maximum					126	128

It is also readily evident from the data that the fish grew during the winter months. There was a definite increase in the minimum, average, and maximum total lengths during the interval between the collection of the fall samples and that of the samples of the spring immediately following. The data for the length frequencies of the black crappies taken during the netting studies and the rotenone study are shown graphically as percentages of the total catch in figure 2.

The maximum age of any of the black crappies taken during the study period was four years. Fish of that age were represented only in the 1946 and 1948 year classes. Only nine such individuals were observed: two in October, 1950; six in the spring of 1951; and one the following spring. No fish that old was taken during any of the other three netting studies or during the rotenone study. Thus of the 14,128 black crappies handled during the three-year study period, only 0.6 per cent had reached the age of four years.

In a study of the age and growth of black crappies in Norris Reservoir, Tennessee, based on 677 specimens captured by various methods, Stroud (1948) found that 47 individuals were four years old and one had reached an age of five years. In that same study, it was further stated that 18.6 per cent of a sample of 194 black crappies caught by anglers from the same body of water were four years old. If the data from White Oak Lake were rearranged to include only those black crappies that might be large enough to interest the angler (7 inches in total length), it is found that only nine of 4870 individuals, or 0.18 per cent, reached an age of four years.

Information on the age and growth of black crappies from Cherokee and Douglas reservoirs, Tennessee, and from Hiwassee Reservoir, North Carolina (Stroud, 1949), indicates that the life span for that species in those waters is about the same as that for Norris Reservoir.

The black crappies of White Oak Lake apparently grew more slowly, on the average, with the possible exception of the first year, than in any of the near-by waters of the Tennessee Valley Authority, as indicated by the data in table 12.

From these data it is apparent that the black crappies in White Oak Lake grew more slowly and their life span was much shorter, perhaps by as much as 25 or 30 per cent on both counts, than individuals of the same species in the larger bodies of water near by.

BLUEGILL

The average total lengths, together with the minima and maxima, for bluegills of different ages as calculated from scale readings

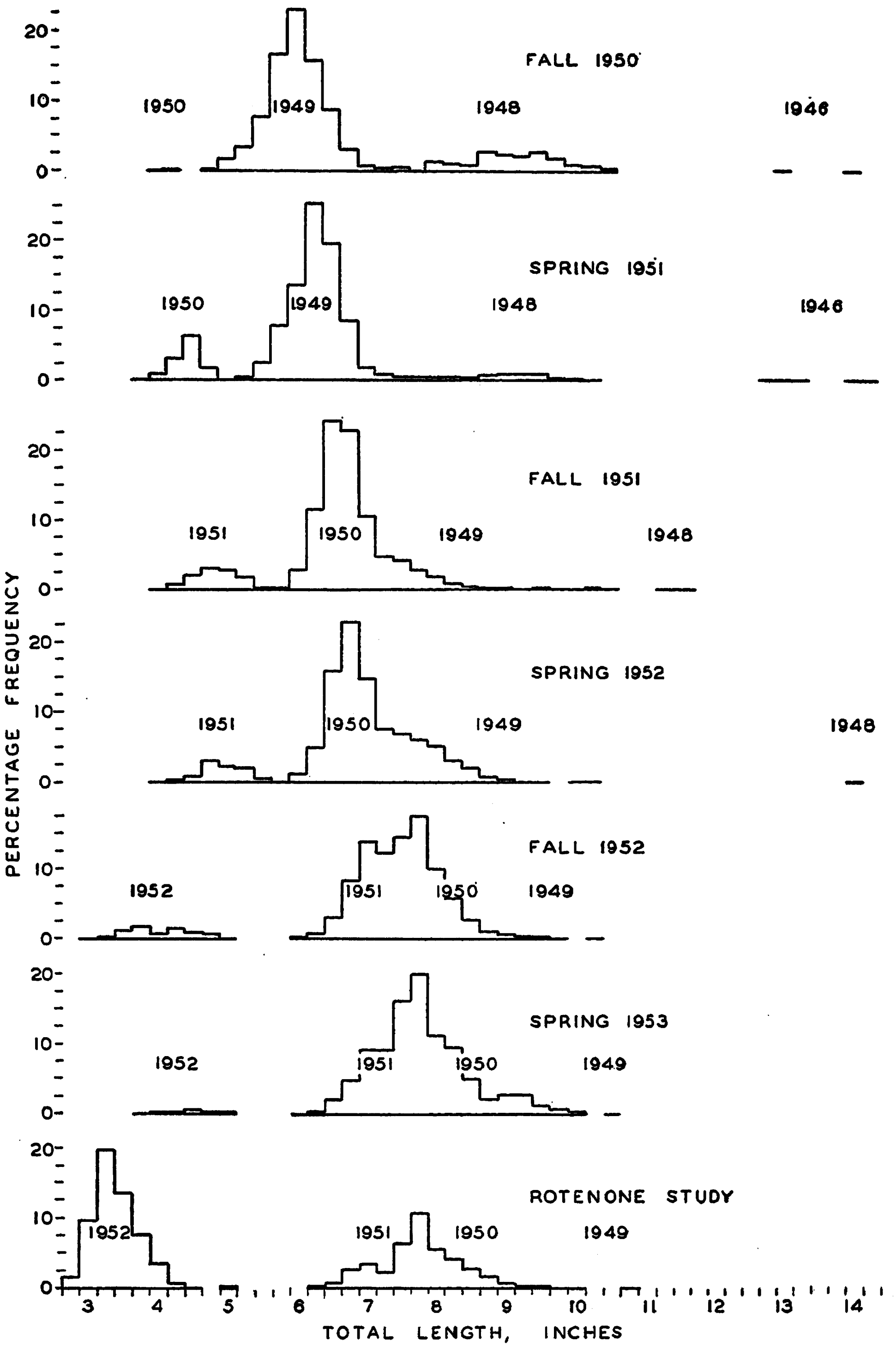

FIG. 2. Length frequencies of black crappies.

TABLE 12

Average Lengths of Black Crappies of Different Ages from White Oak Lake as Compared with Those from Nearby Waters

Body of Water	Average Lengths at End of Year			
	1	2	3	4
White Oak Lake	3.6	6.3	7.6	11.9
Norris Reservoir	2.5	9.2	11.5	12.7
Hiwassee Reservoir	2.9	7.5	10.2	11.5

are listed in table 13. These data indicate that the same phenomena of age and growth were present for the bluegills as for the black crappies. Here, again, it is apparent that the more slowly growing fish lived longer than the faster growing ones. Fish that had only one annulus had an average total length of 42.0 mm., whereas those with two, three, four, and five annuli were 39.0, 36.3, 28.4, and 28.1 mm. long, respectively. Similar trends were present among the higher age groups with the single exception of the fish five years old at the time of the formation of the fourth annulus. The reason for this discrepancy is not known.

TABLE 13

Average Total Lengths, with Minima and Maxima, at Time of Annulus Formation of Bluegills of Different Ages, Calculated from Scale Readings, White Oak Lake, 1950–1953

	No. of Annuli				
	1	2	3	4	5
One Annulus					
Minimum	16				
Average	42.0				
Maximum	96				
Two annuli					
Minimum	19	48			
Average	39.0	91.5			
Maximum	70	136			
Three annuli					
Minimum	20	46	101		
Average	36.3	84.4	127.6		
Maximum	67	114	160		
Four annuli					
Minimum	14	42	77	113	
Average	28.4	66.6	113.1	138.8	
Maximum	51	108	145	176	
Five annuli					
Minimum	21	46	81	124	157
Average	28.1	64.4	106.6	141.4	168.4
Maximum	51	82	133	164	183

TABLE 14

Average Measured Total Lengths, with Minima and Maxima, at Time of Collection of Bluegills of the Different Year Classes, White Oak Lake, 1950–1953

	Fall, 1950	Spring, 1951	Fall, 1951	Spring, 1952	Fall, 1952	Spring, 1953
1947 year class						
Minimum	132	128	155	147	175	178
Average	133.3	134.7	166.1	166.8	183.3	189.4
Maximum	167	168	174	176	194	195
1948 year class						
Minimum	111	116	133	132	151	156
Average	126.4	129.3	144.8	148.0	158.5	162.9
Maximum	149	144	170	176	164	167
1949 year class						
Minimum	110	111	110	105	126	144
Average	118.5	118.6	133.6	138.3	143.5	148.6
Maximum	125	125	159	162	168	164
1950 year class						
Minimum			105	105	98	110
Average			115.2	117.1	126.0	130.3
Maximum			130	132	163	158
1951 year class						
Minimum					89	80
Average					107.5	112.0
Maximum					151	156

Although only very limited data are available from Chicamauga Reservoir, and none from other near-by waters, it is readily evident from a comparison of the two sets of data that the bluegills from White Oak Lake grew more slowly. Actually, for the first three years the fish from White Oak Lake were from 10 to 25 per cent smaller than those from Chicamauga Reservoir, and the bluegills four years old from White Oak Lake were no larger, on the average, than the fish three years old from Chicamauga Reservoir.

The actual lengths of the individuals of the various year classes at the time of capture, together with the minimum and maximum lengths in each size range, for each of the six

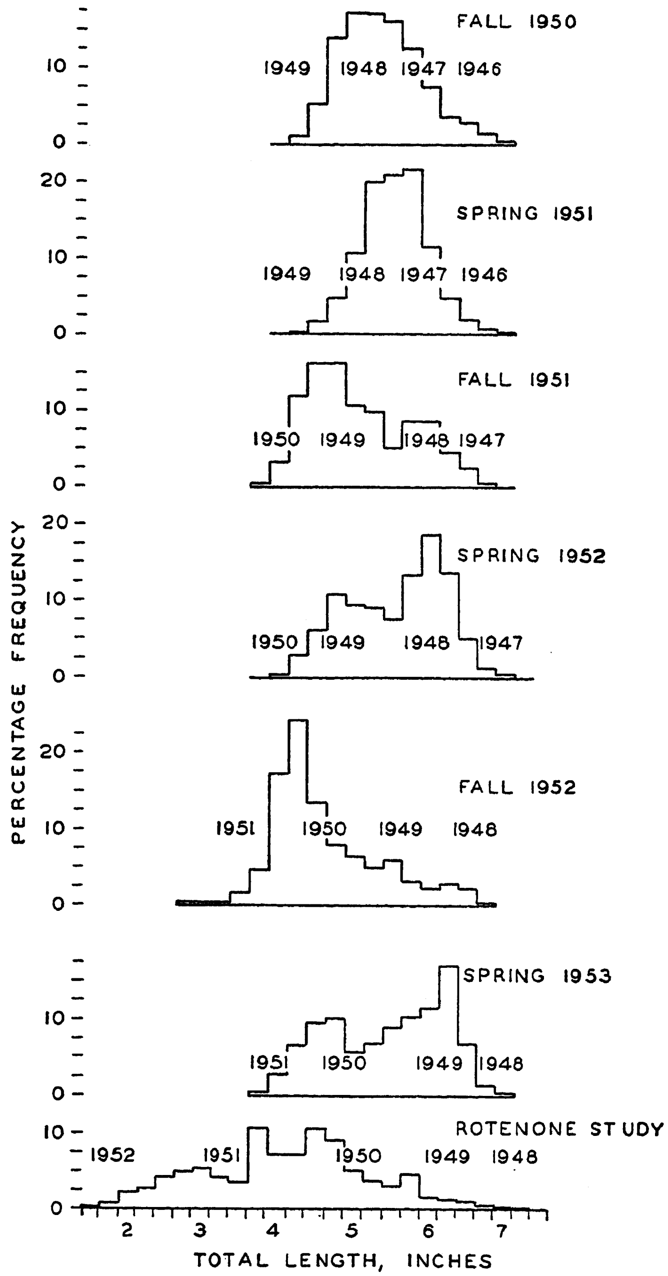

Fig. 3. Length frequencies of bluegills.

semi-annual netting studies are listed in table 14. Here, too, as among the black crappies, it is evident that the bluegills grew during the winter months. The maximum age for bluegills taken during the study was five years. Unfortunately there are no published data on the age and growth of bluegills for any of the Tennessee Valley Authority waters, except those mentioned above, with which to compare the data from White Oak Lake.

In such a slowly growing fish as the bluegill in White Oak Lake, the distribution of the length frequencies does not point up the presence of year classes as in the case of the black crappies. The graphical representation of the length-frequency data for the bluegills (fig. 3) shows that there is no obvious distinction between year classes. The polygons for the collections made in October, 1950, and April, 1951, include data from individuals of the 1946, 1947, 1948, and 1949 year classes, and there is no evidence of any distinct modes which might indicate the presence of year classes. Much the same evidence is present throughout the other length-frequency distributions of the bluegills.

In the length-frequency distributions for the black crappie taken during the last netting study and the rotenone study (fig. 2) it is evident that the nets took a fairly accurate sample of the fish present. However, the data for the bluegills from the same two studies indicate that the nets probably did not take a random sample of the extant population.

White Crappie

The white crappie, although very closely related to the black crappie, grew more slowly than the black crappie at all times during the three-year study period. Nearly all the data on the age and growth of the white crappie were gathered during the first two semi-annual netting studies. The average calculated lengths of the white crappies for different ages, based on scale readings, along with the minimum and maximum measurements to show the range in length, are listed in table 15. No maximum or minimum is listed for the single fish with four annuli. The maximum age of any white crappie taken during the survey period was four years.

In Douglas and Cherokee reservoirs, Stroud (1949) found that the white crappie grew faster than the black crappie, whereas the growth of the two species was about the same in Norris Reservoir. In White Oak Lake, the rate of growth of the white crappie was slower than that in any of the near-by reservoirs, as shown by the data in table 16.

Here, as in the data for the black crappies, the only time the white crappies from White Oak Lake grew faster than those in near-by waters was during the first year.

TABLE 15

Average Total Lengths, with Minima and Maxima, at Time of Annulus Formation of White Crappies of Different Ages, Calculated from Scale Readings, White Oak Lake, 1950–1953

	No. of Annuli 1	2	3	4
One annulus				
Minimum	45			
Average	85.3			
Maximum	130			
Two annuli				
Minimum	32	85		
Average	64.6	136.1		
Maximum	107	180		
Three annuli				
Minimum	30	94	114	
Average	44.5	116.1	176.1	
Maximum	97	163	231	
Four annuli				
Minimum	—	—	—	—
Average	22	67	115	162
Maximum	—	—	—	—

TABLE 16

Average Lengths of White Crappies of Different Ages from White Oak Lake as Compared with Those from Near-by Waters

Body of Water	Average Lengths at End of Year 1	2	3
White Oak Lake	3.4	5.4	6.9
Cherokee Reservoir	1.5	8.7	11.6
Douglas Reservoir	2.9	7.3	9.2
Hiwassee Reservoir	2.4	6.8	9.5
Chickamauga Reservoir	2.4	5.6	8.0

TABLE 17

Average Total Lengths, with Minima and Maxima, at Time of Annulus Formation of Largemouth Bass of Different Ages, Calculated from Scale Readings, White Oak Lake, 1950–1953

	No. of Annuli 1	2	3	4	5
One annulus					
Minimum	63				
Average	102.6				
Maximum	163				
Two annuli					
Minimum	55	129			
Average	100.4	238.6			
Maximum	181	371			
Three annuli					
Minimum	49	120	203		
Average	91.9	232.5	329.6		
Maximum	132	385	441		
Four annuli					
Minimum	62	167	242	259	
Average	80.9	239.7	351.2	406.1	
Maximum	103	341	438	484	
Five annuli					
Minimum	32	103	237	304	383
Average	50.8	159.7	293.3	372.0	429.2
Maximum	75	234	370	427	453

Largemouth Bass

Most of the scale samples from the largemouth bass were taken during the first netting period and during the rotenone study; only very few bass were caught during the other netting periods. The average total lengths for largemouth bass, together with the minima and maxima, calculated from scale readings are listed in table 17. Similar growth phenomena as those described for the black crappie are in evidence.

In his study of the growth of the largemouth bass in Norris Reservoir, Stroud (1948) stated ". . . it is probable that a large proportion of Norris largemouth die of 'old age' before reaching the age of 5 years, although a few live as long as 7 years or even longer." Of the 748 largemouth bass of all sizes studied by Stroud, there were 50 individuals (6.4%) that were five years old or older. In the present study, where scales from a highly selected group of 92 bass of all sizes were analyzed, there were no fish more than five years old, and only six (6.5%) had reached that age. Here, again, there is evidence that the life span of the largemouth bass in White Oak Lake is shorter than it is in one of the near-by reservoirs.

A comparison of the growth of the largemouth bass in White Oak Lake with that in Norris Reservoir indicates that the rate of growth is slower in White Oak Lake, as shown by the data in table 18.

The two tagged largemouth bass that had been placed in White Oak Lake in March, 1950, and were later caught in the nets in October of the same year had not increased in size during that interval.

Carp

The average calculated total lengths based on scale readings, together with the minima and maxima to indicate size range of carp of different ages, are listed in table 19. Lee's phenomenon, as described for the black crappies, is not clearly defined among the carp, especially among the fish one year old. The oldest carp from which scale samples were taken was in its sixth year of life (five annuli). However, there were fish recovered during the rotenone study that were considerably larger than the fish five years old that were taken earlier. Unfortunately, the scales of these large fish could not be read accurately.

TABLE 18

Comparison of Average Lengths of Largemouth Bass of Different Ages from White Oak Lake with Those from Norris Reservoir

Body of Water	Average Lengths at End of Year 1	2	3	4	5	6
White Oak Lake	4.0	9.3	13.0	16.0	16.9	—
Norris Reservoir	6.9	12.2	14.6	16.2	17.5	19.3

TABLE 19

Average Total Lengths, with Minima and Maxima, at Time of Annulus Formation of Carp of Different Ages, Calculated from Scale Readings, White Oak Lake, 1950–1953

	No. of Annuli 1	2	3	4	5
One annulus					
Minimum	71				
Average	123.9				
Maximum	173				
Two annuli					
Minimum	28	119			
Average	90.6	175.7			
Maximum	151	208			
Three annuli					
Minimum	30	115	140		
Average	93.2	162.1	226.7		
Maximum	144	228	300		
Four annuli					
Minimum	32	97	153	170	
Average	98.6	157.6	231.2	264.0	
Maximum	169	239	351	413	
Five annuli					
Minimum	45	90	126	187	213
Average	52.5	95.0	127.0	189.5	213.5
Maximum	60	100	128	192	214

TABLE 20

Average Total Lengths, with Minima and Maxima, at Time of Annulus Formation of Redhorse of Different Ages, Calculated from Scale Readings, White Oak Lake, 1950–1953

	No. of Annuli 1	2	3	4
One annulus				
Minimum	No fish taken			
Average	No fish taken			
Maximum	No fish taken			
Two annuli				
Minimum	82	197		
Average	177.6	261.0		
Maximum	246	303		
Three annuli				
Minimum	68	144	215	
Average	125.2	215.5	283.8	
Maximum	200	263	337	
Four annuli				
Minimum	48	121	224	289
Average	121.6	203.9	277.0	325.6
Maximum	186	263	324	374

Redhorse

The growth phenomena described for the black crappie are manifest in the data for the redhorse (table 20). Although these data indicate the presence of fish of three different ages, the majority of the individuals belonged to the 1948 year class, and scale samples were taken from them during the successive netting studies. The 1949 year class was the last one which was present in White Oak Lake; only two individuals of that year class were taken in the nets. The growth of the redhorse was relatively rapid during the first two years and was considerably slower thereafter. The oldest redhorse recorded during the study were members of the 1948 year class which were killed in the rotenone study at the beginning of their fifth year of life.

Gizzard Shad

The calculated minimum, average, and maximum total lengths, based on scale readings, that indicate the sizes of gizzard shad at different ages are listed in table 21. Here, again, the growth phenomena described for black crappies are readily manifest. About half of the scale samples were gathered during the netting studies and the rest following the treatment of the lake with rotenone. The

TABLE 21

Average Total Lengths, with Minima and Maxima, at Time of Annulus Formation of Gizzard Shad of Different Ages, Calculated from Scale Readings, White Oak Lake, 1950–1953

	No. of Annuli 1	2	3
One annulus			
Minimum	186		
Average	240.8		
Maximum	291		
Two annuli			
Minimum	169	242	
Average	225.5	293.4	
Maximum	276	334	
Three annuli			
Minimum	138	216	269
Average	174.0	242.0	291.5
Maximum	208	268	314

1952 year class of gizzard shad was the largest observed during the study period. These fish grew more slowly during their first summer of life than any of the less abundant year classes, a further indication that the growth of the individuals of any particular year class is governed to a considerable extent by the size of the year class. The oldest gizzard shad observed in White Oak Lake were in their fourth year of life (three annuli). There were no more than three annuli on the scales of any of the fish examined following the mass mortality of gizzard shad during the winter of 1950–1951.

LENGTH-FREQUENCY DISTRIBUTIONS

All fish caught during the netting studies were measured in total length to the nearest millimeter. When the data for length frequencies were assembled, the lengths were placed in either half-inch or quarter-inch groups, depending on the species of fish under consideration. Each quarter-inch group included measurements on those fish the lengths of which were between one-eighth of an inch smaller and one-eighth of an inch larger than the quarter-inch around which the group was centered. Similarly, the half-inch groups included those measurements in the range from one-quarter of an inch smaller to one-quarter of an inch larger than the half-inch which served as a center for the group. Such fractional measurements of inches as were necessary were made to the nearest millimeter. Thus the quarter-inch group for 5 inches (127 mm.) included those measurements between 125 and 130 mm., inclusive, whereas the half-inch group for 5 inches included those lengths between 121 and 133 mm., inclusive.

The data for the bluegills, black crappies, and white crappies were assembled into quarter-inch groups and those for the other five species into half-inch groups. In the cases of the black crappies, bluegills, carp, and bullheads, there were sufficient data on which to base percentage frequencies of the different length groups for graphic presentation, as illustrated in figures 2, 3, 4, and 5, respectively. The data for the white crappies, largemouth bass, redhorse, and gizzard shad were inadequate for such treatment, and the actual numbers of those fish measured during the study period are listed in tables 22, 23, 24, and 25, respectively.

In the length-frequency histograms for the black crappies, and bluegills, the numbers that correspond to the various year classes have been inserted in the approximate location above the appropriate total length for each of the sampling periods. These data for the black crappies indicate that the 1950 year class comprised the major portion of the catch in the fall of 1950 and the spring of 1951 and to a lesser extent during the next two netting periods. However, by the spring of 1953, the 1950 year class had largely been supplanted by the class of 1951. The 1952 year class was the largest single year class of black crappies in White Oak Lake during the study period, and members of that year class made up approximately 56 per cent of the total numbers of black crappies recovered after the rotenone treatment.

Among the bluegills there was no particular year class which was outstanding. Members of each of the 1947, 1948, 1949, 1950, and 1951 year classes made up the major part of the total bluegill population at one time or another during the study. However, because of their relatively slow growth as compared with the black crappies, the fish were usually about two years old or older when first taken in the nets.

So far as the data for the carp and bullheads are concerned, it was not practicable to assign year classes to the length frequencies in the histograms. The relatively great size ranges for each year class of carp precluded any assignment of a particular class to any part of the histogram. No attempt was made to determine the ages of the bullheads.

An examination of the data for the white crappies indicates that the species was gradually disappearing from the lake.

The reason for the relatively large catch of largemouth bass during the first netting study, as compared with the catches from later studies, is not known. It may be, however, that the lake was so turbid during the first study that the fish could not see the nets and thus could not avoid them. During the

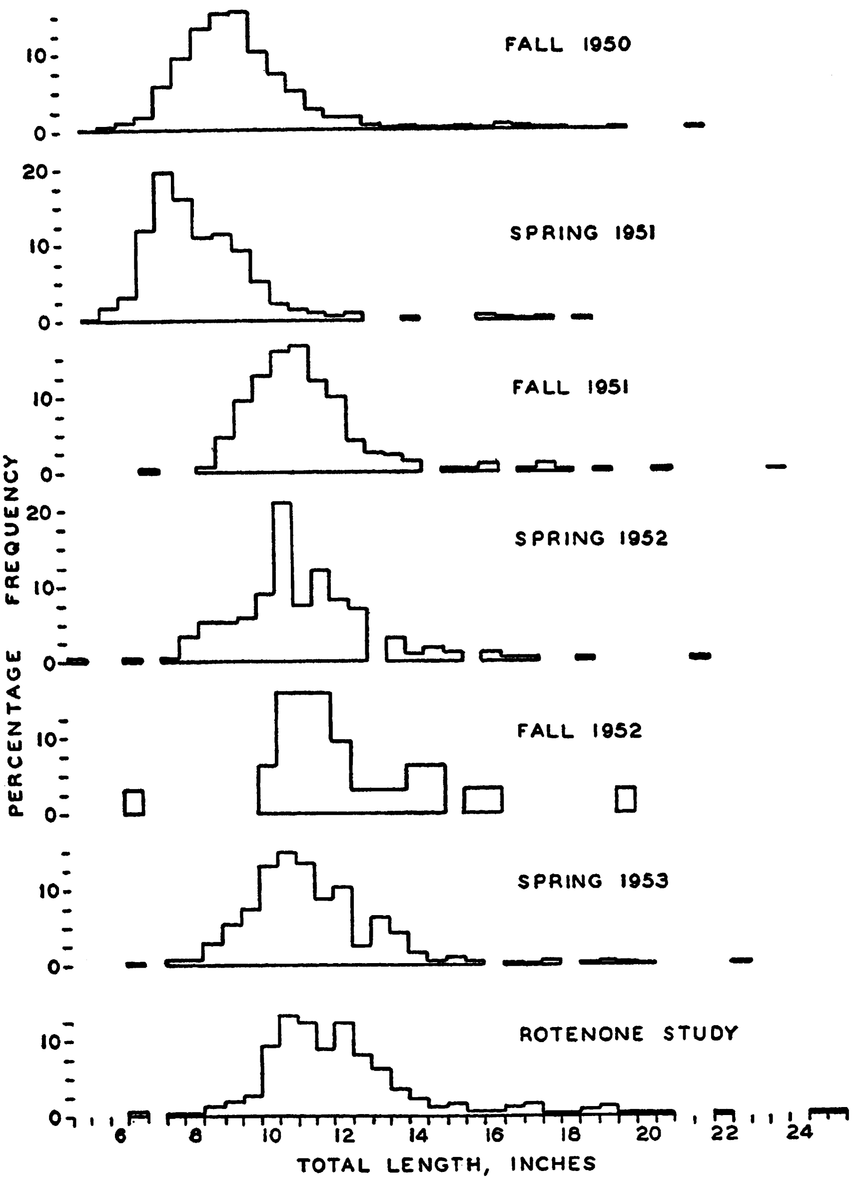

FIG. 4. Length frequencies of carp.

last five studies the water was much clearer. The data for the length frequencies of the largemouth bass were not adequate for the determination of the presence or absence of dominant year classes.

From the data on the redhorse it is obvious that the majority of the fish caught in the nets as well as those taken during the rotenone study were members of the same year class. For some unknown reason the redhorse did not raise a successful brood of young in White Oak Lake after 1949.

Following the heavy winter mortality of large gizzard shad in January, 1951, the remaining fish spawned successfully and young-of-the-year fish were prominent in the fall catch of 1951. Such small shad were present in all the remaining netting periods. The

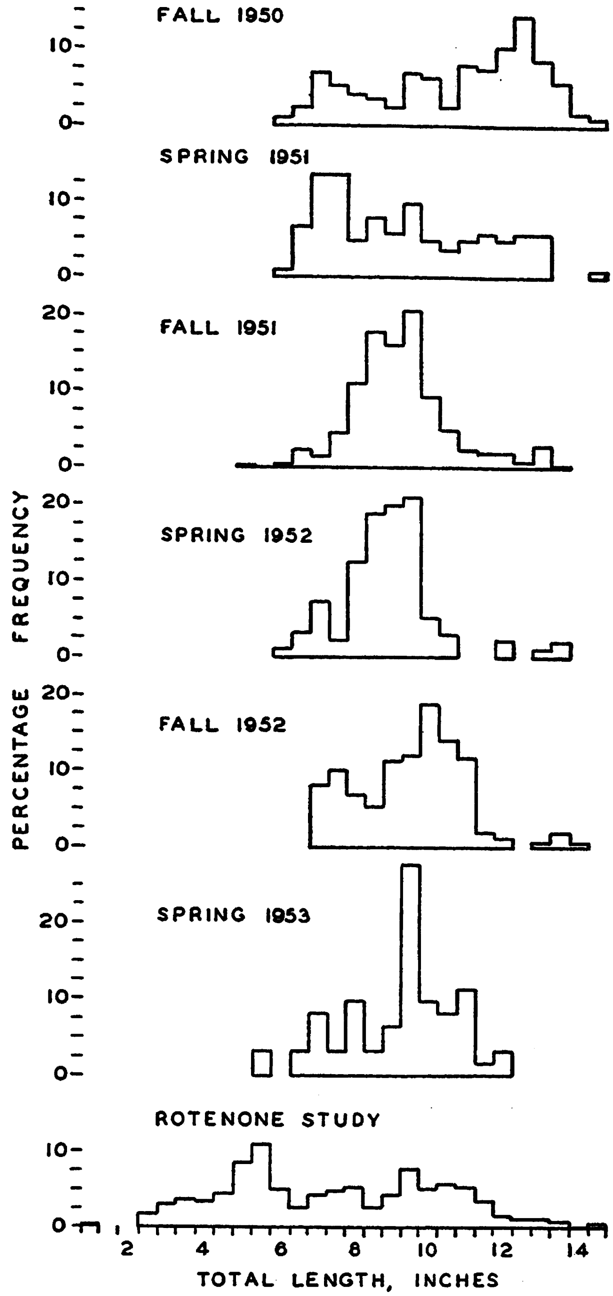

FIG. 5. Length frequencies of bullheads.

average total length of the individuals of the 1952 year class at the end of the first summer of life was considerably shorter than that for the 1951 year class at a comparable age. The obvious reason for the difference in average total length is traceable to the difference in abundance of the two year classes; there were many more individuals in the 1952 year class than in the class of 1951.

TABLE 22

Numbers of White Crappies, Arranged According to Total Length in Quarter-Inch Groups, Measured During Six Semi-annual Studies for Estimating Size and Composition of Fish Population of White Oak Lake, 1950–1953, with Similar Data from Rotenone Study, April, 1953

Size Group (Inches)	Fall, 1950	Spring, 1951	Fall, 1951	Spring, 1952	Fall, 1952	Spring, 1953	Rotenone, 1953
4.25	—	1	1	—	—	—	—
4.50	—	7	1	—	—	—	—
4.75	—	3	1	—	—	—	—
5.00	3	1	10	—	—	—	—
5.25	3	5	7	2	—	—	—
5.50	8	11	5	1	—	—	—
5.75	17	52	2	1	—	—	—
6.00	13	59	2	—	—	—	—
6.25	3	78	12	4	—	—	—
6.50	5	52	12	1	—	—	—
6.75	5	23	31	9	—	—	—
7.00	5	16	27	5	—	—	—
7.25	1	11	12	3	—	—	—
7.50	2	7	6	17	—	—	—
7.75	2	5	6	4	—	1	—
8.00	—	1	2	3	—	—	—
8.25	1	2	2	5	1	2	—
8.50	1	—	1	—	—	—	—
8.75	1	2	2	2	—	—	—
9.00	2	2	—	—	—	—	—
9.25	—	1	2	1	—	1	—
9.50	1	1	1	2	—	—	—
9.75	—	3	1	—	2	—	—
10.00	1	—	—	—	—	2	—
10.25	—	1	—	—	—	—	—
10.50	—	—	—	—	—	—	—
10.75	—	—	—	—	—	—	—
11.00	1	—	—	—	—	—	—
Totals	75	344	146	60	3	6	0

LENGTH-WEIGHT RELATIONSHIPS

The relationship between the length and weight of any fish is generally used as an indication of condition or plumpness. The average weights, in grams, of bluegills, black crappies, and white crappies of different length groups are listed in table 26. From these data it is obvious that the bluegills were much heavier for their length than either of the two species of crappies. However, the black crappies were consistently heavier than the white crappies in each length group.

The average weights, in grams, of the largemouth bass, carp, bullheads, and gizzard shad of different lengths are listed in table 27. From these data it is evident that, up to the maximum size taken, the bullheads were heaviest for their lengths and the shad were the lightest. The carp were heavier than the bass at all lengths up to 10.5 inches, whereas at lengths greater than 11 inches the bass were consistently heavier.

No length-weight data were compiled for the redhorse.

In as much as all fish caught during the netting studies were measured to total length, estimates of the total weight for each species for each study were made by the application of the average weights for the various length groups listed in tables 26 and 27.

TABLE 23

NUMBERS OF LARGEMOUTH BASS, ARRANGED ACCORDING TO TOTAL LENGTH IN HALF-INCH GROUPS, MEASURED DURING SIX SEMI-ANNUAL STUDIES FOR ESTIMATING SIZE AND COMPOSITION OF FISH POPULATION OF WHITE OAK LAKE, 1950–1953, WITH SIMILAR DATA FROM ROTENONE STUDY, APRIL, 1953

Size Group (Inches)	Fall, 1950	Spring, 1951	Fall, 1951	Spring, 1952	Fall, 1952	Spring, 1953	Rotenone, 1953
3.5	—	—	—	—	—	—	3
4.0	—	—	—	—	—	—	3
4.5	—	—	—	—	—	—	4
5.0	—	—	—	—	—	—	4
5.5	—	—	—	—	—	—	6
6.0	—	—	—	—	—	—	3
6.5	—	—	—	—	—	—	6
7.0	—	—	—	—	—	—	2
7.5	—	—	—	—	—	—	—
8.0	1	—	—	—	—	—	—
8.5	5	—	—	—	—	—	—
9.0	8	—	—	—	—	—	2
9.5	—	—	—	—	—	—	—
10.0	4	—	—	—	3	—	6
10.5	3	—	1	—	2	—	9
11.0	3	—	—	—	—	1	4
11.5	2	—	—	1	—	2	5
12.0	8	—	—	—	—	—	4
12.5	6	—	1	—	—	—	4
13.0	3	—	—	—	—	—	3
13.5	—	1	—	—	—	1	4
14.0	3	—	—	—	—	—	5
14.5	2	—	—	1	—	—	3
15.0	2	—	—	1	—	—	2
15.5	2	—	1	—	—	—	1
16.0	1	—	—	3	—	—	3
16.5	2	1	—	1	—	—	2
17.0	2	2	1	—	—	—	1
17.5	—	—	4	2	—	—	2
18.0	2	—	1	2	—	—	—
18.5	1	—	1	2	—	—	—
19.0	2	—	—	—	—	—	1
19.5	—	—	—	1	—	—	2
20.0	—	—	—	—	—	—	1
Totals	67	4	10	14	5	4	97

DISCUSSION

Although there are a number of large reservoirs near by which differ considerably from White Oak Lake in their physical and biological characteristics, there are no smaller impoundments of a size comparable to that of White Oak Lake which have been studied intensively. Even if such an impoundment were available for study, it is doubtful that the environmental conditions would be similar to those of White Oak Lake. It must be remembered that White Oak Lake has received relatively large quantities of various unusual waste materials from the Oak Ridge National Laboratory almost continuously since it was impounded.

Because no data from lakes of comparable size are available, much of the discussion of the fish population of White Oak Lake of

TABLE 24

NUMBERS OF REDHORSE, ARRANGED ACCORDING TO TOTAL LENGTH IN HALF-INCH GROUPS, MEASURED DURING SIX SEMI-ANNUAL STUDIES FOR ESTIMATING SIZE AND COMPOSITION OF FISH POPULATION OF WHITE OAK LAKE, 1950–1953, WITH SIMILAR DATA FROM ROTENONE STUDY, APRIL, 1953

Size Group (Inches)	Fall, 1950	Spring, 1951	Fall, 1951	Spring, 1952	Fall, 1952	Spring, 1953	Rotenone, 1953
7.0	—	1	—	—	—	—	—
7.5	5	1	1	—	—	—	—
8.0	—	—	—	—	—	—	—
8.5	—	—	—	—	—	—	—
9.0	2	1	—	—	—	—	—
9.5	—	—	—	1	—	—	—
10.0	2	—	—	—	—	—	—
10.5	1	2	—	1	1	—	—
11.0	23	6	1	2	—	—	—
11.5	57	6	11	2	—	1	—
12.0	44	26	14	—	2	—	—
12.5	24	21	21	8	2	2	—
13.0	3	1	29	16	5	3	2
13.5	—	—	35	19	12	5	2
14.0	—	—	12	17	11	5	3
14.5	1	—	1	4	12	23	5
15.0	—	—	—	—	5	12	3
15.5	—	—	—	—	2	—	1
Totals	162	65	190	69	52	51	16

necessity is based on general information that has been accumulated over the years from a variety of sources. The methods and practices used in collecting the data for making estimates of the size and composition of the fish population, whether by netting studies or by rotenone, have become well established and generally accepted in the field of fishery biology. Still, there is much to be learned about the over-all dynamics of fish populations, their fluctuations, both interspecific and intraspecific, which are brought about through the pressures exerted by one species against another or by one year class of a particular species against the other year classes of the same species, and the interdependence or antagonism of the different species concerned, together with the general picture of the ability of the different components of a fish population to maintain themselves.

The general fertility and productivity of White Oak Lake are believed to be much higher than in most other lakes of the region. The primary cause of that increased fertility is that the lake receives treated domestic sewage effluent equivalent to that from a municipality with a population of about 3000 inhabitants. Any increase in fertility usually results in an increased productivity in any body of water. However, the increased fertility in itself cannot be held directly responsible for any changes in the species composition of the fish population. Changes in the populations of planktonic and other invertebrate organisms may result directly from increases or decreases in the amounts of certain elements or nutrient materials, whereas changes in the species composition of the fish population are usually traceable to marked changes in habitat, food supply, protracted periods of turbidity, chemical characteristics of the water, and so forth.

It is not known what changes in the size and composition of the fish population of White Oak Lake took place during the first seven years of impoundment (1943 to 1950). However, the composition of the fish population was considerably different from that of

TABLE 25

NUMBERS OF GIZZARD SHAD, ARRANGED ACCORDING TO TOTAL LENGTH IN HALF-INCH GROUPS, MEASURED DURING SIX SEMI-ANNUAL STUDIES FOR ESTIMATING SIZE AND COMPOSITION OF FISH POPULATION OF WHITE OAK LAKE, 1950–1953, WITH SIMILAR DATA FROM ROTENONE STUDY, APRIL, 1953

Size Group (Inches)	Fall, 1950	Spring, 1951	Fall, 1951	Spring, 1952	Fall, 1952	Spring, 1953	Rotenone, 1953
4.5	—	—	—	—	—	—	1
5.0	—	—	—	—	3	—	8
5.5	—	—	—	—	11	27	76
6.0	—	—	—	—	13	27	40
6.5	—	—	1	—	5	19	17
7.0	—	—	—	—	5	8	4
7.5	—	—	4	1	1	—	—
8.0	—	—	16	3	—	—	—
8.5	—	—	16	9	—	—	—
9.0	—	—	27	11	1	1	—
9.5	—	—	15	10	—	1	—
10.0	—	—	4	8	4	6	—
10.5	2	—	1	6	13	18	3
11.0	—	—	—	2	6	37	10
11.5	—	—	1	—	5	29	9
12.0	—	1	1	—	4	18	5
12.5	—	—	—	—	5	14	9
13.0	—	—	—	—	1	6	1
13.5	—	—	—	1	1	1	2
14.0	—	—	—	2	2	—	2
14.5	—	—	—	3	1	—	—
15.0	—	—	—	1	1	1	—
15.5	—	—	—	3	1	—	—
16.0	—	—	—	3	—	—	—
Total	2	1	86	63	83	213	187

Watts Bar Reservoir, of which it was originally a part, at the beginning of the study period. Much silting has occurred in the basin of White Oak Lake since its impoundment in 1943. This in itself is a major deterrent to the well-being of many fish populations. Since the beginning of the present study in 1950, there have been marked changes in the species composition, and it can safely be assumed that other changes had taken place prior to that time. The only information the present study provides is the changes observed during the three-year period from 1950 to 1953.

Several general conclusions may be drawn from the results of the six semi-annual netting studies.

First, the gear used was highly selective for certain species of fish. The vulnerability of both species of crappies to netting was exceptionally high and was about twice that for the bluegills, which in turn were readily caught during most of the netting periods. The carp, on the other hand, were caught in decreasing numbers as the study progressed. The reason for such a decrease in the catch of carp is not obvious. However, the physical shape of the lake basin precluded the placement of nets where the large concentrations of carp were known to occur. The catches of bullheads and redhorse were usually large enough to furnish bases for what are believed to be fairly good estimates of the sizes of those populations. In only one of the netting studies were enough largemouth bass caught on which to base an estimate. Although increasingly large numbers of gizzard shad were caught as the study progressed, no estimates were made for

TABLE 26

AVERAGE WEIGHTS (IN GRAMS) OF BLUEGILLS, BLACK CRAPPIES, AND WHITE CRAPPIES OF DIFFERENT QUARTER-INCH GROUPS, WHITE OAK LAKE

Size Group (Inches)	Bluegills	Black Crappies	White Crappies
1.50	1.0	—	—
1.75	1.6	—	—
2.00	2.2	—	—
2.25	3.2	—	—
2.50	4.5	2.8	—
2.75	6.1	3.9	—
3.00	8.7	5.6	—
3.25	10.7	7.6	—
3.50	14.0	9.7	—
3.75	18.2	11.9	—
4.00	22.2	14.6	—
4.25	26.6	17.3	12.0
4.50	31.2	20.4	14.7
4.75	36.6	24.1	18.5
5.00	44.4	27.7	22.6
5.25	50.8	32.0	26.0
5.50	57.2	36.9	30.6
5.75	66.3	41.8	35.2
6.00	71.8	47.0	40.3
6.25	82.0	53.8	46.5
6.50	92.8	59.8	52.5
6.75	104.5	67.1	59.1
7.00	119.5	73.0	67.5
7.25	132.3	83.6	75.2
7.50	146.0	94.0	84.0
7.75	—	105.8	95.0
8.00	—	116.0	105.8
8.25	—	128.6	119.0
8.50	—	141.6	131.8
8.75	—	153.4	145.0
9.00	—	178.0	162.0
9.25	—	195.5	177.5
9.50	—	217.0	193.8
9.75	—	240.0	213.1
10.00	—	272.5	230.0

that species because of its inability to withstand handling.

Second, although the last two netting studies failed to yield adequate data for sound estimates, the first four studies indicated that there was a definite decrease in the total weight of the fish population over winter. That same phenomenon of a decrease in the standing crop during the colder months of the year has been discussed by Krumholz (1948b) in a preliminary account of the fish popula-

TABLE 27

AVERAGE WEIGHTS (IN GRAMS) OF LARGEMOUTH BASS, CARP, BULLHEADS, AND GIZZARD SHAD OF DIFFERENT HALF-INCH GROUPS, WHITE OAK LAKE

(Figures in parentheses taken from a curve; no actual weights available.)

Size Group (Inches)	Large-mouth Bass	Carp	Bull-heads	Gizzard Shad
2.5	—	—	3.5	—
3.0	—	—	5.0	—
3.5	—	—	7.6	—
4.0	—	—	11.4	—
4.5	12.6	—	15.8	10
5.0	19.4	—	24.0	19
5.5	26.1	—	34.2	28
6.0	34.2	68	45.5	37
6.5	47.5	79	57.0	47
7.0	52.4	91	70.0	58
7.5	78.9	110	88.0	(69)
8.0	96.0	125	109.3	(81)
8.5	117.0	145	132.7	(95)
9.0	140.0	166	175	(110)
9.5	166.0	190	210	(127)
10.0	201.5	215	291	(147)
10.5	240.2	245	356	171
11.0	282.0	278	467	198
11.5	328.4	316	—	233
12.0	390.0	365	652	274
12.5	444.0	412	—	319
13.0	520.0	467	765	370
13.5	602.0	528	—	427
14.0	697.5	592	850	490
14.5	795	656	—	—
15.0	900	735	—	—
15.5	1014	813	—	—
16.0	1120	898	—	—
16.5	1248	992	—	—
17.0	1358	1088	—	—
17.5	1468	1185	—	—
18.0	1575	1292	—	—
18.5	1700	1408	—	—
19.0	1818	1527	—	—
19.5	1940	1645	—	—
20.0	2060	1758	—	—
20.5	—	1900	—	—
21.0	—	2025	—	—
21.5	—	2155	—	—
22.0	—	2285	—	—
22.5	—	2420	—	—
23.0	—	2540	—	—
23.5	—	2670	—	—
24.0	—	2800	—	—
24.5	—	2925	—	—
25.0	—	3055	—	—

tions in ponds in Michigan and Indiana. In further studies along the same line in Indiana (unpublished data), there was an average decrease of about 20 per cent in the weight of the total fish population each winter with the exception of three individual cases in which populations of only a single species were involved. In those experiments, each of five ponds that had been stocked at known rates with various combinations of species was drained each fall and spring for six summers and the intervening winters, and all the fish recovered were counted, weighed, and measured to total length. Following such periods of over-winter decrease, there was an increase in the weight of the population during the ensuing summer to a level equal to or greater than that of the preceding fall. The same sort of seasonal fluctuation in the size of the standing crop was observed in four other ponds which were under observation for three years each. From such evidence, it seems reasonable to conclude that the estimates based on the netting studies, even though they may not have been quantitatively accurate, certainly provided good qualitative information which followed an established pattern.

In a consideration of the estimates for the fall of 1950 and the spring of 1951, it appears that there was an over-winter decrease of nearly 45 per cent. During the following winter there was a decrease of about 32 per cent. These two figures are considerably higher than the average observed decrease in the Indiana ponds. However, the range of decrease in the Indiana ponds was from 3 per cent to 47 per cent. The maximum estimated weights for the first two fall studies in White Oak Lake were similar (table 8). The greater decrease during the winter of 1950–1951 may have been the result of the relatively severe winter. The experimental ponds in Indiana were similar to White Oak Lake in that there was no exploitation of the fishery.

Third, there is substantial evidence that all species of fish in White Oak Lake grew appreciably during the winter months, as indicated by the increased average lengths in the spring studies as compared with those of the preceding fall. This same phenomenon was observed in ponds in Michigan and Indiana by Krumholz (1948b). In all these cases there was not only an increase in the average sizes over winter, but also there were corresponding increases in the minimum and maximum sizes.

The reason for the disappearance of the white crappies and redhorse from the fish population is not immediately obvious. Perhaps the most reasonable explanation is to be found in some slight change or changes in the environmental conditions. Such a change could not have been drastic, or the populations would probably have been wiped out in a short period of time. Rather, the change was very likely one to which neither species could completely adapt itself in the allotted time, and thus the well-being of the two populations gradually deteriorated. It may be that the competition with the black crappies caused the gradual decrease in the white crappie population. It is likely that the pollution in the streams at the head of White Oak Lake prevented the redhorse from reproducing successfully. It is also possible, as is shown below, that the constant exposure of the populations to external and internal irradiation, although at relatively low levels, could have had a deleterious effect. However, many of the normal properties of population dynamics among relatively closely related species in the same lake did not appear to have been adversely affected.

The complete absence of minnows, other than the carp and the goldfish, may be an indication that those species had disappeared from the lake between 1943 and 1950. There is a fairly abundant and varied minnow fauna in Watts Bar Reservoir, and prior to 1943, when the cofferdam was installed, White Oak Embayment was a part of that reservoir. It is almost inconceivable that no minnows were trapped in the impounded arm of Watts Bar Reservoir along with the other species present in the lake in 1950. Certainly there are several species of fish present in Watts Reservoir, such as the sauger (*Stizostedion canadense*), which could not survive in such a shallow muddy lake. However, many of the minnows that are an integral part of the fish population of Watts Bar Reservoir are commonly found in embayments similar to that in White Oak Creek prior to 1943.

Neither of the last two estimates of the size and composition of the fish population of White Oak Lake based on the netting studies is reliable. Thus it is impossible to compare the quantitative estimates of the netting studies with the data from the rotenone study. There is no obvious reason why the same nets in the same locations that caught fish during the first four studies should fail to do so during the last two. There were no changes in the techniques or methods of operation. However, the fact remains that during two of the six semi-annual netting studies the numbers of fish caught were inadequate to serve as bases for an estimate of the sizes of the various components of the fish population. Such inconsistencies in the results from a routine procedure point up the fallibility of the method and indirectly show that there is still much to be learned about the responses of the different species of fish to netting procedures.

The data for age and growth of the bluegills, black crappies, and largemouth bass from White Oak Lake indicated that these fish did not grow so fast as individuals of the same species in near-by reservoirs of the Tennessee Valley Authority. Furthermore, there is substantial evidence that the life spans of those species that had spent their entire lifetimes in White Oak Lake were substantially shorter than those of the same species in Norris Reservoir and perhaps other impoundments of the regions as well.

In the histogram of the length-frequency distribution of the black crappie (fig. 2), it is apparent that the members of the 1950 year class, which first appeared in the catch in October, 1950, and which constituted the major portion of the catch a year later, had largely been supplanted in the spring catch of 1953 by individuals of other year classes. None of the other year classes observed during the three-year period of the study lived to make up a major part of the catch for a longer time. Furthermore, the evidence from scale readings shows that only a very few black crappies attained an age of four years in White Oak Lake. Thus it seems reasonable to conclude that the maximum life span for black crappies in White Oak Lake was about three or four years. This short life span and slow rate of growth as compared with those for the same species in near-by waters may well be traceable to the continuous exposure to low levels of radioactivity.

The length-frequency data and the data for age and growth of the bluegills in White Oak Lake indicate that they were growing very slowly. It has been pointed out by Bennett (1948), Krumholz (1950a), and others that bluegills tend to overpopulate waters where there are insufficient numbers of predatory fish. It is probable that the bluegills in White Oak Lake, which were thought to be on a near-starvation diet as pointed out elsewhere in this paper, grew slowly and became stunted because of overpopulation.

When the scales of fishes from White Oak Lake were studied, it was found that the time of annulus formation ranged from early May until late July. In general the smaller fish formed their annuli earlier in the summer than did the larger ones. A few fish that were collected in August had not yet formed an annulus that year. An examination of those scales disclosed that the fish could not have attained their current size and still have belonged to the same year class. It may be that in this particular instance the fish did not form an annulus that year. Reid (1950) reported the failure of some black crappies to form an annulus each year in Florida.

If it is assumed that the annulus is laid down early in the summer, say in May or June, an examination of the data for the calculated and actual lengths of black crappies (tables 10 and 11) will show that the actual lengths of the fish taken during the spring netting studies were considerably greater than the calculated lengths for the same groups of fish. For instance, the greatest average calculated length at the time of the formation of the first annulus was 90.5 mm., as compared with an average measured length of 113.0 mm. for the individuals of the 1952 year class collected at the time of the rotenone study in April, 1953. Here it should be pointed out that the 1952 year class was smaller in average size at that age than any of the other year classes of black crappies observed during the study, and that the measured lengths were recorded at least a month before the assumed time of annulus formation. This difference in lengths amounted to about 23 mm. It is well known that small fishes are scaleless for a certain period of time early in life. If the black crappies did not begin to form scales until they were slightly less than an inch long, the discrepancy between the calculated and measured lengths referred to above could largely be accounted for by merely adding the length of the fish before it had any scales to the calculated length at the time of formation of the first annulus. An examination of the data for the calculated and measured lengths of the bluegills from White Oak Lake (tables 13 and 14) reveals the same sort of discrepancy.

The recovery, during the rotenone study, of approximately 60 per cent of the fish that had been marked several weeks earlier during the spring netting study is very good when the tremendous numbers of fish involved and the limited time for recovering the fish are considered. Much more time would have been spent in picking up the dead fish except for the fact that at the end of the first week the fish were in such an advanced stage of decomposition that they could not be picked up. In similar studies elsewhere, Krumholz (1944, 1950b) reported recovering 86 per cent of the marked fish from a pothole lake, 7 acres in extent, in Oscoda County, Michigan, and 91 per cent from a small pond on a farm near Evansville, Indiana. In both instances, all fish were picked up for a period of 10 days following the application of the rotenone. Carlander and Lewis (1948) recovered about 60 per cent of the marked fish from a small farm pond in Iowa in five days, and Ball (1948) recovered 59 per cent of the marked bluegills and 45 per cent of the marked trout, for a total of 52 per cent, in six days following the treatment of Ford Lake, Michigan, with rotenone. Although only seven days could be spent in recovering fish from White Oak Lake, as many fish were recovered as by other workers under comparable conditions. However, Ball, and Carlander and Lewis marked the fish immediately prior to the rotenone treatment, whereas, in the studies at White Oak Lake and the one reported by Krumholz (1944) for Michigan, the fish were marked as a part of a population estimate based on the mark and recovery method as long as six weeks before the rotenone study was started. During such a long period of time, many of the marked fish could have disappeared from the populations.

From these data on the fish population of White Oak Lake, and from a comparison of the data on the age and growth of those fish with data presented by Eschmeyer, Stroud, and Jones (1944) and by Stroud (1948, 1949), the following general conclusions may be drawn:

1. The netting studies yielded information on the seasonal fluctuations in the weight of the total fish population. Although the data were not quantitatively sound as related to the size of the populations of the different species, they were qualitative in that they supplied information on the relative abundance of the various species of fish present.

2. Two species of fish, the white crappie and the redhorse, disappeared from the lake during the three-year study period. It may well be that other species, such as some of the smaller minnows, had been present when the lake was impounded and had disappeared during the seven-year period between the impoundment of White Oak Lake and the beginning of the present study.

3. The rate of growth of all species of fish in White Oak Lake was noticeably slower than for similar species in near-by impoundments of the Tennessee Valley Authority.

4. The life spans of the black crappie and the largemouth bass, and perhaps of other species as well, were noticeably shorter than those for the same species in near-by reservoirs.

5. Individuals of all species of fish increased in length during the winter months.

6. The time of annulus formation for all species occurred between early May and late July and was similar to that for the near-by impoundments of the Tennessee Valley Authority.

7. There is a good indication that some individual fish did not form an annulus every year.

8. The length frequencies for all species of fish in White Oak Lake were well within the expected ranges.

9. The length-weight relationships for the various species of fish were much the same as those for fish in the large reservoirs of the Tennessee Valley Authority which were located near by.

WEIGHTS OF FISH TISSUES

Because White Oak Lake constituted an environment that was contaminated with radioactive wastes, it was essential to determine how much radioactivity was accumulated in the various tissues as well as in the entire body of the fish. Accordingly an attempt was made to set up a series of standard weights for each particular kind of tissue and to determine what percentage of the total weight of the fish was contributed by each tissue. In order to set up such a series, several individuals of each species large enough to be retained in the nets used in the population studies were completely dissected, so that all the tissue which belonged to each of the following categories was recovered as far as possible and weighed: scales, skin, muscle, bone, fins, gill filaments, gill arches and rakers, eyes, stomach and pyloric caeca, intestine, heart, liver, gall bladder and contents, spleen, kidneys, head kidney or pronephros, central nervous system, abdominal fat, gonads, and the contents of the digestive tract. For example, all the muscle tissue (flesh) in the entire body was separated from all other tissues and weighed as a unit. Each of the other tissues was handled in the same manner. So far as the bone was concerned,

TABLE 28

Average Percentages of Total Weight of Stable Tissues Contributed by Each Tissue Dissected from Individuals of Eight Species of Fish from White Oak Lake

(The recovered weight indicates the percentage of the live weight recovered during dissection.)

	Bluegill	Black Crappie	White Crappie	Large-mouth Bass	Carp	Bullhead	Redhorse	Gizzard Shad
Stable tissues								
Scales	5.54	5.39	4.73	3.55	7.08	—	8.60	6.33
Skin	2.68	3.18	2.19	3.27	3.32	8.12	2.69	1.16
Muscle	67.96	65.52	68.10	65.64	61.97	61.01	68.08	70.38
Compact bone	5.20	7.22	5.78	7.05	5.10	8.53	4.65	3.67
Cancellous bone	4.67	4.97	4.46	5.89	6.32	5.35	4.62	2.70
Dorsal fin	2.41	1.76	1.29	0.94	1.35	0.62	0.78	0.43
Anal fin	1.35	2.09	1.69	0.50	0.68	1.09	0.48	0.57
Other fins	1.93	2.12	2.20	1.27	2.28	1.81	2.28	1.56
Gill filaments	0.84	0.91	1.06	2.06	1.79	2.71	1.46	2.71
Gill arches	0.93	1.64	1.10	3.01	1.88	1.60	1.00	0.83
Eyes	2.03	1.96	2.02	2.30	1.12	0.17	1.11	1.16
Stomach	1.32	1.20	1.24	2.40	—	2.89	—	3.66
Intestine	0.55	0.39	0.43	0.45	1.25	1.76	0.99	1.07
Heart	0.16	0.09	0.14	0.08	0.24	0.12	0.13	0.21
Liver	1.19	1.03	1.17	0.84	3.65	2.25	2.00	1.90
Gall bladder	0.21	0.25	0.18	0.26	0.55	0.28	0.27	0.37
Spleen	0.11	0.10	0.06	0.08	0.13	0.05	0.11	0.14
Kidney	0.24	0.11	0.16	0.20	0.59	0.98	0.57	0.78
Head kidney	0.27	0.23	0.23	0.20	0.16	0.30	0.42	0.15
Central nervous system	0.45	0.33	0.34	0.28	0.72	0.36	0.37	0.22
Variable tissues								
Contents of digestive tract	0.46	0.49	0.56	0.98	1.14	0.23	1.06	0.74
Fat	0.45	0.42	0.19	1.24	0	0.27	0.40	0
Ovaries	4.21	1.50	1.55	0.91	6.13	0.24	0.72	—
Testes	0.22	0.44	0.52	0.06	2.22	0.34	1.03	2.98
Recovered weight	92.67	94.12	94.41	94.28	91.57	91.86	93.30	92.65

all the dermal elements of the skull, together with the lower jaw, vertebral spines, ribs, girdles, hypural elements, gill arches, and any other bones that were compact in their adult structure, were grouped together as compact bone, whereas the base of the skull and the vertebral bodies were grouped together as cancellous bone. No attempt was made to retrieve and weigh the body fluids.

For analysis, and for determination of the percentage composition of tissues in the body, the tissues were regrouped into stable tissues (those present in all individuals in relatively consistent amounts) and variable tissues (those that were present, if at all, in more or less variable amounts). The stable tissues included the scales, skin, muscle, bone, fins, gills, eyes, elements of the digestive tract, heart, liver, gall bladder and contents, spleen, kidney, head kidney, and central nervous system. The contents of the digestive tract, the abdominal fat, and the gonads were grouped together as the variable tissues. In some fishes the stomach and intestines were fuller than in others, and the gonads in some individuals were relatively much larger than in others, as the size of the gonads changed from season to season in relation to reproductive activities.

There are many anatomical differences between the various species of fish under consideration. Generally speaking, the anatomy of the bluegill is very similar to that of the other centrarchids, and the different parts of the body are almost identical in structural formation. However, among the other four

TABLE 29

PERCENTAGES OF TOTAL WEIGHT OF STABLE TISSUES CONTRIBUTED BY EACH TISSUE DISSECTED FROM BLUEGILLS

	Fish No.										
	1	2	3	4	5	6	7	8	9	10	11
Stable tissues											
Scales	4.43	5.85	5.72	5.05	5.04	6.25	6.29	6.61	5.17	5.03	7.20
Skin	2.41	2.81	3.42	3.19	2.42	2.37	2.53	2.41	3.07	2.15	3.24
Muscle	72.69	65.00	65.84	68.96	69.81	66.33	66.60	69.19	67.93	67.20	65.79
Compact bone	3.55	6.38	5.30	4.99	5.60	5.39	5.07	4.47	5.21	6.01	5.45
Cancellous bone	3.59	4.95	4.67	4.55	4.56	4.88	5.11	4.49	4.83	5.09	4.93
Dorsal fin	1.96	2.49	2.52	2.46	2.11	2.37	2.41	2.38	2.61	2.75	2.67
Anal fin	1.11	1.26	1.20	1.29	1.21	1.34	1.54	1.21	1.61	1.74	1.67
Other fins	1.76	2.01	1.92	1.68	1.85	2.12	2.06	1.94	1.84	2.15	2.07
Gill filaments	0.68	0.89	1.20	0.74	0.71	0.74	0.87	0.78	0.88	0.94	0.74
Gill arches and rakers	0.68	1.16	1.08	0.76	0.67	1.03	1.07	0.99	0.88	1.00	0.95
Eyes	1.96	1.99	2.31	1.84	1.85	1.89	2.49	2.04	1.92	1.99	1.82
Stomach and pyloric caeca	1.34	1.60	1.63	1.54	1.16	1.92	1.03	0.88	1.05	1.05	0.80
Intestine	0.52	0.61	0.65	0.74	0.54	0.56	0.55	0.39	0.48	0.43	0.47
Heart	0.23	0.20	0.15	0.16	0.13	0.17	0.12	0.15	0.15	0.13	0.10
Liver	1.30	1.40	0.99	0.96	1.16	1.38	0.95	1.19	1.28	1.25	1.10
Gall bladder and contents	0.13	0.32	0.31	—	0.21	0.23	0.20	—	0.17	0.13	0.20
Spleen	0.42	0.05	0.16	0.04	0.09	0.10	0.04	0.05	0.04	0.11	0.05
Kidney	0.23	0.27	0.25	0.28	0.26	0.27	0.20	0.22	0.23	0.22	0.18
Head kidney	0.46	0.27	0.23	0.30	0.19	0.29	0.24	0.24	0.27	0.20	0.22
Central nervous system	0.55	0.49	0.45	0.40	0.43	0.37	0.63	0.34	0.38	0.43	0.35
Variable tissues											
Contents of digestive tract	0.33	0.25	0.42	0.12	0.41	0.54	0.12	1.27	0.79	0.40	1.19
Adipose tissue	0.59	0.47	0	0	0.17	0.70	0.91	0.14	0.19	0	0.18
Ovaries	1.53	1.55	—	—	—	0.70	0.47	6.70	8.55	9.94	11.03
Testes	—	—	0.16	0.18	0.32	—	—	—	—	—	—
Live weight recovered	93.82	92.91	91.00	91.37	96.68	92.47	90.07	94.94	91.08	92.33	93.43
Total length, mm.	123	139	156	152	140	149	123	157	141	157	157
Weight, grams	33.5	44.7	68.0	62.0	48.5	56.7	28.7	67.0	57.5	66.0	72.0

species that were present in White Oak Lake the differences are much greater. In the carp and the redhorse there is no stomach as such. Rather, the posterior end of the gullet opens directly into an enlarged anterior portion of the intestine. That enlargement gradually tapers off posteriorly into the intestine, and there is no obvious pyloric valve as in the centrarchids. Thus the entire digestive tract in the carp and the redhorse, from the posterior end of the gullet to the anus, was considered as the intestine. In the gizzard shad, the gizzard was included as part of the stomach. In all the centrarchids, the pyloric caeca were included with the stomach.

The anal and dorsal fins of all species were dissected out, together with their bony elements for attachment to the vertebral column, whereas only the exposed portions of the pectoral, pelvic, and caudal fins were included in the category of other fins.

During dissection some of the body fluids were lost. Part of these fluids were undoubtedly lost through evaporation and part through absorption by the paper towels that were used in cleaning some of the tissues. However, in all cases it was possible to recover more than 90 per cent of the live weight of the individual fish (table 28).

In the calculations for the percentage of the total weight contributed by any particular organ or tissue, the combined weight of all the stable tissues recovered during dissection was considered as 100 per cent. Then the weight of each of the stable or the variable tissues was figured as a percentage of the total

TABLE 30

PERCENTAGES OF TOTAL WEIGHT OF STABLE TISSUES CONTRIBUTED BY EACH TISSUE DISSECTED FROM BLACK CRAPPIES

	Fish No.										
	1	2	3	4	5	6	7	8	9	10	11
Stable tissues											
Scales	4.45	4.70	6.40	4.47	5.30	6.67	6.04	5.11	5.03	5.27	6.19
Skin	8.06	3.77	2.02	2.08	1.85	3.12	1.92	2.62	2.26	2.23	2.06
Muscle	61.88	61.02	67.11	65.32	68.68	63.52	66.08	70.52	70.41	71.22	69.19
Compact bone	9.56	11.34	6.41	7.91	5.26	7.84	4.11	5.32	4.46	4.70	4.47
Cancellous bone	4.93	6.64	4.48	5.89	4.59	5.17	3.93	4.09	4.49	3.62	4.05
Dorsal fin	{2.72 (dorsal and anal fins)	{5.83 (dorsal, anal, and other fins)	1.78	2.02	1.52	1.65	1.95	1.63	1.95	1.81	1.92
Anal fin			2.34	1.96	1.90	2.18	2.19	1.98	2.63	2.27	2.50
Other fins	1.64		2.36	2.08	2.37	2.26	2.43	1.67	1.95	2.19	1.98
Gill filaments	0.79	0.74	0.78	{2.27 (gill filaments, arches and rakers)	0.94	1.25	1.15	0.72	0.93	0.96	0.98
Gill arches and rakers	1.85	1.38	0.78		1.14	1.35	4.15	0.82	1.07	0.90	1.05
Eyes	1.39	1.67	2.16	2.51	2.17	1.49	2.21	2.08	2.03	2.06	2.23
Stomach and pyloric caeca	1.22	1.14	1.29	1.04	1.43	1.49	1.15	0.82	0.73	0.72	0.69
Intestine	0.39	0.40	0.58	0.43	0.44	0.27	0.26	0.34	0.31	0.23	0.16
Heart	0.07	0.06	0.15	0.12	0.10	0.10	0.03	0.10	0.14	0.12	0.16
Liver	0.60	0.76	0.83	0.92	1.28	0.92	1.58	1.33	0.82	0.98	1.52
Gall bladder and contents	0.12	—	—	0.37	—	0.26	—	—	0.06	0.08	0.11
Spleen	0.08	0.20	0.07	0.06	0.15	0.07	0.10	0.07	0.14	0.04	0.05
Kidney	0.06	0.08	0.12	0.12	0.21	0.10	0.12	0.10	0.06	0.10	0.08
Head kidney	—	—	—	—	0.21	0.08	0.22	0.27	0.17	0.21	0.30
Central nervous system	0.17	0.27	0.34	0.43	0.44	0.21	0.36	0.41	0.34	0.29	0.31
Variable tissues											
Contents of digestive tract	0.27	0.03	0.61	0.37	0.36	1.04	0.38	0.89	1.50	0.30	0.66
Adipose tissue	—	—	—	—	—	0.06	0.17	1.02	1.61	1.08	1.70
Ovaries	1.01	—	2.48	1.10	—	1.40	—	—	—	0.59	—
Testes	1.01	0.37	—	—	0.71	—	0.53	0.17	0.11	—	0.03
Live weight recovered	97.54	97.58	95.24	92.00	91.62	92.66	91.25	95.08	95.13	95.50	92.32
Total length, mm.	238	213	145	111	171	255	170	134	139	175	162
Weight, grams	153	125.5	44.5	18	68	198	64.6	31.5	38.4	82	71

TABLE 31

Percentage of Total Weight of Stable Tissues Contributed by Each Tissue Dissected from White Crappies and Largemouth Bass

	White Crappie					Largemouth Bass				
	1	2	3	4	5	1	2	3	4	5
Stable tissues										
Scales	5.24	5.35	4.78	4.01	4.29	3.03	3.09	4.90	3.17	5.14
Skin	1.35	3.67	2.20	1.74	1.98	5.62	1.61	4.17	1.69	4.20
Muscle	64.41	66.55	69.61	68.05	71.88	69.00	61.33	64.72	67.53	64.52
Compact bone	13.49	6.52	4.93	6.73	4.93	3.55	12.60	7.45	4.59	7.62
Cancellous bone	3.37	4.95	5.09	4.65	4.26	4.93	7.59	6.66	4.38	6.06
Dorsal fin	1.33	1.20	1.20	1.19	1.53		1.38	0.62	0.83	1.17
Anal fin	1.65	1.61	1.80	1.65	1.74	2.55	0.60	0.48	0.43	0.57
Other fins	2.28	2.10	2.09	2.46	2.09		1.23	1.17	1.42	1.80
Gill filaments	0.65	1.20	1.06	1.48	0.91	0.66	1.15	1.34	5.08	1.92
Gill arches and rakers	1.57	0.84	1.06	1.19	0.86	1.76	2.99	2.18	5.12	1.90
Eyes	1.71	1.91	2.07	2.44	1.98	5.71	0.93	1.14	1.42	0.81
Stomach and pyloric caeca	1.01	1.36	1.38	1.41	1.05	1.93	3.42	2.68	1.56	2.01
Intestine	0.20	0.48	0.60	0.53	0.35	0.26	0.54	0.49	0.51	0.35
Heart	0.10	0.11	0.18	0.19	0.11	0.07	0.10	0.12	0.04	0.11
Liver	1.11	1.11	1.24	1.17	1.21	0.69	0.72	0.73	1.20	0.83
Gall bladder and contents	—	0.15	—	0.21	0.19	—	0.22	0.41	0.16	0.24
Spleen	0.04	0.04	0.16	0.05	0.03	0.12	0.07	0.11	0.02	0.13
Kidney	0.12	0.19	—	0.19	0.16	0.10	0.27	0.18	0.24	0.17
Head kidney	—	0.31	0.20	0.33	0.08	—	—	0.29	0.10	0.32
Central nervous system	0.32	0.35	0.35	0.33	0.37	—	0.16	0.16	0.51	0.13
Variable tissues										
Contents of digestive tract	0.71	1.16	0.57	0.26	0.11	0.26	3.13	0.05	0.49	0.14
Adipose tissue	0	0	0	0	0.19	2.45	0	0	0.02	0.12
Ovaries	1.55	—	—	—	—	—	—	0.91	—	—
Testes	—	0.76	0.31	0.50	0.51	0.10	0.05	—	0.02	0.02
Live weight recovered	97.52	95.21	92.67	90.21	96.44	95.34	95.48	91.05	95.15	85.80
Total length, mm.	160	163	162	157	151	437	317	354	161	441
Weight, grams	52	56	49	47	39	1247	434	536	52	1010

recovered weight of the stable tissues.

A total of 43 individual fish, referable to eight species as follows, were dissected: 10 bluegills, eight black crappies, five white crappies, four largemouth bass, five carp, three bullheads, six redhorse, and one gizzard shad.

The average percentages of the total weight of the stable tissues of each of the eight species, contributed by each of the stable and the variable tissues, are listed in table 28. The data for the percentage of the total weight of the stable tissues, contributed by each of the stable and the variable tissues, for each of the bluegills are listed in table 29, for the black crappies in table 30, for the white crappies and largemouth bass in table 31, for the carp, yellow bullheads, and gizzard shad in table 32, and for the redhorse in table 33.

From these data, several general conclusions may be drawn:

1. Approximately the same percentage of the total body weight was contributed by the scaleless integument of the bullhead (8.1%) as by the combined skin and scales of the black crappie (8.6%) or by the combined skin and scales of the bluegill (8.2%).

2. The percentage of the total weight con-

TABLE 32

PERCENTAGE OF TOTAL WEIGHT OF STABLE TISSUES CONTRIBUTED BY EACH TISSUE DISSECTED FROM CARP, YELLOW BULLHEADS, AND GIZZARD SHAD

	Carp					Yellow Bullhead			Gizzard Shad
	1	2	3	4	5	1	2	3	1
Stable tissues									
Scales	6.11	8.30	7.10	7.20	6.68	—	—	—	6.33
Skin	3.61	2.48	4.18	3.58	2.78	10.43	7.99	5.93	1.16
Muscle	59.70	60.90	62.13	63.14	63.99	56.81	58.44	67.77	70.38
Compact bone	7.40	4.33	4.72	4.30	4.73	9.22	9.30	7.06	3.67
Cancellous bone	7.25	5.97	6.23	5.87	6.29	5.39	5.73	4.94	2.70
Dorsal fin	1.76	1.44	1.21	1.38	1.35	0.97	0.41	0.49	1.00
Anal fin		0.71	0.62	0.71	0.66	1.62	0.83	0.81	
Other fins	1.67	1.99	2.18	2.91	2.67	1.63	1.94	1.87	1.56
Gill filaments	2.15	2.17	2.10	1.71	0.83	2.88	3.47	1.77	2.71
Gill arches and rakers	2.80	1.68	1.71	1.50	1.69	1.68	1.78	1.35	0.83
Eyes	1.11	1.42	1.02	0.95	1.10	0.17	0.19	0.16	1.16
Stomach	—	—	—	—	—	2.87	3.67	2.12	3.68
Intestine	1.37	1.64	1.19	1.22	0.84	1.79	1.99	1.51	1.07
Heart	0.22	0.26	0.25	0.21	0.27	0.12	0.13	0.11	0.21
Liver	3.01	4.40	3.48	3.50	3.88	2.62	2.07	2.06	1.90
Gall bladder and contents	0.65	—	0.46	0.43	0.66	0.24	0.32	0.27	0.37
Spleen	0.09	0.12	0.18	0.11	0.13	0.05	0.02	0.09	0.14
Kidney	0.46	0.85	0.59	0.50	0.54	0.91	1.00	1.02	0.78
Head kidney	—	0.14	0.14	0.15	0.21	0.27	0.41	0.22	0.15
Central nervous system	0.65	1.10	0.51	0.63	0.70	0.33	0.31	0.45	0.22
Variable tissues									
Contents of digestive tract	1.48	1.04	0.79	1.29	1.11	0.34	0.17	0.17	0.74
Adipose tissue	0	0	0	0	0	0.25	0.28	0.28	0
Ovaries	—	—	6.13	—	—	—	0.24	—	2.98
Testes	1.97	0.24	—	3.58	3.10	0.34	—	0.33	—
Live weight recovered	92.47	91.73	91.61	91.94	90.09	90.42	91.24	93.91	92.65
Total length, mm.	239	170	285	257	240	285	293	217	275
Weight, grams	162	56	256	193	157	272	248	125	203

tributed by the combined bony structures varied from species to species, presumably because of differences in structural requirements, and ranged from 6.3 per cent in the gizzard shad to 13.9 per cent in the bullhead.

3. The percentage of the total body weight made up by the muscle tissue was approximately the same for all species. The range of the averages for the species was from 61.0 per cent in the bullhead to 70.4 per cent for the gizzard shad.

4. The relative sizes of the kidneys in all the centrarchids (0.11% to 0.24%) were markedly smaller than those in any of the other species (0.57% to 0.98%).

5. The relative sizes of the livers in all the centrarchids (0.8% to 1.2%) were considerably smaller than those of any of the other species which ranged from 1.9 per cent to 3.7 per cent.

6. The relative weights of the eyes of the centrarchids, which feed largely by sight, were considerably larger (2.0% to 2.3%) than those of any of the other species (0.2% to 1.2%), which do not feed primarily by sight.

Perhaps the most remarkable item indicated by these data is the similarity in the amounts of muscle tissue in the bodies of the different species. Each of the different kinds of fish is quite different in shape, with the exception of the two species of crappies, yet the amount of skeletal muscle in each kind is relatively similar.

TABLE 33

PERCENTAGE OF TOTAL WEIGHT OF STABLE TISSUES CONTRIBUTED BY EACH TISSUE DISSECTED FROM REDHORSE

	Fish No. 1	2	3	4	5	6	7	8
Stable tissues								
Scales	10.48	8.63	8.40	7.28	8.28	8.04	8.04	8.61
Skin	2.60	3.11	2.77	2.69	2.07	2.92	2.38	2.58
Muscle	66.49	70.05	66.88	70.35	66.96	67.75	70.68	68.82
Compact bone	3.84	3.22	4.07	3.53	4.30	4.27	4.11	3.65
Cancellous bone	5.78	4.04	5.27	3.37	4.74	4.51	4.63	5.26
Dorsal fin	0.75	0.66	0.81	0.85	0.75	0.83	0.77	0.86
Anal fin	0.48	0.37	0.52	0.46	0.55	0.53	0.57	0.55
Other fins	1.80	2.17	2.53	2.24	2.44	2.47	1.79	2.06
Gill filaments	1.19	1.33	1.74	1.39	1.57	1.57	1.31	1.70
Gill arches and rakers	0.76	0.68	1.06	0.89	1.45	1.15	1.22	1.22
Eyes	1.15	0.95	1.28	1.02	1.17	1.11	0.95	0.91
Intestine	1.15	0.84	1.28	0.64	1.01	1.03	0.51	0.74
Heart	0.10	0.15	0.09	0.21	0.10	0.13	0.10	0.12
Liver	1.60	2.08	1.90	1.98	2.62	1.80	1.51	1.61
Gall bladder and contents	0.25	0.13	—	0.30	0.38	0.30	0.32	0.21
Spleen	0.10	0.11	0.12	0.07	0.17	0.09	0.07	0.08
Kidney	0.36	0.69	0.47	0.68	0.59	0.61	0.43	0.44
Head kidney	0.34	0.42	0.37	0.40	0.47	0.51	0.33	0.29
Central nervous system	0.32	0.37	0.40	1.65	0.38	0.38	0.28	0.29
Variable tissues								
Contents of digestive tract	1.07	1.11	1.25	0.38	1.12	1.43	0.36	0.91
Adipose tissue	0	0.27	0.20	0.96	0.33	0.26	1.01	1.29
Ovaries	1.51	0.31	—	0.35	—	—	0.66	0.71
Testes	—	—	1.43	—	0.53	1.13	—	—
Live weight recovered	93.84	94.80	94.44	94.65	91.07	90.99	91.45	90.53
Total length, mm.	288	218	287	207	282	296	317	293
Weight, grams	261	107	245	89	236	253	342	314

FOOD HABITS OF SOME FISHES

IN CONJUNCTION WITH studies on the seasonal changes in the accumulation of radiomaterials in the fishes of White Oak Lake, as described elsewhere in this report, it became essential to obtain information on the food habits of these animals. As presumably representative samples of two species of fish, the bluegill and the black crappie, were being dissected each week for radioassay, the contents of the stomach of each individual were used to supply the necessary data. The stomach contents of the fish dissected during 1952 formed the basis for this study. As each fish was dissected, the relative amount of food in the stomach was visually estimated, the stomach contents were removed, placed in a 25-milliliter Erlenmeyer flask, weighed, and preserved in 70 per cent alcohol. From January until May the stomach contents of all fish were kept in preservative, but after May the fresh material was prepared for radioassay and counted. By means of an assay of the samples for gross beta radioactivity, a comparison between the amounts of radioactivity in the stomach contents and those accumulated in the various tissues could be made.

The contents of each stomach were examined through a binocular dissecting microscope, and the various organisms and other food materials were separated out and identified by Mr. W. T. Miller. After all the material was identified, the percentage of the total volume contributed by each kind of food in the sample was estimated. The variety and extremely small size of the various food materials made it impractical to obtain accurate weights for each item. However, in some instances, where the entire contents of the stomach consisted of a single species of organism, the weight of that sample was recorded.

The food habits of the two species of fish under consideration were quite different. The black crappies fed primarily on those macroplankters that live as free-swimming organisms in the pelagic zone of the lake, whereas the bluegills were more omnivorous and generally foraged for food along the littoral zone.

FOOD OF THE BLACK CRAPPIE

The food habits of the black crappies in White Oak Lake were undoubtedly affected by the ecological and climatic conditions that prevailed during the study period. Under different conditions, they might have utilized larger quantities of other foods, even in the presence of large populations of pelagic plankton. Only during periods when there was an apparent shortage of pelagic plankters did the black crappies forage for other kinds of food along the littoral zone. Any decrease in the amounts of pelagic forms in the stomachs examined usually occurred during the winter months. At that time, there was usually an increase in the types of food organisms common to the littoral zone of White Oak Lake.

The contents of the stomachs of 156 black crappies were examined during this study. Of those, 50 were empty. The remaining 106 stomachs ranged from about one-fifth full to full, and in most instances they were at least half full. The average weight of the contents recovered from those stomachs that were considered as full was slightly more than half a gram (0.558 gram). None of these full stomachs seemed to be abnormally distended.

The fish of which the stomachs were sampled ranged in size from 7 to 9 inches in total length. Although these fish were not all of the same year class, it is reasonable to assume that the food requirements of all individuals were similar.

The variety of food materials found in the crappie stomachs is believed to be not so comprehensive as the following list implies. Rather, it is believed that some of the smaller organisms, which were only occasionally present in the stomachs, were picked up accidentally with other food items. The following list includes the names of all organisms and animal materials identified from the stomachs of black crappies in 1952:

Arachnida (pieces of spiders)
Arthropoda (pieces of grasshoppers)
Aquatic Coleoptera
  Gyrinidae (larva)
  Hydrophilidae (adult)
Cladocera

Alonella (adult)
Chydorus (adult)
Daphnia (adult)
Eurycercus (adult)
Moina (adult)
Pseudosida (adult)
Copepoda
Cyclops (adult)
Diaptomus (adult)
Diptera
Chaoborus (larva)
Tendipedidae (larva)
Culicinae (larva)
Ephemeroptera (unidentified larva)
Hemiptera
Corixa (adult)
Hymenoptera (small adult wasp)
Odonata
Anisoptera (larva)
Zygoptera (larva)
Rotifera (unidentified)
Trichoptera (unindentified larva)
Vertebrata (small fish)

In addition to the material listed above, there was frequently some vegetable matter present. Most of those materials were believed to have been ingested accidentally, such as phytoplankton which had been ingested along with the sought-after zooplankters, and pieces of vascular plants or small wood fibers which had either been mistaken for organisms or had been eaten along with the organisms that clung to them. Plant materials included in the following list made up less than 1 per cent of the contents of all the stomachs examined:

Algae
Various filamentous types, chiefly *Oscillatoria*
Diatoms (very rare)
Volvox (found only when this organism was sufficiently abundant to make the lake appear green)
Pieces of vascular plants and seeds
Detritus (pieces of decayed wood and dead leaves, sand, and disintegrated pieces of rock)

The main preference for food exhibited by the black crappie was for planktonic organisms, as indicated by the data listed in table 34. There the percentages of the various food items that were found in the stomachs each month are shown, together with the percentage composition of the diet for the entire year.

Of particular importance in the stomach contents of the black crappie was the occurrence of large numbers of larvae of the phantom midge, *Chaoborus*. These larvae exhibit

TABLE 34

PERCENTAGE OF TOTAL VOLUME MADE UP BY MAJOR GROUPS OF MATERIALS FOUND IN STOMACHS OF BLACK CRAPPIES EACH MONTH DURING 1952, WHITE OAK LAKE, WITH THE PERCENTAGE COMPOSITION OF THE DIET FOR THE ENTIRE YEAR

Month Number of fish	Jan. 4	Feb. 6	Mar. 10	Apr. 12	May 11	June 7	July 14	Aug. 11	Sept. 11	Oct. 11	Nov. 3	Dec. 6	Total 106
Terrestrial insects and spiders	—	0.9	—	—	—	—	0.7	—	2.7	—	—	—	0.4
Aquatic Coleoptera	—	—	—	4.5	—	0.4	—	—	—	—	—	—	0.4
Cladocera	—	—	—	17.3	40.4	0.3	—	2.0	1.2	6.4	14.7	0.2	6.9
Copepoda	49.0	36.7	29.6	0.3	0.2	—	—	0.4	0.5	3.9	30.3	10.3	13.4
Dipterous larvae, *Chaoborus*	26.0	16.0	32.5	61.1	37.4	61.4	82.5	85.9	60.0	15.0	33.0	1.7	42.7
Dipterous larvae, Tendipedidae	22.5	9.6	23.0	11.0	4.2	5.1	0.9	3.4	20.7	39.1	0.3	4.5	12.0
Aquatic Hemiptera, *Corixa*	2.0	31.3	12.4	5.3	7.9	0.9	0.7	—	0.5	0.3	11.7	—	6.1
Other aquatic insect larvae	—	5.0	—	—	—	0.1	0.7	—	—	4.4	—	—	0.8
Fish remains	—	—	2.0	—	0.1	1.7	5.0	—	—	8.6	—	80.8	8.2
Digested animal material	—	—	—	—	6.7	21.9	9.1	7.8	14.1	22.3	10.0	2.5	7.9
Algae and plant material	0.5	0.5	—	—	3.1	0.3	0.2	0.3	0.3	—	—	—	0.4
Detritus and indigestible material	—	—	0.5	0.5	—	7.9	0.2	—	—	—	—	—	0.8

a diurnal movement towards the water surface at night, and apparently they were most vulnerable to predation by the crappies during that nocturnal migration. Frequently the stomachs of the fish contained larvae in a stage just prior to pupation, which indicates that the fish caught them at or near the surface. The time of day when most of these larvae seemed to be caught was early morning. Quite frequently the fish taken from the nets early in the morning had full stomachs.

Larval *Chaoborus* were found in the crappie stomachs every month of the year, and during five separate months, such larvae constituted more than 60 per cent of the total volume. For the entire year, *Chaoborus* larvae made up about 43 per cent of the total contents of the stomachs analyzed and thus constituted the major item in the annual diet of the black crappies in White Oak Lake.

The copepods were grouped together, because the fish showed no preference for any particular species. This group of plankters was the second most abundant group in the contents of the stomachs examined, and made up 13.4 per cent of the annual diet.

Midge larvae of the family Tendipedidae made up 12 per cent of the annual diet of the black crappies in White Oak Lake. These larval forms were numerous in the lake but were usually confined to the littoral zone. They were found on almost any type of submerged material, where they constructed protective cases around themselves. As they were almost constantly squirming, that motion apparently attracted some fish. However, when they were about to pupate, the larvae swam to the surface. These larvae, at this stage of development, were most frequently found in the crappie stomachs.

The cladocerans or water fleas were grouped together in the same manner as the copepods, and this group of animals constituted about 8 per cent of the annual diet. When combined with the copepods, the two groups made up more than 20 per cent of the total annual food found in the stomachs of the black crappies.

Small fish were eaten only occasionally and were probably caught while the crappies foraged in the shallow water, because none of these small fishes were ever found out in the open water of the lake.

Other organisms from the littoral zone that were eaten by the crappies were the aquatic hemipteran *Corixa* and the larval forms of aquatic Coleoptera. Corixids were quite numerous along the littoral zone and made up about 6 per cent of the annual diet during 1952.

FOOD OF THE BLUEGILL

One hundred of the 156 stomachs of the bluegills examined contained identifiable food materials. The stomachs ranged from one-sixth full to full, and only a few were less than half full. The average weight of the contents of those stomachs that were considered full was 0.383 gram, which was approximately two-thirds of that for the black crappie. From all appearances, none of the bluegill stomachs was abnormally distended. The total lengths of the bluegills from which the stomach samples were taken ranged from about 5 to about 7 inches.

The following list of food items taken from the stomachs of bluegills gives the impression that that species of fish will eat almost anything. However, the general scarcity of food organisms in much of the littoral zone where the water was deep enough to be negotiated by fish other than fingerlings indicates that many of the bluegills, particularly the larger individuals, may have been on a near-starvation diet. Such an observation corroborates the data on age and growth which shows that the bluegills in White Oak Lake grew very slowly. The list of the food items follows:

Arachnida (pieces of spiders, water mites)
Hymenoptera (small ants, bees, wasps)
Diptera
- Black flies (terrestrial)
- *Chaoborus* (adult and larva)
- *Tendipes* (adult and larva)

Lepidoptera (butterfly, pieces of moths, caterpillars)
Coleoptera (terrestrial: small beetles, June beetles; aquatic: Haliplidae, adult; Hydrophilidae, adult)
Hemiptera (terrestrial: lace-bug; aquatic: *Corixa*)
Cladocera
- *Alonella*
- *Chydorus*

TABLE 35

PERCENTAGE OF TOTAL VOLUME MADE UP BY MAJOR GROUPS OF MATERIALS FOUND IN STOMACHS OF BLUEGILLS EACH MONTH DURING 1952, WHITE OAK LAKE, WITH THE PERCENTAGE COMPOSITION OF THE DIET FOR THE ENTIRE YEAR

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Number of fish	3	5	10	12	8	10	13	11	12	8	2	6	Total 100
Water mites	—	—	3.0	1.8	—	—	—	—	—	—	—	—	0.4
Terrestrial insects and spiders	1.7	8.0	10.3	12.1	23.5	1.1	0.2	2.2	0.9	22.6	—	1.8	7.0
Aquatic Coleoptera	—	—	5.5	2.2	—	7.0	0.2	—	—	0.1	12.5	1.0	2.4
Cladocera	—	—	0.1	0.2	14.2	—	—	0.3	0.3	—	—	0.8	1.3
Copepoda	—	—	0.2	0.2	0.1	—	—	—	0.8	—	—	—	0.5
Chaoborus (larvae)	—	—	—	4.5	12.5	22.8	32.0	27.9	9.8	—	—	—	9.1
Tendipedidae (larvae)	3.0	23.4	37.2	14.2	23.6	6.2	1.1	2.3	6.3	8.8	10.0	2.2	11.5
Corixa	—	2.0	10.8	2.5	1.2	—	—	—	0.2	—	—	—	1.4
Other aquatic insect larvae	0.7	3.0	0.1	0.7	—	0.1	—	6.0	—	—	1.5	—	1.0
Fish remains	—	0.4	0.1	3.1	1.1	0.6	7.3	0.6	—	6.4	15.0	—	2.9
Digested animal material	—	6.0	3.0	19.1	6.8	21.0	7.6	32.5	12.8	8.1	11.0	48.7	14.7
Filamentous algae	37.6	17.2	—	16.9	4.6	23.1	16.0	7.6	38.2	33.8	48.5	35.0	23.2
Vascular plant materials	48.3	37.0	28.4	19.2	3.1	17.1	27.3	18.7	14.2	12.9	—	8.8	19.6
Detritus and indigestible material	8.7	3.0	1.3	3.2	9.1	1.0	8.2	2.0	17.1	7.4	1.5	1.7	5.2

Daphnia
Copepoda
Cyclops
Odonata
Anisoptera (larva)
Zygoptera (larva)
Ephemeroptera (unidentified larvae)
Trichoptera (unidentified larva)
Pulmonata
Gyraulus
Vertebrata (small fish, eggs)
Bryozoa (statoblasts from *Pectinatella*)
Homogeneous mass of partially digested but unidentifiable animal material
Algae (filamentous)
Spirogyra
Oscillatoria
Volvox (accidental to diet)
Euglena (encysted stages)
Vascular plants (pieces of stems, leaves, and some seeds)
Bryophytes (pieces of moss)
Detritus (pieces of wood, sand, disintegrated rock fragments, and feathers)

There was actually very little preference for any particular kind of food among the bluegills of White Oak Lake, as indicated by the data in table 35. The high percentages of plant remains and algae in the stomachs, which made up about 43 per cent of the annual volume of the stomach contents, may result from these items' having been eaten inadvertently. These forms of vegetation occurred in considerable abundance along the shores of the lake where the bluegills did most of their feeding. The stomachs contained a large variety of organisms, and it was only during the hottest months of the year that the pelagic *Chaoborus* larvae made up an important segment of the diet. At that time of the year, these organisms were very abundant in the deep water, and the relatively high temperatures of the water in the littoral zone may have forced the bluegills to seek the cooler water in the middle of the lake. Larval *Tendipes* were numerous along the shore of the lake and were frequently eaten. That group of midges made up more than 11 per cent of the total annual diet.

The variety of foods eaten by the bluegills in White Oak Lake indicates that they were probably searching for food constantly, and by foraging along the shallow waters of the shoreline they encountered many terrestrial insects which had fallen into the water. Portions of such animals were found in the bluegill stomachs throughout the year and apparently provided an important segment of the annual diet.

RADIOACTIVITY IN THE STOMACH CONTENTS

The stomach contents were prepared for radioassay and counted in the same manner as the other tissues. In those samples that had been preserved in alcohol, that liquid was evaporated off before the digestion with nitric acid was begun.

The amounts of radioactivity in the contents of the stomachs of the black crappies ranged from 105 to 1800 counts per minute per gram, whereas those of the bluegill stomachs ranged from 250 to 14,350. The average for the contents of the full crappie stomachs was 960 counts per minute per gram, whereas that for the full bluegill stomachs was 1250. The differences in the amounts of radioactivity in the stomach contents of the two species of fish is probably traceable to the greater abundance of filamentous algae ingested by the bluegills. Samples of *Oscillatoria* and *Spirogyra* taken from the lake yielded counts as high as 13,000 and 17,000 counts per minute per gram, respectively.

Four bluegill stomachs which contained rather large amounts of radioactivity also contained fairly large quantities of filamentous algae as follows: (1) 40 per cent algae, 5340 counts per minute per gram; (2) 90 per cent algae, 7170 counts per minute per gram; (3) 95 per cent algae, 5400 counts per minute per gram; and (4) 70 per cent algae, 4350 counts per minute per gram. However, the contents that contained the greatest amount of radioactivity contained no algae whatsoever, but contained a group of small round objects similar to cladoceran eggs. Unfortunately there were no parent animals present for purposes of identification.

Samples of *Tendipes* collected from the lake ranged in radioactive content from 150 to 2770 counts per minute per gram, whereas those of *Chaoborus* ranged from 540 to 1340.

None of the samples of stomach contents were analyzed radiochemically. However, analyses of samples of *Chaoborus*, *Tendipes*, and a mixed sample of *Daphnia* and *Diaptomus* were shown to contain several radio-elements, as listed in table 36.

Among the filamentous algae, samples of *Oscillatoria* and *Spirogyra* contained various amounts of different radioelements, as shown by the data in table 37.

TABLE 37

PERCENTAGES OF SOME SELECTED RADIOELEMENTS IN VARIOUS FILAMENTOUS ALGAE AS DETERMINED BY RADIOCHEMICAL ANALYSIS

	Phosphorus	Rare Earths	Strontium	Cesium
Oscillatoria	9.6	32.4	3.4	9.8
Spirogyra	13.6	11.8	7.3	1.0
Spirogyra	42.3	38.3	22.0	—

From these data it is apparent that the majority of the zooplankters analyzed had concentrated radiophosphorus more than any other radioelement, whereas among the filamentous algae, the rare earths were assimilated in amounts almost equal to the radiophosphorus. In addition, there was an accumulation of definite amounts of radiostrontium in all organisms. In another section of this report, it is pointed out that the bony structures of the fish concentrated various amounts of radiomaterials depending on the metabolism of the animals as correlated with temperature changes during the different seasons of the year. Yet in that concentration of radiomaterials, it has been shown

TABLE 36

PERCENTAGES OF SOME SELECTED RADIOELEMENTS IN VARIOUS ZOOPLANKTERS AS DETERMINED BY RADIOCHEMICAL ANALYSIS

	Phosphorus	Rare Earths	Strontium	Cesium
Chaoborus (July, 1952)	95.0	2.0	0.5	1.1
Tendipes (June, 1952)	50.0	6.4	6.6	3.5
Mixed Cladocera (June, 1952)	55.4	25.7	12.0	4.6

that approximately 85 per cent of the radioactivity in the bones was emitted by radiostrontium and only 10 per cent by radiophosphorus, irrespective of the time of the year.

Furthermore, the concentration of radiomaterials in the stomach contents of the two species of fish under consideration indicates that the bluegills contained an average of about 25 per cent more radioactivity than the black crappies. However, as is shown below in detail, the black crappies accumulated about 50 per cent more radiomaterials in the hard parts of the body than did the bluegills. Among the soft tissues, the bluegills concentrated more radiomaterials than the crappies.

DISCUSSION

The food of the black crappie varies considerably according to the age of the fish, the locality in which it lives, and the season of the year.

Pearse (1919) examined the contents of the stomachs of black crappies collected between February and September from Lake Wingra, Wisconsin. He reported the following percentages of the total volume of food ingested by 140 black crappies during the period in question: cladocerans, 33.0; chironomids (all stages), 27.4; amphipods, 10.9; fish, 8.8; Ephemeroptera nymphs, 5.6; copepods, 5.0; Odonata nymphs, 2.3; *Corethra* (*Chaoborus*), 2.1; and the remainder consisted, for the most part, of amphipods, copepods, and cladocerans. During the summer, larvae, pupae, and adult insects were eaten in large quantities, but cladocerans continued to be utilized. In the autumn, cladocerans, small fishes, and chironomid larvae were the chief foods. Of the 276 black crappies of all sizes examined during the study, he found *Corethra* larvae in only 20 stomachs, and they were eaten throughout the year. He did not report the finding of any *Corethra* pupae or adults.

Ewers (1933) studied the contents of 29 black crappie stomachs from individuals 40 to 70 mm. in total length which had been collected during the summer of 1929 from southwestern Lake Erie and vicinity. She found that all the stomachs contained Entomostraca and that that group of animals constituted about 84 per cent of the total volume of food. The majority of the remaining 16 per cent consisted of debris (13.4%), and only one stomach contained fish; that one fish made up 1.4 per cent of the total food for all fishes studied.

Dendy (1946) examined the contents of the stomachs of 79 black crappies collected from Norris Reservoir, Tennessee, during 1943 and 1944 and found that 31 of them were empty. On the basis of the information from the contents of the 48 stomachs that contained food, he reported that the adult black crappies ate aquatic insects (chiefly chaoborines and chironomids) and plankton (*Leptodora*) during the spring and early summer, but relied chiefly on young fish as a main part of the diet in the late summer and early fall.

Reid (1950) studied the food habits of the black crappie in Orange Lake, Florida. Based on a sample of 902 fish taken over a 12-month period from June, 1947, through May, 1948, he found that the gizzard shad formed the most important item in the diet of black crappies except during February, March, and April when the frequency of their occurrence was exceeded or equaled by Malacostraca. In the summer and the fall the crappies fed largely on fishes, and to a lesser extent on Malacostraca, dipterous larvae and pupae, and Entomostraca. *Chaoborus* and chironomids were the most common insect forms; they were taken throughout the year and constituted about 52 per cent of the Diptera consumed. The dipterous pupae and adults occurred in 27 per cent of the stomachs examined.

The food of the bluegill, as reported in the literature, is considerably more varied than that of the black crappie but is not so greatly influenced by the season of the year. In general, the bluegill is much more omnivorous.

Leonard (1940), in his study of the food habits of the bluegill in Ford Lake, Michigan, found that there was a marked difference in the selection of food as related to the size of the fish. The contents of the stomachs of nine fish, which ranged from 18 to 33 mm. in total length, contained the following percentages of food items: Entomostraca, 51.7; Ephemeroptera, 21.7; Diptera, 20.0; and Malacostraca, 6.6. The stomachs of 15 fish, which ranged from 42 to 63 mm. in total length, contained the same items in the following percentages: Entomostraca, 20.9; Ephemeroptera, 8.5; Diptera, 20.7; and Malacostraca, 4.7. In addition, there were Odonata, 13.5 per cent, and Mollusca, 1.9 per cent. The remainder of the contents of those stomachs was largely terrestrial insects. The stomachs of 18 fish, which ranged in total length from 132 to 160 mm., contained 82.4 per cent Odonata, 4.0 per cent annelids, and 2.6 per cent mollusks, with less than 1 per cent of each of Diptera and Trichoptera. The remainder of the contents of those 18 stomachs was terrestrial insects and plant and animal debris.

In a study of the winter food habits of the bluegill in Cedar Lake, Michigan, Moffett and Hunt (1945) found that the fish fed primarily on *Daphnia* and *Bosmina* during the early winter. These two forms were subordinate to ostracods during midwinter but were again highly dominant in late winter. Mayfly nymphs were generally the most numerous insect forms in the stomachs, but in midwinter they were outnumbered by chironomids and *Chaoborus*.

From this information, it is apparent that the annual diet of the black crappies in White Oak Lake was considerably different from that in other waters. In White Oak Lake, the phantom midge, *Chaoborus*, made up 43 per cent of the annual diet, whereas in other waters it was not a preferred food. However, it may be that *Chaoborus* is a preferred food and the numbers in White Oak Lake were so enormous that its presence in the diet masked out the other foods that were more numerous elsewhere. Also, in White Oak Lake, fish made up only a very small portion of the diet, whereas in all other studies they generally constituted a major portion.

So far as the food of the bluegill is concerned, it is probably not much different in White Oak Lake than in other waters. Bluegills are apparently omnivorous and will eat almost anything they happen to encounter.

ACCUMULATION OF RADIOMATERIALS BY FISHES

ONE OF THE PRIMARY FUNCTIONS of this study was the determination of the amounts and kinds of radioactive substances accumulated by the fishes of White Oak Lake during their normal life processes. Accordingly a program of sampling the different tissues of individuals of the various species of fish present in the lake was set up to show which tissues concentrated the greatest amounts of such materials and which radioelements they concentrated.

MATERIALS AND METHODS

All fishes used in this study were caught in hoop nets set in the same location at netting station 4 (fig. 1). Whenever the net was lifted, the fish to be used for radioassay were selected so that individuals of the different sizes of the several species under consideration would be sampled. The fish were removed from the net, placed in a bucket of lake water, and taken to the laboratory.

Each animal was removed from the bucket, killed, and dissected so that samples of the various tissues could be taken for radioassay. As the samples were taken, they were placed in glass-stoppered Erlenmeyer flasks of 25-milliliter capacity which had been weighed previously. The stopper was then inserted so that drying out of the tissues would be held to a minimum. Whenever possible, a sample of at least 0.5 gram in weight was used. Samples of the tissues were taken as follows:

SCALES: The fish was wiped clean with a fresh paper towel and the scales, together with the attached epidermal tissue, were removed from one side of the body. No effort was made to clean each individual scale. If the fish was relatively large, the sample of scales usually weighed more than a gram.

SKIN: After all the scales had been removed from one side of the fish, the skin of that entire side, including the dermis and the remaining epidermis, was peeled away from the flesh. It was then scraped clean of all attached tissue.

MUSCLE: The sample of flesh was usually taken from the dorsolateral area immediately posterior to the head. That area is free from bones and is easily removed. The sample of muscle tissue usually weighed more than a gram.

BONE: For purposes of this study, the bones of the fish were separated into two categories: compact bone and cancellous bone. The samples of compact bone usually consisted of both cleithra, about 10 ribs, and some bones of the opercular series. These bones were cleaned of flesh and wiped off with facial tissue. The samples of cancellous bone usually included the bodies of all the vertebrae from which all the processes and attached flesh had been removed.

FINS: The fins were separated into three categories: the dorsal fin and attachments, the anal fin and attachments, and the entire pectoral, pelvic, and caudal fins. The entire dorsal fin, both the spiny-rayed and soft-rayed portions, together with the bones for attachment to the vertebral column, was scraped clean of attached muscle and wiped with facial tissue. No attempt was made to remove the skin that covered the exposed parts of the fin. The anal fin was removed in much the same manner as the dorsal fin, and the entire appendage was used as the sample. Preliminary assay indicated that the exposed portions of the pectoral, pelvic, and caudal fins accumulated approximately the same amount of radiomaterials. Accordingly those fins were excised at their bases, wiped clean of any attached scales and moisture, and only the exposed portions were used as the samples.

GILLS: The gill structures were separated into two categories: the gill filaments, and the gill arches together with the covering and gill rakers. In the sample for gill filaments, all the filaments were removed and blotted free of excess moisture. In the sample for gill arches and rakers, all arches and rakers from both sides were removed and blotted free of excess moisture. None of the median bones were included in the samples.

EYES: The samples included both entire eyeballs, exclusive of the attached muscles and nerves.

STOMACH AND PYLORIC CAECA: The stomach was excised at its anterior and posterior ends, and all contents were removed. The attached caeca were left intact, together with their contents.

INTESTINE: The entire intestine from the posterior end of the stomach to the anus was excised and separated from its contents and any attached fat. As the carp and redhorse had no well-defined stomach, the entire gut, exclusive of its contents, was used as the sample.

HEART: The entire heart, including the conus arteriosus and the sinus venosus, free of any blood was used.

LIVER: The entire liver exclusive of the gall bladder.

GALL BLADDER AND CONTENTS: The gall bladder and its contents free from any other tissue.

SPLEEN: The entire spleen.

KIDNEY: The entire kidneys on both sides including the ducts.

HEAD KIDNEY OR PRONEPHROS: The entire head kidney on both sides.

CENTRAL NERVOUS SYSTEM: The entire brain and spinal cord exclusive of the protective sheaths.

GONADS: Whenever feasible, both ovaries or both testes were included in the sample. In instances where the ovaries were too large for both to be included, a sample more than 1 gram in weight was used.

CONTENTS OF DIGESTIVE TRACT: Early in the study, the contents of the stomach were combined with those of the intestine. After the first week in May, 1952, the contents of the stomach and the contents of the intestine were assayed separately.

FAT: In those fish in which there was enough abdominal fat to afford an adequate sample, that sample was taken. Radioassay of the samples indicated that little or no radioactivity was accumulated in that tissue, and after May 1, 1952, it was no longer sampled.

The methods used in the preparation of the samples for radioassay are described above. As the entire sample prepared for radioassay was not used in the counting procedure, the remaining portion of the solution of each tissue from each species of fish was composited with the remaining portions of solutions of the same tissue from other fish of the same species. For example, the unused portions of all samples of bluegill scales were placed in a single bottle, accumulated for a period of two or three months, and then analyzed. There was no need for immediate analysis following radioassay, because preliminary analyses had shown that well over 90 per cent of the radioactivity present was emitted by radionuclides with relatively long physical half lives. Furthermore, it was found through preliminary analyses that more than 90 per cent of the radiomaterials in the fish were radioactive isotopes of strontium, the rare earths, cesium, and ruthenium. Consequently analyses were made only for those elements.

SEASONAL CHANGES IN THE ACCUMULATION OF RADIOMATERIALS BY FISHES

During the winter of 1950–1951, preliminary radioassays were made on individual fish of each species known to be present in White Oak Lake. Many of these same fish had been used in the determination of the percentages of the total body weight contributed by the various tissues, and had also served as the basis in the perfecting of the method of radioassay. Similar radioassay of a few fishes during the following summer revealed that these fish had accumulated considerably greater amounts of radioactivity than fish of the same species that had been assayed during the preceding winter.

In the light of these preliminary findings, a year-round study was inaugurated to determine whether or not there were any seasonal differences in the amounts of radiomaterials accumulated in the fish. Accordingly, three black crappies and three bluegills were dissected each week from September, 1951, until January, 1953. These two species were selected for study because they were abundant in the lake and were easily caught in hoop nets. All these dissections were made by either Mr. W. T. Miller or the writer in order to minimize any discrepancies that might have arisen from individual techniques.

TABLE 38

Amounts of Radioactivity (in Counts per Minute per Gram of Tissue) Found in Different Tissues of Individual Black Crappies from White Oak Lake

Date	Fish Number	Scales	Skin	Muscle	Compact Bone	Cancellous Bone	Dorsal Fin	Anal Fin	Other Fins	Gill Filaments	Gill Arches and Rakers
1950											
11/7	1	2890	240	170	2660	1460	2240		1680	30	600
11/7	2	2510	180	120	2460	1530	—	1550	—	220	1040
11/27	3	2640	110	120	1700	1530	1460	1510	1360	—	1250
11/23	4	3540	220	200	3020	2350	2250	2890	2490	530	
12/6	5	2020	120	45	2620	—	1760	1640	2020	340	1360
1951											
1/25	6	1770	105	150	2080	1370	1370	1290	1330	120	850
2/7	7	1500	30	30	2690	1220	1200	1040	1280	5	230
7/13	8	5770	310	200	10790	4020	4175	4110	5860	520	4130
7/24	9	4610	175	170	6450	3740	3200	2780	3930	260	2730
7/25	10	3200	95	100	3620	2540	2160	1740	2070	100	1710
7/25	11	4570	200	70	3470	2730	1980	1870	2290	180	1620
8/10	12	3230	70	70	4330	2590	1290	1600	2460	—	2160
8/12	13	4580	90	80	4650	2630	2630	2430	2530	240	3220
8/22	14	2930	140	100	5050	2510	1310	2050	2600	160	2420
8/22	15	4160	15	140	7850	3390	3040	3520	4200	300	3600
8/23	16	4620	260	120	8410	2290	3160	2850	2975	150	3460
8/24	17	2720	150	40	4900	1670	1460	1580	2580	150	2020
8/31	18	4970	25	70	6990	2420	2410	2160	3720	200	2770
8/31	19	4380	220	50	7420	2980	2460	2360	2930	170	2700
9/5	20	4370	160	90	6600	3090	2830	2960	3190	210	2250
9/5	21	4100	190	55	6000	2690	2550	1970	2890	140	2340
9/6	22	3080	95	40	4970	1230	1780	1530	2490	110	2030
9/6	23	3760	130	60	4980	2770	2060	1460	2400	175	2470
9/11	24	2900	170	60	6420	2500	2000	1500	1900	110	2070
9/19	25	3360	100	30	5820	2130	1070	2030	2050	110	1970
9/19	26	3340	220	50	4890	2250	1730	1650	2640	150	2170
9/20	27	3070	—	50	4670	2190	1390	1290	2060	70	1680
9/21	28	2910	160	80	5120	2350	1220	1500	1700	130	1900
9/26	29	3340	60	90	5630	1930	1740	1490	1780	80	1960
9/26	30	3670	150	100	5910	2870	1350	1860	1900	60	2280
9/27	31	3600	50	60	4590	2520	2110	1770	2490	50	2320
10/1	32	3370	180	80	6360	2240	1880	1230	3190	190	2460
10/4	33	3940	160	40	5640	2970	1580	1970	2000	200	2390
10/4	34	4360	160	90	6520	3190	2100	2340	2890	260	2520
10/9	35	4840	170	30	7750	3480	2680	2390	3320	400	3350
10/10	36	4020	200	90	6370	2900	2780	2830	3160	370	880
10/10	37	6570	340	270	10780	4530	3340	2680	4220	500	3900
10/10	38	5400	170	120	10240	4140	2770	2620	4300	410	3010
10/15	39	4230	—	240	8590	3630	3340	2140	3280	430	3670
10/16	40	5640	230	210	—	3540	2780	1910	4390	650	6040
10/18	41	3580	210	160	5600	3140	1670	2180	2610	470	2600
10/24	42	5060	80	120	8320	3600	2270	1690	3440	370	3100
10/24	43	4360	240	230	7720	3870	3210	2670	4310	730	5620
10/26	44	4020	2060	300	12760	5360	3960	3540	8370	650	4340
10/30	45	5100	440	330	9190	4370	2750	2650	4400	720	5890
10/31	46	2790	240	140	5640	2890	1850	1960	3120	360	2420
11/1	47	4980	300	240	8570	3700	1980	2300	3460	440	2760
11/6	48	4350	250	260	8510	3260	2360	2630	3460	510	3320
11/6	49	4490	220	210	7830	3130	1840	1980	3080	520	2660
11/7	50	3400	130	150	7070	3820	3280	1920	2170	410	2500
11/13	51	3790	120	80	5220	2540	2060	2170	1860	350	2220
11/13	52	4620	200	320	7370	4360	1870	2280	3220	420	2860
11/14	53	3680	110	140	5500	2780	1670	1630	2270	270	1680
11/20	54	3510	100	30	4770	2830	1820	1890	2350	240	1630
11/20	55	4010	90	70	6440	2900	2320	2350	1900	290	2540

Date	Fish Number	Eyes	Stomach and Pyloric Caeca	Intestine	Heart	Liver	Gall Bladder and Contents	Spleen	Kidney	Head Kidney	Central Nervous System	Contents of Digestive Tract	Adipose Tissue/or Stomach Contents[a]	Ovaries	Testes[b]
1950															
11/7	1	75	210	420	520	300	210	530	860	—	190	860	—	360	—
11/7	2	100	260	390	100	390	—	340	280	—	170	130	—	—	290
11/27	3	75	320	330	310	340	—	1100	260	—	140	410	—	200	—
11/23	4	150	250	570	440	770	260	600	790	—	230	300	—	400	—
12/6	5	80	280	420	—	340	—	160	170	280	70	950	—	—	280
1951															
1/25	6	75	65	120	130	110	45	45	280	200	110	20	90	130	—
2/7	7	—	75	30	290	55	—	30	180	130	5	80	—	—	—
7/13	8	200	340	610	—	530	—	590	140	640	200	630	140	—	510
7/24	9	170	410	230	550	670	480	290	—	450	190	380	90	—	860
7/25	10	70	210	—	400	380	—	600	250	180	140	260	70	50	—
7/25	11	140	220	140	280	340	250	—	380	150	380	330	80	—	200
8/10	12	120	190	170	250	380	430	1240	130	370	190	240	90	250	—
8/12	13	120	230	490	230	360	—	480	410	70	130	270	—	—	110
8/22	14	140	220	260	150	410	160	700	220	210	100	540	30	180	—
8/22	15	140	200	150	—	530	—	—	—	120	60	310	50	—	380
8/23	16	120	250	440	280	370	1090	—	540	230	200	270	120	—	390
8/24	17	80	130	430	—	260	290	510	590	170	180	250	70	130	—
8/31	18	150	220	80	230	610	250	460	240	610	210	310	10	200	—
8/31	19	130	240	200	—	510	—	—	490	250	330	290	10	—	560
9/5	20	100	210	90	360	580	1330	200	—	260	400	220	20	—	300
9/5	21	120	220	450	300	450	—	210	980	50	190	320	20	—	120
9/6	22	90	230	250	50	390	—	—	—	180	170	320	—	200	—
9/6	23	80	200	110	20	460	—	290	470	110	310	320	10	—	—
9/11	24	110	110	440	340	430	240	200	30	—	340	210	30	—	290
9/19	25	100	150	310	280	320	—	—	—	100	20	190	20	—	350
9/19	26	80	110	260	710	470	—	60	310	280	190	220	60	120	—
9/20	27	60	400	200	30	250	—	—	—	—	100	550	20	80	—
9/21	28	60	160	80	560	270	610	300	180	200	40	1000	50	—	190
9/26	29	100	90	140	330	400	100	50	40	180	100	—	30	130	—
9/26	30	60	160	110	—	500	310	620	—	300	190	300	2	—	350
9/27	31	110	230	210	530	480	300	1250	160	270	230	260	40	—	310
10/1	32	100	260	20	300	450	—	280	—	190	150	630	4	150	—
10/4	33	100	270	400	340	770	310	—	630	350	130	970	30	—	280
10/4	34	100	390	380	60	740	230	150	570	260	410	710	60	—	290
10/9	35	160	540	720	—	980	—	150	140	290	350	750	40	—	890
10/10	36	160	460	580	540	940	790	370	1230	460	—	1210	40	340	—
10/10	37	220	790	830	480	1180	190	430	160	220	470	1040	160	410	—
10/10	38	170	630	480	100	1040	130	530	1240	500	360	1380	20	440	—
10/15	39	180	940	320	750	1380	430	660	410	650	360	1560	100	—	730
10/16	40	250	910	—	1150	1750	550	2110	1020	860	260	1550	170	—	990
10/18	41	150	790	820	480	880	550	430	750	720	530	1560	140	400	—
10/24	42	80	770	—	700	790	620	200	600	1920	340	1010	190	600	—
10/24	43	250	890	670	680	1290	550	1070	960	790	440	880	140	500	—
10/26	44	310	1300	10140	7560	1480	20	8670	—	1290	3730	7540	110	1840	—
10/30	45	240	990	1280	1090	970	420	1070	1000	1150	510	1090	780	—	1040
10/31	46	140	610	470	450	670	—	580	320	590	200	650	270	370	—
11/1	47	200	860	1220	7710	710	90	1010	40	720	220	1440	180	—	600
11/6	48	120	850	11300	820	880	770	1020	1000	810	430	750	150	810	—
11/6	49	210	650	1270	740	720	2060	1480	850	730	500	830	240	—	610
11/7	50	160	600	710	590	570	190	710	430	—	340	450	110	890	—
11/13	51	140	410	520	440	610	160	480	370	480	270	290	30	—	440
11/13	52	130	670	300	350	520	—	100	560	650	480	1220	150	400	—
11/14	53	90	380	460	180	470	270	440	400	390	260	380	50	250	—
11/20	54	100	500	560	70	410	—	260	390	450	320	—	70	200	—
11/20	55	150	420	300	120	490	80	120	510	360	180	—	110	—	340

TABLE 38—(*continued*)

Date	Fish Number	Scales	Skin	Muscle	Compact Bone	Cancellous Bone	Dorsal Fin	Anal Fin	Other Fins	Gill Filaments	Gill Arches and Rakers	Eyes	Stomach and Pyloric Caeca	Intestine	Heart	Liver	Gall Bladder and Contents	Spleen	Kidney	Head Kidney	Central Nervous System	Contents of Digestive Tract	Adipose Tissue/or Stomach Contents[a]	Ovaries	Testes
11/21	56	3880	140	130	5550	2560	2420	2350	2810	250	2140	150	720	810	350	560	—	40	570	660	340	1300	100	370	—
11/27	57	3050	90	—	4870	2250	1480	1560	1780	160	1850	100	400	540	260	410	70	250	160	240	180	660	40	300	—
11/28	58	3010	100	110	5160	2320	1510	1600	1910	190	2070	100	330	340	500	420	—	50	240	170	200	510	30	—	290
11/28	59	3610	150	110	7170	3380	2160	2200	2530	260	2180	140	460	710	390	690	800	640	170	360	170	680	100	350	—
12/5	60	3080	70	90	5260	2420	1760	1810	2020	200	1940	100	480	400	230	450	20	100	310	190	100	440	100	290	—
12/6	61	3030	40	70	5620	2760	1580	1740	1470	110	1780	80	110	230	260	240	90	300	220	120	90	210	40	—	150
12/7	62	2620	60	80	5420	2670	1640	1740	1810	110	1550	80	150	260	—	280	130	510	330	190	80	190	70	160	—
12/11	63	2960	70	50	5350	2590	1760	1980	2180	130	1520	90	250	240	180	350	230	370	120	130	90	790	—	—	160
12/12	64	—	150	—	6140	2720	1660	1950	2750	180	2180	110	550	370	200	—	50	490	130	200	160	890	60	—	260
12/12	65	3300	60	50	5530	2940	1610	1320	2060	140	1780	90	360	290	370	460	540	300	200	100	90	760	50	—	150
12/18	66	3220	40	80	6160	3250	1880	2150	2400	220	2100	110	800	510	70	530	340	—	140	300	90	2240	110	—	120
12/18	67	3600	20	50	6040	3050	1860	1960	2390	160	1940	80	690	480	—	430	—	—	270	100	160	1970	160	150	—
12/19	68	3100	60	50	5890	2600	1390	1850	2250	110	1820	70	360	350	120	470	—	90	490	190	180	830	60	—	100
12/27	69	3180	100	80	5540	2790	1880	1990	2040	120	1810	100	550	310	40	440	200	230	10	120	40	230	30	200	—
12/28	70	2480	30	30	3960	2400	1800	1770	1680	70	1340	50	160	200	100	190	70	—	160	80	90	180	40	90	—
12/29	71	1960	50	20	4060	2340	1750	1400	1670	90	1820	60	110	200	60	350	120	80	100	100	25	220	60	—	120
1952																									
1/3	72	2740	60	30	4130	2240	1270	1460	1650	80	1530	50	100	25	180	240	100	90	430	130	40	130	4	—	100
1/4	73	3230	40	50	5970	2600	1570	1700	2400	100	1720	60	270	300	40	610	25	—	—	—	20	300	90	—	120
1/5	74	2940	40	40	3440	1460	950	1060	610	80	930	50	90	150	150	70	240	50	100	60	70	280	50	70	—
1/8	75	2690	100	40	5640	1500	1470	1330	1860	100	1090	90	270	290	150	200	30	210	130	110	120	380	50	160	—
1/8	76	2440	20	20	3540	1910	1470	1550	1830	50	1100	50	120	140	220	180	130	240	60	70	110	30	20	110	—
1/8	77	2450	—	30	4890	3130	1680	1750	1930	110	1090	70	220	—	130	410	210	—	410	90	230	80	30	—	130
1/15	78	3040	10	20	5590	2090	1780	1770	2310	100	1910	60	210	250	160	130	260	—	60	160	110	590	—	110	—
1/15	79	4600	110	40	4200	2120	1420	1260	1760	40	1240	60	70	—	280	170	—	10	270	120	80	80	40	100	—
1/16	80	3150	50	30	4200	2490	1680	1640	2170	170	1620	70	240	230	—	510	270	90	440	260	180	570	250	—	70
1/22	81	2990	30	40	5350	2680	1790	1760	2300	90	1510	60	150	280	510	310	310	320	—	330	60	300	120	110	—
1/23	82	3000	80	40	5700	2040	1890	1350	1760	30	1670	60	130	300	70	250	150	400	130	130	130	580	90	80	—
1/23	83	3190	50	40	5950	1550	1530	1640	1300	60	1610	60	90	—	100	350	—	70	—	70	20	340	—	—	90
1/29	84	3150	80	50	5740	2800	2030	1940	1750	110	1190	50	110	180	420	130	120	—	40	90	—	130	25	140	—
1/29	85	2830	110	40	5650	2720	2090	1920	2150	80	1700	60	270	170	110	470	1180	—	—	5	140	810	120	—	90
1/30	86	2570	30	20	4770	2210	1670	1620	1960	50	1300	40	90	110	180	110	—	60	20	20	—	260	130	70	—
2/5	87	2560	2	30	2640	1290	1150	1530	1640	60	840	10	50	90	—	40	15	—	80	100	130	60	15	50	—
2/5	88	3200	20	80	5690	2450	1880	1830	2200	60	1840	—	320	400	240	370	90	—	150	260	70	630	—	140	—
2/5	89	2630	20	20	4520	2020	1410	1290	1960	50	1290	70	70	—	0	370	110	220	160	80	110	100	20	—	40
2/12	90	2630	30	30	4570	2150	1500	1600	1930	50	1100	60	70	160	210	40	520	150	40	70	70	170	30	50	—
2/12	91	3460	70	40	5490	2290	1830	1780	2320	30	1670	80	80	310	60	410	40	290	190	100	20	—	10	—	30
2/12	92	2800	10	20	5150	1980	1440	1520	2020	80	1540	70	180	20	360	190	190	—	—	70	190	110	70	90	—
2/19	93	2880	70	40	4580	2290	1490	1740	1740	20	1360	50	80	250	—	90	30	160	220	110	130	300	10	80	—
2/20	94	2730	10	20	4090	1810	1460	1540	1670	60	1220	30	80	30	—	90	30	180	80	130	70	230	30	60	—
2/21	95	2940	40	40	4880	2430	1660	1640	1750	100	1390	50	170	280	220	120	—	—	110	110	140	250	10	60	—
2/27	96	2900	70	30	4700	2180	1690	1470	1830	70	1500	30	150	280	240	430	650	40	210	80	120	480	20	—	30
2/29	97	2630	20	20	4230	1970	1200	1370	1650	60	1180	50	50	60	110	200	30	—	50	60	100	60	—	—	10
3/1	98	2630	30	30	6740	2450	1640	1710	1910	80	1950	70	160	260	140	500	210	540	10	40	130	390	120	—	60
3/4	99	2600	70	50	4690	2300	1500	1500	1680	70	1380	60	130	90	360	160	—	270	220	60	40	180	50	90	—
3/4	100	2930	120	40	4740	2320	1660	1840	2180	50	1650	60	10	80	200	110	220	50	250	60	10	120	—	80	—
3/5	101	3410	40	20	5220	2550	1890	1820	2140	40	1270	40	90	50	40	330	—	30	320	60	180	—	70	—	10
3/11	102	2550	10	30	5980	1750	1210	1240	1800	40	1450	90	190	140	470	340	350	460	30	90	120	500	110	—	50
3/11	103	3340	30	20	5690	1730	1860	1780	2080	80	1700	60	—	200	100	120	180	550	230	10	50	300	230	90	—
3/11	104	2730	60	20	4490	2390	1360	1500	1920	40	1300	50	80	30	60	230	200	300	520	110	170	390	140	40	—
3/19	105	2730	20	20	4550	2000	1640	1670	1800	60	1540	30	60	100	—	470	40	—	30	80	—	110	—	—	30
3/19	106	2380	40	30	4690	2210	1840	1640	1490	70	1680	80	90	30	450	350	—	—	130	—	100	190	130	—	40
3/20	107	4950	70	40	5320	1500	1500	1670	2100	40	1680	60	90	170	400	90	—	—	—	130	190	220	60	70	—

3/24	108	2220	50	20	4910	2460	1970	1970	2270	60	1580	30	90	70	10	380	20	440	140	90	130	640	210	—	20
3/24	109	3220	40	20	5090	2610	1800	1890	2240	110	1830	70	230	310	420	260	200	250	90	110	150	450	150	140	—
3/24	110	3210	70	40	5930	2730	2070	1930	2270	50	1580	50	130	160	190	280	140	730	—	70	180	270	220	120	—
3/31	111	3270	60	20	5650	2530	1990	1870	2540	30	1520	60	180	370	—	620	230	320	140	70	100	290	490	—	70
4/2	112	1400	10	20	3720	3020	1300	1850	1670	70	1610	60	50	170	—	400	—	—	70	—	90	510	70	—	40
4/2	113	3100	120	50	5900	1900	2440	2510	2360	120	1950	70	360	530	250	760	130	—	100	60	90	430	—	—	110
4/8	114	4360	20	20	4300	2230	1520	1610	1830	40	1380	50	140	270	60	360	—	100	150	—	60	170	—	—	20
4/8	115	2660	20	30	5400	3060	2360	2390	2230	100	1780	90	230	60	130	610	260	240	330	—	10	380	—	—	80
4/8	116	2900	40	30	4830	2620	840	1680	1500	90	1650	60	220	280	250	630	210	170	—	—	30	330	—	—	40
4/14	117	2150	110	10	4480	2560	1720	1610	1530	160	1740	60	280	390	—	600	210	490	80	—	110	830	—	—	60
4/14	118	2550	90	60	4390	2200	1810	1830	1990	190	1560	100	660	700	—	190	—	60	290	—	150	1540	—	200	—
4/15	119	2260	80	50	4690	2570	1980	1850	2530	200	1850	90	660	650	80	420	—	460	300	—	170	1310	—	230	—
4/22	120	2730	90	90	3970	2490	1570	1690	1710	40	1060	100	340	480	170	400	190	—	150	—	70	—	—	190	—
4/22	121	2600	90	50	4740	2230	1920	1720	2260	150	1480	60	380	240	—	480	—	520	590	—	110	720	—	230	—
4/22	122	3520	90	60	6050	1740	1880	2100	2760	130	1810	110	570	—	20	630	180	—	120	—	80	1100	—	330	—
4/28	123	3570	190	150	5400	2380	2220	1500	2600	370	2430	90	940	750	490	980	10	620	580	—	80	1360	—	660	—
4/30	124	3530	—	100	5630	2840	2010	1570	2740	320	2140	140	840	1040	370	1060	—	—	350	—	220	1370	—	780	—
4/30	125	3400	80	100	5380	2920	2300	2260	1720	350	2310	110	710	370	380	990	700	—	180	—	170	1310	—	730	—
5/6	126	3700	250	150	6210	3230	2510	2440	3200	650	2760	170	1070	1260	160	1420	240	780	680	—	260	1950	—	1400	—
5/7	127	4580	220	200	6830	3060	2250	2610	3430	540	2960	210	1180	1610	1390	1500	490	1480	1130	—	430	2180	—	—	450
5/7	128	3870	150	110	5860	3240	2310	2170	2990	340	2430	130	870	1170	—	1030	10	—	850	—	140	1640	—	—	190
5/13	129	3300	110	70	4940	2900	1860	1410	2240	320	2200	100	680	660	250	850	80	490	560	—	250	1510	—	—	330
5/13	130	2940	220	150	6560	2960	2850	2540	2240	560	3030	140	1370	1420	560	1660	610	720	780	—	350	3120	—	—	630
5/13	131	3980	180	100	6830	3640	2600	2550	3020	370	2850	110	710	920	240	1100	700	820	390	310	210	2140	—	—	340
5/19	132	4140	320	260	7080	3480	2640	1430	3580	740	3490	240	980	890	740	1400	—	820	1230	1080	330	1150	—	1650	—
5/19	133	3290	280	200	6740	3310	2930	2650	3680	730	2980	200	810	790	670	1520	500	1070	1010	1010	330	1270	—	1180	—
5/19	134	3020	90	40	8310	2290	2210	2000	2440	210	1730	60	490	460	—	1140	200	—	520	270	140	4390	380	—	240
5/26	135	3370	130	100	4530	2730	1670	1820	2150	440	2410	130	620	500	1040	950	300	710	650	590	330	1050	360	950	—
5/26	136	9710	410	460	16840	5690	5310	5700	7620	770	4870	340	950	920	950	1850	590	1060	950	1280	610	—	200	—	910
5/26	137	3950	120	140	5290	3230	2520	2090	3420	500	2540	180	760	790	680	1060	—	390	500	450	410	—	560	1120	—
6/3	138	4540	240	200	7440	4090	2800	2940	4140	540	3180	220	740	690	480	1130	—	720	1020	1050	440	—	580	880	—
6/3	139	5250	320	230	9130	5820	4090	4010	2550	550	4580	190	640	820	580	1230	360	660	880	1110	550	—	—	1140	—
6/3	140	6180	390	180	10740	5900	4280	3800	4850	610	4550	250	660	940	610	1490	—	680	850	950	510	—	—	—	320
6/10	141	5470	270	270	8770	4920	3630	2850	5190	560	3740	240	800	880	310	1300	680	1010	800	750	400	1080	500	—	630
6/10	142	5920	260	290	9080	5580	4300	3750	6020	710	4260	270	900	840	890	1830	1390	1040	330	740	490	1800	740	—	940
6/10	143	6350	330	310	9970	5540	3800	3730	5810	580	4520	270	690	910	620	1600	430	590	540	620	710	1150	—	—	820
6/17	144	4040	150	120	5530	2780	2260	2340	2420	370	2400	110	500	470	370	670	30	10	270	480	140	1030	710	270	—
6/17	145	5770	210	180	10130	5850	4820	3770	4870	540	4610	180	620	580	470	1170	—	560	350	790	340	—	—	520	—
6/17	146	10520	340	370	19520	10030	7670	7780	8580	510	6200	280	660	740	890	1650	1240	70	270	500	640	590	1050	—	360
6/24	147	4700	100	100	8080	4510	3510	2490	4150	390	3660	170	440	360	1150	1010	140	160	490	510	240	370	630	410	—
6/24	148	5170	130	200	10130	4820	3430	3670	5360	380	4780	230	210	530	1210	1130	220	—	670	360	310	790	820	—	540
6/25	149	5240	110	190	9460	5510	3320	3810	5510	530	5250	200	640	620	1810	1310	300	—	590	580	420	720	810	—	970
7/1	150	7210	200	170	9810	5460	2730	4460	5410	520	4770	200	700	580	780	1060	260	740	640	410	510	780	—	630	—
7/1	151	6910	280	220	12830	7050	5280	5040	5380	590	6240	270	730	730	540	1060	550	640	970	870	590	820	980	—	—
7/1	152	5050	200	220	8830	7350	4320	3830	4290	560	5070	220	770	810	510	1300	650	720	1000	840	370	810	470	—	—
7/1	152A	10950	180	200	18420	9560	5840	6890	8300	470	6640	130	510	940	490	1860	410	580	270	700	170	1210	1300	—	—
7/8	153	4600	160	150	7950	4800	3400	2840	3940	500	4590	170	850	780	870	1170	640	610	860	710	400	830	920	—	—
7/8	154	7410	280	250	10300	5750	4270	3920	5570	550	5440	250	740	1040	1030	990	540	560	1300	1020	1400	880	750	630	—
7/8	155	5740	260	125	11550	6150	2880	4410	—	480	4980	—	250	580	790	940	400	440	680	580	400	—	910	580	—
7/15	156	5690	380	350	7930	4350	3160	3000	2770	450	4090	310	600	720	1060	1330	890	900	660	810	550	1420	620	—	—
7/15	157	6440	420	130	9730	3350	4360	4950	5520	600	5100	250	830	940	710	1530	490	1280	800	1170	550	—	—	—	—
7/15	158	5240	200	100	10000	6650	4560	4660	5690	440	5700	220	600	540	470	1130	570	400	610	570	450	940	1430	590	—
7/22	159	6970	400	270	9660	2440	3630	2630	5500	920	4970	320	1440	1490	620	1580	220	1230	800	970	480	1710	1440	—	—
7/22	160	8320	360	310	13670	7390	4940	5740	5800	940	5560	340	1130	1480	1310	1660	520	1610	810	970	510	1440	1510	—	—
7/22	161	12840	680	450	13030	10580	6760	6300	9340	1080	6480	430	1560	1660	1280	1700	450	1010	480	1000	670	1600	1080	940	—
7/29	162	8670	500	290	11270	6960	5790	5460	7580	770	6230	370	1090	1260	790	1620	590	980	540	560	690	1600	1290	920	—
7/29	163	12160	540	360	18720	9180	8030	7360	9890	980	8000	440	1200	1500	980	1870	950	1160	750	840	770	1340	1450	—	—
7/30	164	7820	380	330	13220	7660	2700	5880	6860	950	6970	360	1200	1200	740	1740	380	770	830	1280	630	1660	1700	900	—
8/5	165	8320	260	230	11000	6150	5060	5150	5180	570	4870	310	630	1070	700	1530	490	1130	380	1940	500	1620	1240	—	1130
8/5	166	8790	240	270	12080	6390	4470	3970	6070	560	5580	310	770	640	530	1500	630	940	610	1090	530	1080	1050	—	920
8/5	167	11080	290	360	16400	9140	6500	6260	8780	700	6900	370	880	650	920	1620	—	—	1410	880	640	1040	1080	1080	—
8/12	168	7120	190	250	9600	4730	2980	3380	4540	430	3930	260	540	580	440	800	490	1080	250	320	380	710	520	660	—
8/12	169	10180	290	270	14630	7880	4170	6000	7750	490	5720	370	620	620	690	1510	880	1820	620	1110	610	670	1030	—	640
8/12	170	9760	200	260	15480	7760	6340	6490	7990	500	6530	290	630	960	110	1510	510	790	600	450	310	460	480	—	—
8/18	171	10660	270	200	16030	8560	5180	6710	7740	570	6120	340	540	590	470	1290	630	270	490	950	450	580	640	700	—
8/18	172	7350	270	190	9330	5170	4300	3900	5580	540	4700	230	590	470	650	1220	930	380	670	710	450	860	480	—	—
8/18	173	10630	240	220	15400	7400	5300	5850	6790	620	5430	300	620	880	810	1400	1810	1360	1070	960	510	830	620	—	—
8/28	174	8930	320	210	13300	7610	6070	5100	4900	550	5400	280	500	500	620	1100	110	—	230	490	350	1270	510	—	610

TABLE 38—*(continued)*

Date	Fish Number	Scales	Skin	Muscle	Compact Bone	Cancellous Bone	Dorsal Fin	Anal Fin	Other Fins	Gill Filaments	Gill Arches and Rakers	Eyes	Stomach and Pyloric Caeca	Intestine	Heart	Liver	Gall Bladder and Contents	Spleen	Kidney	Head Kidney	Central Nervous System	Contents of Digestive Tract	Adipose Tissue/or Stomach Contents[a]	Ovaries	Testes[b]
8/29	175	8630	210	210	11120	6140	4660	4910	7180	420	4220	220	490	650	330	1110	330	590	300	510	330	930	770	850	—
8/29	176	7450	210	190	11530	7110	4850	4230	5980	370	5140	210	470	320	560	1170	350	780	380	280	590	1020	600	470	—
9/3	177	6350	160	90	9880	5480	4180	3860	4350	320	4440	190	350	410	590	790	70	200	410	390	320	780	700	370	—
9/3	178	8940	110	160	11720	6440	4170	4440	6980	440	4350	230	510	350	140	960	70	—	900	420	470	690	820	—	610
9/3	179	8410	130	170	12980	6480	5260	5050	6660	410	4700	270	500	350	380	1350	—	1930	1390	1070	440	860	710	470	—
9/10	180	8010	200	150	12320	5980	4300	3890	3300	390	4620	240	510	660	1010	1100	470	370	—	390	310	520	770	410	—
9/11	181	6910	120	130	10990	5060	3810	4170	5720	270	4180	190	350	530	130	960	—	—	960	250	550	670	100	—	380
9/11	182	8920	130	150	9610	6130	4860	4810	6810	370	4770	200	430	700	250	1310	350	1680	320	240	340	860	580	360	—
9/16	183	4380	120	70	6490	3810	3090	3380	3700	210	3900	140	260	230	460	1280	330	—	130	—	130	490	—	—	500
9/16	184	8230	110	150	10920	5420	5310	4460	6470	280	3780	190	340	210	250	1180	160	—	750	360	350	320	540	—	680
9/17	185	10640	120	50	7280	3350	2620	2580	2260	200	2930	130	310	430	—	1110	210	—	390	210	290	740	520	250	—
9/24	186	6430	60	80	8340	4070	3650	3980	4070	190	4100	160	430	300	120	1030	500	250	100	110	250	620	1580	200	—
9/25	187	7060	170	100	11280	5780	4930	4600	5220	290	3930	170	490	710	700	1070	850	460	1000	800	210	790	820	380	—
9/26	188	7610	110	110	11280	6480	4970	4970	5600	340	3740	160	450	790	80	1210	740	830	710	670	440	1080	1340	180	—
10/1	189	5440	100	60	8130	4150	3450	3400	3660	170	3140	140	320	660	200	640	110	160	190	400	180	—	1150	260	—
10/1	190	5700	50	80	7770	5200	2810	3390	4230	190	3700	130	420	210	—	930	390	—	220	50	110	—	700	290	—
10/2	191	5020	110	100	7300	3500	3200	2980	3410	220	3320	150	460	490	300	1320	1000	—	450	350	210	940	1070	—	580
10/6	192	5950	110	60	8550	4770	3420	3610	4430	250	3180	140	310	530	170	910	440	110	400	150	120	620	1810	—	420
10/7	193	5240	40	50	7150	4020	2820	3000	3370	160	3640	120	210	230	240	950	—	140	90	150	120	640	—	—	330
10/7	194	6360	90	50	10730	5720	4010	4420	5290	310	4190	150	520	650	350	1480	230	570	980	530	120	780	1080	—	710
10/13	195	5130	60	60	7020	3920	3310	2960	3130	140	2980	140	270	370	200	960	220	180	200	200	190	740	930	—	380
10/13	196	6310	130	90	9600	5400	3980	4470	4160	200	3810	150	260	300	120	870	540	—	—	250	200	1810	870	—	340
10/14	197	6060	130	70	9850	5200	4260	4080	4880	220	3470	120	400	230	—	1170	120	240	—	240	50	480	1310	—	400
10/22	198	4600	90	40	6520	3430	2740	3100	3170	160	2980	100	240	240	230	720	340	240	220	250	100	400	1370	160	—
10/24	199	5280	40	50	7940	4300	3060	3330	3180	150	1590	90	240	230	330	590	150	300	560	400	120	170	460	190	—
10/24	200	4830	60	40	8430	4130	3600	3480	3350	100	2780	100	170	120	160	500	80	20	470	160	140	270	—	180	—
10/27	201	5630	70	40	8620	4360	3320	3130	3580	110	3060	90	200	140	190	530	0	240	410	200	150	—	—	170	—
10/28	202	5100	50	40	7800	4230	3560	3280	3250	150	2770	90	260	260	10	730	—	150	190	170	110	330	—	—	240
10/28	203	6190	30	40	9560	5060	4370	3820	4600	140	3200	100	370	570	180	740	—	120	310	230	280	480	1230	240	—
11/4	204	4550	50	30	6270	3470	2580	2770	3110	110	2600	90	150	190	100	900	160	250	50	170	50	500	—	—	180
11/4	205	5010	40	40	8090	4090	2760	2980	3510	100	2610	100	170	210	220	650	—	—	220	110	20	380	—	—	180
11/4	206	5120	60	40	8940	4360	3860	4150	3110	160	3000	120	230	510	410	490	—	90	—	250	50	610	—	150	—
11/11	207	4950	10	30	6330	3460	2780	2960	2860	70	3480	70	140	160	0	410	90	460	290	150	80	170	—	130	—
11/11	208	5010	20	40	7260	4520	2870	2930	3170	90	3030	90	110	60	10	480	0	140	110	10	70	120	—	—	120
11/11	209	5500	70	40	9490	4830	4200	4000	4040	120	3270	100	370	590	160	860	—	—	220	70	170	930	1800	—	130
11/18	210	3600	70	30	5650	2980	2690	2190	2450	60	2130	90	90	160	—	640	—	—	—	—	140	—	—	—	100
11/18	211	4360	80	10	7700	4860	3620	3890	3270	50	2340	80	130	290	—	830	—	—	60	—	40	260	—	—	90
11/18	212	3840	60	20	5810	3610	2660	2550	2440	50	2560	60	140	120	—	330	—	—	300	—	15	—	310	80	—
11/25	213	3660	30	20	5600	2110	2380	2430	2440	50	2190	60	60	0	—	290	—	—	320	—	110	—	—	75	—
11/25	214	4300	70	30	8690	4400	3300	3300	3390	80	2350	80	200	180	—	580	—	—	340	—	90	—	—	—	100
11/25	215	4940	10	20	8430	4340	3520	3420	3360	90	2290	80	130	—	—	490	—	—	280	—	80	—	—	—	50
12/2	216	4230	50	30	7140	2820	3290	3050	3030	60	2620	90	120	110	—	250	—	—	120	—	80	370	—	100	—
12/2	217	4350	10	30	6560	3730	3120	3530	3010	30	2460	60	100	80	—	350	—	—	—	—	30	750	190	80	—
12/2	218	4130	40	20	6220	3960	2370	2590	2420	70	2350	80	100	90	—	350	—	—	—	—	20	400	670	—	40
12/9	219	5000	30	50	7870	4420	3620	2900	3160	70	2830	110	110	280	—	710	—	—	300	—	130	100	—	—	100
12/9	220	5060	20	30	6970	3600	2790	2980	3690	70	2890	80	90	140	—	520	—	—	260	—	40	—	—	—	60
12/9	221	4380	60	20	6410	3850	3130	3040	2900	70	2950	70	150	60	—	350	—	—	60	—	140	690	—	90	—
12/15	222	3710	40	20	6740	3910	2960	2950	2370	40	2730	60	90	10	—	540	—	—	—	—	60	140	420	—	60
12/15	223	5150	30	30	7700	4650	3490	3740	3270	50	2910	80	110	290	—	350	—	—	—	—	40	970	130	100	—
12/16	224	4970	50	20	7890	4310	3440	3330	—	70	2380	70	130	—	—	420	—	—	—	—	50	—	800	—	80
12/22	225	3800	60	30	6250	2680	2440	2350	2800	60	2320	90	30	50	—	270	—	—	—	—	—	—	—	60	—
12/22	226	4540	40	70	6290	3260	2290	2890	3240	30	2250	100	170	260	—	620	—	—	—	—	260	—	—	—	130
12/22	227	4870	60	40	7580	3560	2600	2050	3450	60	2250	60	30	—	—	250	—	—	—	—	50	—	720	90	—
12/30	228	3770	20	40	6160	3660	2720	2880	2630	80	2180	80	90	170	—	520	—	—	—	—	90	—	—	—	100

12/30	229	4810	20	20	8000	4190	3000	3290	2930	50	2350	80	40	10	—	490	—	—	—	—	60	—	—	—	110
12/30	230	5240	40	30	8910	4500	3420	3310	3210	50	3050	100	60	—	—	380	—	—	—	—	30	—	—	—	30
1953																									
1/7	231	4390	10	20	6770	3730	2880	2850	2850	80	2370	70	50	—	—	140	—	—	—	—	20	—	—	70	—
1/7	232	4850	10	20	7080	4010	2820	2940	2550	30	2600	80	220	240	—	470	—	—	—	—	60	—	—	—	80
1/7	233	5080	50	30	7760	4260	3110	3280	3050	50	2930	90	100	240	—	400	—	—	—	—	—	—	—	130	—
1/12	234	4450	—	30	6460	4010	—	—	2300	—	—	100	—	—	—	330	—	—	—	—	170	—	—	—	—
1/12	235	5500	—	20	10630	5240	—	—	3770	—	—	100	—	—	—	350	—	—	—	—	140	—	—	—	—
1/12	236	4520	—	10	8750	4070	—	—	2960	—	—	70	—	—	—	490	—	—	—	—	90	—	—	—	—
1/12	237	4940	—	40	9550	4470	—	—	3690	—	—	80	—	—	—	530	—	—	—	—	0	—	—	—	—
1/19	238	4540	—	20	7740	4270	—	—	3090	—	—	80	—	—	—	560	—	—	—	—	100	—	—	—	—
1/19	239	4030	—	40	6230	3600	—	—	2810	—	—	90	—	—	—	540	—	—	—	—	10	—	—	—	—
1/20	240	3640	—	30	—	3200	—	—	2410	—	—	70	—	—	—	150	—	—	—	—	50	—	—	—	—
1/20	241	4950	—	30	7700	4800	—	—	3350	—	—	100	—	—	—	430	—	—	—	—	60	—	—	—	—
1/26	242	3870	—	20	5240	2880	—	—	2250	—	—	60	—	—	—	310	—	—	—	—	80	—	—	—	—
1/26	243	3880	—	30	5000	3220	—	—	2000	—	—	60	—	—	—	460	—	—	—	—	20	—	—	—	—
1/26	244	4260	—	20	6590	3820	—	—	3800	—	—	60	—	—	—	170	—	—	—	—	10	—	—	—	—
1/26	245	5550	—	20	5600	2270	—	—	2970	—	—	80	—	—	—	630	—	—	—	—	90	—	—	—	—
2/3	246	3340	—	20	4780	2650	—	—	2590	—	—	70	—	—	—	620	—	—	—	—	10	—	—	—	—
2/3	247	3670	—	20	6070	3130	—	—	2560	—	—	70	—	—	—	240	—	—	—	—	140	—	—	—	—
2/3	248	5150	—	20	9060	4880	—	—	3870	—	—	80	—	—	—	680	—	—	—	—	80	—	—	—	—
2/3	249	4450	—	20	7300	3890	—	—	3280	—	—	70	—	—	—	770	—	—	—	—	170	—	—	—	—
2/10	250	4110	—	20	5850	2540	—	—	2370	—	—	70	—	—	—	170	—	—	—	—	40	—	—	—	—
2/10	251	3990	—	20	6180	3270	—	—	2490	—	—	70	—	—	—	300	—	—	—	—	30	—	—	—	—
2/11	252	3820	—	10	6130	2500	—	—	2740	—	—	80	—	—	—	500	—	—	—	—	0	—	—	—	—
2/12	253	4860	—	10	7540	3930	—	—	3210	—	—	60	—	—	—	270	—	—	—	—	10	—	—	—	—
2/17	254	2620	—	30	6170	3350	—	—	2340	—	—	50	—	—	—	780	—	—	—	—	80	—	—	—	—
2/17	255	3640	—	30	6550	3710	—	—	2940	—	—	80	—	—	—	360	—	—	—	—	120	—	—	—	—
2/17	256	4450	—	20	6860	3920	—	—	2380	—	—	90	—	—	—	110	—	—	—	—	40	—	—	—	—
2/17	257	4180	—	30	5300	2850	—	—	2530	—	—	80	—	—	—	340	—	—	—	—	10	—	—	—	—
2/24	258	3920	—	20	5500	3320	—	—	1970	—	—	60	—	—	—	230	—	—	—	—	90	—	—	—	—
2/24	259	4860	—	20	7350	4740	—	—	3600	—	—	100	—	—	—	720	—	—	—	—	0	—	—	—	—
2/24	260	5000	—	50	6560	2960	—	—	3220	—	—	80	—	—	—	540	—	—	—	—	0	—	—	—	—
2/26	261	4390	—	20	7040	4640	—	—	2900	—	—	60	—	—	—	550	—	—	—	—	0	—	—	—	—
3/3	262	3790	—	30	6000	3780	—	—	2760	—	—	70	—	—	—	650	—	—	—	—	70	—	—	—	—
3/3	263	3650	—	20	5050	3350	—	—	2770	—	—	60	—	—	—	260	—	—	—	—	0	—	—	—	—
3/3	264	3690	—	20	6950	4180	—	—	3280	—	—	80	—	—	—	600	—	—	—	—	0	—	—	—	—
3/3	265	3450	—	10	5510	3060	—	—	2400	—	—	80	—	—	—	180	—	—	—	—	0	—	—	—	—
3/10	266	3700	—	20	4850	2720	—	—	2460	—	—	50	—	—	—	190	—	—	—	—	40	—	—	—	—
3/10	267	4160	—	20	6370	2980	—	—	2940	—	—	70	—	—	—	440	—	—	—	—	90	—	—	—	—
3/10	268	5060	—	50	7260	3810	—	—	3780	—	—	100	—	—	—	720	—	—	—	—	120	—	—	—	—
3/10	269	5300	—	30	7040	3600	—	—	3920	—	—	60	—	—	—	520	—	—	—	—	10	—	—	—	—
3/18	270	4030	—	30	6510	3810	—	—	2470	—	—	80	—	—	—	220	—	—	—	—	50	—	—	—	—
3/18	271	4910	—	30	7150	4100	—	—	3250	—	—	60	—	—	—	170	—	—	—	—	0	—	—	—	—
3/18	272	5320	—	20	7960	3810	—	—	3160	—	—	90	—	—	—	860	—	—	—	—	10	—	—	—	—
3/18	273	4270	—	30	6970	3900	—	—	3270	—	—	100	—	—	—	450	—	—	—	—	50	—	—	—	—
3/23	274	3770	—	20	4930	3420	—	—	2700	—	—	90	—	—	—	180	—	—	—	—	80	—	—	—	—
3/23	275	3540	—	30	5030	3220	—	—	2780	—	—	80	—	—	—	410	—	—	—	—	70	—	—	—	—
3/23	276	4220	—	20	6500	4370	—	—	3230	—	—	50	—	—	—	210	—	—	—	—	180	—	—	—	—
3/23	277	4550	—	20	6840	3600	—	—	3090	—	—	100	—	—	—	210	—	—	—	—	70	—	—	—	—
4/2	278	5490	—	30	8320	5510	—	—	4590	—	—	100	—	—	—	1060	—	—	—	—	40	—	—	—	—
4/2	279	5670	—	80	9920	5150	—	—	4470	—	—	120	—	—	—	840	—	—	—	—	160	—	—	—	—
4/2	280	4960	—	30	7390	4090	—	—	3700	—	—	90	—	—	—	350	—	—	—	—	40	—	—	—	—
4/2	281	5510	—	30	8180	4810	—	—	3850	—	—	100	—	—	—	510	—	—	—	—	4	—	—	—	—
4/6	282	4910	—	30	7500	4280	—	—	3830	—	—	80	—	—	—	1130	—	—	—	—	60	—	—	—	—
4/6	283	5620	—	50	9550	5090	—	—	4470	—	—	110	—	—	—	1200	—	—	—	—	90	—	—	—	—
4/6	284	4260	—	30	6750	4330	—	—	3480	—	—	280	—	—	—	820	—	—	—	—	90	—	—	—	—
4/6	285	5080	—	50	9090	4830	—	—	4550	—	—	120	—	—	—	650	—	—	—	—	140	—	—	—	—
4/13	286	3920	—	80	5710	3310	—	—	2600	—	—	150	—	—	—	930	—	—	—	—	80	—	—	—	—
4/13	287	5150	—	70	7370	4010	—	—	3970	—	—	130	—	—	—	810	—	—	—	—	280	—	—	—	—
4/13	288	5150	—	70	5100	3490	—	—	3260	—	—	120	—	—	—	650	—	—	—	—	350	—	—	—	—
4/13	289	4250	—	60	6270	3890	—	—	3140	—	—	100	—	—	—	890	—	—	—	—	170	—	—	—	—

[a] Data in this column are for adipose tissue prior to May 1, 1952, and for stomach contents thereafter.
[b] Fishes Nos. 159, 160, 163, 172, and 173 were males, but the gonads were too small to provide an adequate sample.

TABLE 39

Amounts of Radioactivity (in Counts per Minute per Gram of Tissue) Found in Different Tissues of Individual Bluegills from White Oak Lake

Date	Fish Number	Scales	Skin	Muscle	Compact Bone	Cancellous Bone	Dorsal Fin	Anal Fin	Other Fins	Gill Filaments	Gill Arches and Rakers	Eyes	Stomach and Pyloric Caeca	Intestine	Heart	Liver	Gall Bladder and Contents	Spleen	Kidney	Head Kidney	Central Nervous System	Contents of Digestive Tract	Adipose Tissue/or Stomach Contents[a]	Ovaries	Testes[b]
1950																									
12/1	1	1890	60	55	2240	1810	1340	1570	1530	120	950	50	180	80	—	290	—	—	70	200	70	320	90	40	—
12/29	2	1690	65	65	1780	1070	990	1500	1350	140	690	150	310	240	330	300	50	—	200	200	100	440	65	110	—
1951																									
1/5	3	1530	40	25	1950	950	810	1340	1390	140	530	45	170	240	—	220	50	230	170	100	75	200	—	—	140
1/8	4	1710	45	55	1980	810	1110	1140	1350	240	830	40	150	100	240	220	810	—	—	85	170	270	—	—	260
1/15	5	1420	90	40	1600	600	1250	1310	1520	70	710	100	240	180	570	220	170	290	110	110	50	200	—	—	200
1/18	6	780	25	35	1330	690	700	850	770	200	290	60	50	80	180	80	90	100	40	80	70	130	50	40	—
1/25	7	1440	—	90	1980	750	1170	1230	1220	480	830	160	180	280	390	260	—	—	—	—	210	660	110	—	—
7/18	8	2600	220	120	2640	1560	1420	2240	2130	240	1530	160	400	380	420	570	—	720	400	640	220	400	340	520	—
7/18	9	3630	230	210	4130	2500	1920	2470	2780	500	2900	180	520	520	450	780	340	740	550	650	490	910	440	760	—
7/19	10	2300	170	100	2270	1330	1360	1760	1600	230	1230	130	240	330	80	390	—	480	240	450	60	470	—	460	—
7/26	11	1200	—	—	1600	980	850	1470	1250	50	820	60	30	80	—	250	—	—	40	170	30	130	190	300	—
8/8	12	2500	90	130	3650	1600	1290	1450	1410	200	1040	130	200	170	710	—	130	600	350	270	150	210	50	—	70
8/9	13	2090	60	70	2200	980	820	1060	1590	140	510	90	170	130	—	240	30	—	40	60	80	240	—	150	—
8/10	14	2440	80	80	2980	1380	1120	1230	1580	90	1190	160	250	120	280	370	150	370	190	100	60	420	30	—	240
8/15	15	4230	380	200	7450	4000	3920	4280	3620	390	3200	200	430	460	—	470	—	—	490	160	210	490	440	300	—
8/16	16	2360	70	110	2990	1550	1630	1660	1690	210	1300	80	210	230	80	490	—	270	270	470	160	730	—	340	—
8/16	17	2630	160	130	2890	1570	1050	2080	1940	260	2260	120	300	440	—	340	—	—	250	250	100	550	—	240	—
8/16	18	3000	250	160	4760	1870	2240	2910	2450	150	1780	140	330	—	540	500	150	540	330	630	220	890	320	320	—
8/24	19	1650	80	30	2860	1390	1000	—	1220	130	880	80	140	50	30	260	800	230	160	240	220	210	—	—	200
8/28	20	4150	430	230	7460	2120	3360	4190	4460	310	1900	280	450	340	290	920	—	—	550	650	120	780	40	430	—
8/29	21	3280	190	170	7150	1720	3000	2950	4520	330	1920	180	360	150	—	660	520	350	240	590	530	310	40	90	—
8/29	22	3950	30	190	6140	2580	2130	2200	3300	380	2060	180	480	480	440	830	—	270	700	480	—	980	80	290	—
8/30	23	3230	320	100	5390	2030	1900	2550	3170	220	1820	150	270	350	1490	970	—	—	300	300	80	410	40	—	1330
9/5	24	3200	180	80	3950	2090	1610	2020	2180	170	1030	140	180	160	210	870	1300	80	290	400	340	320	70	—	130
9/6	25	4180	350	110	6180	2050	2250	2630	2960	410	1590	160	280	370	—	880	540	—	670	810	380	410	220	200	—
9/10	26	3550	—	150	7200	2550	1710	2620	2100	440	1700	70	250	200	—	460	—	850	250	—	250	750	70	190	—
9/11	27	2280	120	85	2370	1190	1170	1320	1320	110	900	60	190	120	—	1050	—	180	180	190	180	480	—	—	200
9/11	28	3520	740	70	5740	2030	2200	2210	3380	230	1950	120	250	250	410	1300	670	2980	380	250	100	540	30	—	960
9/12	29	2520	860	70	3920	1360	1160	1110	2140	180	680	90	180	130	—	440	80	120	190	110	10	230	20	100	—
9/12	30	3750	110	130	5050	2410	2220	2270	2990	120	1180	90	190	170	—	580	—	—	230	—	260	380	20	—	—
9/20	31	1520	30	40	1920	960	770	910	970	40	450	120	80	50	140	320	240	20	60	120	10	690	40	—	40
9/20	32	4510	70	60	3670	1780	1160	1530	1870	130	930	80	160	40	180	670	270	180	100	180	120	250	70	—	150
9/27	33	3010	90	70	2100	1680	1590	1440	1120	120	890	100	200	220	390	390	220	260	200	40	120	450	70	120	—
9/27	34	2870	50	20	4320	2130	1520	1460	2080	170	1220	80	130	60	50	1090	—	—	160	300	150	430	60	—	190
9/28	35	1800	30	50	3050	1430	980	1420	1580	200	850	90	210	130	20	1730	120	—	330	370	150	280	130	—	—
10/1	36	2770	80	70	3800	2050	1520	1540	1940	80	1120	80	240	150	—	780	—	120	70	260	160	800	80	—	520
10/5	37	2500	180	70	3630	1880	1390	1600	1640	130	1140	100	290	270	270	630	340	370	150	330	40	470	180	—	260
10/11	38	2240	90	70	3030	1360	1290	1340	1410	160	860	100	270	130	280	750	140	110	340	220	300	430	150	—	120
10/12	39	2860	150	60	3570	1260	1380	1330	1980	120	820	120	600	180	70	800	—	360	190	320	80	860	300	—	570
10/15	40	3330	270	140	5000	2570	2450	2310	2060	640	2260	200	800	470	630	1620	440	1300	560	760	380	840	270	—	780
10/16	41	3260	190	100	4560	2250	1860	1990	2770	400	1260	220	1050	400	690	1170	300	980	600	670	260	1370	400	370	—
10/18	42	2950	100	5	4460	1390	1740	1840	2670	400	1470	570	980	430	480	1040	210	950	520	700	330	2460	500	280	—
10/26	43	6940	900	1500	10120	6310	3580	4730	5080	1200	4340	400	1800	2970	1250	2100	2080	9900	153000	2760	11640	4900	440	12240	—
10/26	44	3550	280	310	4700	1530	1520	1900	3370	10250	14050	380	1180	27500	5550	3300	140	17300	6990	2180	570	2120	9210	3540	—
10/30	45	3610	450	180	4370	1620	1720	1900	2860	560	2850	220	130	540	900	1310	930	1410	840	810	240	1210	320	400	—
10/31	46	3650	540	310	6530	3080	2090	2910	2790	700	2640	230	800	480	360	1410	1230	1470	890	1180	1260	1520	2370	—	1270
11/1	47	2780	150	70	2090	1860	1300	1510	1850	460	930	140	750	80	270	1000	280	370	480	640	380	910	360	—	500
11/6	48	2370	100	90	2930	1300	1100	1120	1350	250	850	120	600	280	140	1280	70	—	310	470	210	620	450	—	490
11/7	49	4810	380	250	7750	3140	2560	2820	2970	650	2350	250	1000	610	630	1470	610	980	960	960	490	980	270	1600	—

11/7	50	3120	170	80	5500	2620	1210	1930	2420	440	1700	190	280	260	—	1190	—	1170	500	600	350	930	130	310	—
11/13	51	2900	200	130	—	1500	1130	1430	1610	440	1750	180	670	470	—	1180	—	690	390	560	310	1600	450	—	210
11/14	52	3300	250	140	6540	2260	2120	1620	2420	520	1640	190	700	420	—	410	—	1220	770	760	400	850	160	360	—
11/14	53	2750	160	100	1680	1680	1410	1600	2000	350	1250	130	580	410	580	650	570	740	440	430	230	490	250	220	—
11/20	54	2740	130	60	3200	1240	1560	1690	1780	230	980	130	510	270	220	590	—	210	300	280	330	1510	30	230	—
11/21	55	2340	190	50	2780	1290	1090	1560	1580	200	660	100	400	330	400	540	—	630	250	300	240	—	100	180	—
11/21	56	2790	200	60	3690	1400	1250	1850	1910	350	1200	160	410	320	900	610	190	1360	400	400	400	1200	450	620	—
11/27	57	3200	120	90	4700	2000	1550	2050	2060	210	1080	120	350	130	610	960	40	—	270	310	180	890	150	—	320
11/27	58	2120	70	80	3260	1450	1350	1250	1560	130	840	100	270	60	400	1180	140	140	190	150	100	460	150	—	170
11/28	59	2380	—	80	3830	1650	1300	1200	1590	200	960	100	280	220	390	560	210	480	420	250	150	470	40	—	—
12/4	60	2470	30	40	3960	1790	1450	1730	1540	160	940	100	160	120	40	420	50	—	90	170	20	520	—	140	—
12/5	61	2460	90	40	3600	1500	1400	1630	1660	150	840	80	190	80	160	390	120	—	130	210	140	250	60	140	—
12/6	62	2200	70	80	4210	1840	1210	1180	1840	170	980	110	440	200	240	940	20	500	330	280	160	1620	240	—	220
12/11	63	2410	140	80	4580	1550	1640	—	2200	230	1160	110	640	330	210	1100	260	440	410	410	60	1550	260	—	570
12/11	64	2830	190	90	5500	2200	1800	2100	2370	170	930	120	300	350	530	920	830	1330	460	160	160	1350	150	—	1400
12/12	65	2560	90	50	3120	1620	1390	1480	—	60	860	60	500	310	80	540	60	700	220	240	80	2720	100	130	—
12/18	66	2850	140	80	3620	1520	1560	1730	2070	280	1000	120	640	420	360	760	270	160	330	420	170	1330	440	240	—
12/19	67	1750	70	50	3430	1500	1100	1280	1540	65	760	80	250	80	190	580	160	—	160	110	110	1260	25	—	200
12/19	68	2230	—	30	3180	1290	1400	1440	1680	140	540	70	330	210	20	490	90	170	220	240	100	410	120	110	—
12/27	69	1890	60	30	2700	1300	1370	1270	1810	85	560	50	370	200	160	270	10	220	230	220	130	5000	130	130	—
12/27	70	2140	20	20	3790	2020	1500	1670	1680	130	990	70	230	190	100	530	20	—	170	150	110	830	100	—	20
12/28	71	1730	40	40	2520	1510	1320	1350	1220	80	500	50	90	100	150	290	30	320	100	190	50	130	50	50	—
1952																									
1/3	72	1880	70	30	2650	1210	1060	1210	1410	85	650	100	490	270	210	490	—	790	210	180	190	2500	180	90	—
1/3	73	930	60	30	2700	1050	1010	1250	1160	110	550	70	100	110	80	250	210	140	130	80	80	170	50	40	—
1/4	74	2800	190	40	4750	1900	1700	1870	2200	120	790	90	180	300	40	660	360	1080	150	—	100	50	160	160	—
1/9	75	2170	50	80	3310	1250	1120	1380	1750	170	780	100	280	310	250	650	20	190	260	200	10	1170	—	120	—
1/9	76	2420	140	150	2060	1390	1470	1430	1870	200	800	140	260	130	160	2080	290	460	400	850	1180	20	240	—	250
1/9	77	2120	150	150	4900	1910	1420	1810	1670	190	820	120	500	110	350	960	20	—	190	210	90	570	610	—	650
1/15	78	2060	50	30	3050	1340	1400	1280	1410	140	640	90	290	200	5	790	60	50	100	90	40	1030	—	—	30
1/16	79	1890	70	40	2970	1340	1450	1650	—	60	530	60	120	70	0	480	140	—	100	110	90	280	240	100	—
1/16	80	2310	30	—	3050	1380	1180	1580	1690	40	430	60	30	100	200	320	40	140	180	140	40	260	50	50	—
1/22	81	1950	90	40	2470	980	1040	1210	1430	100	460	70	150	50	80	660	340	270	60	90	10	200	50	—	—
1/22	82	1300	90	30	2650	1200	1100	1210	1510	85	640	60	180	110	30	540	—	—	100	210	40	170	10	80	—
1/23	83	2150	90	30	3060	1300	1500	1810	1840	120	700	110	340	150	260	400	130	300	190	90	40	2470	—	160	—
1/29	84	1430	110	20	3280	1150	1580	1760	1510	240	720	70	370	250	20	700	270	600	80	120	100	730	590	110	—
1/31	85	1880	120	50	2980	1240	1060	1290	1430	160	1200	60	300	70	250	440	—	330	250	90	—	2310	40	30	—
2/1	86	1840	110	10	2720	1130	1080	1280	1530	160	600	90	250	150	90	1050	120	—	260	280	130	1470	240	—	140
2/5	87	1930	40	30	2960	1270	1240	1430	1660	130	780	60	200	130	90	420	730	220	270	150	30	2520	80	100	—
2/7	88	2140	70	10	3440	1560	890	1310	1670	120	540	70	100	180	—	—	—	90	210	160	40	1920	60	—	50
2/8	89	1890	30	40	2840	1250	1200	1180	1590	100	560	60	100	60	30	760	580	190	—	40	180	600	—	—	100
2/11	90	2140	60	10	3130	1370	1340	1570	1740	110	520	90	310	150	—	550	100	330	140	120	100	4510	90	—	30
2/14	91	1850	30	30	2840	1230	1070	1370	1280	110	500	50	410	200	30	250	50	150	50	150	110	3000	100	60	—
2/14	92	1930	60	10	2970	1290	1320	1290	1770	80	530	50	70	120	380	290	60	—	230	130	10	180	380	70	—
2/19	93	2100	50	30	2920	1350	1020	1540	1470	50	510	40	130	100	180	850	—	40	10	—	10	1640	300	—	—
2/20	94	1980	70	40	2640	980	1060	—	1380	—	560	40	110	180	—	180	—	350	140	110	140	2130	40	60	—
2/21	95	1800	60	20	2830	1260	1380	1280	1490	150	540	60	540	530	210	850	820	480	110	140	20	3670	470	—	260
2/26	96	1430	150	60	3630	1520	1170	1500	1800	430	1320	140	5280	1810	380	1280	210	130	720	480	250	12800	530	—	510
2/26	97	2180	60	60	2900	1360	1150	1520	1460	150	970	120	630	380	220	600	—	—	480	120	240	3080	200	120	—
2/26	98	2450	110	60	2960	1530	1150	1600	1920	300	880	240	2350	1640	190	900	40	90	370	300	220	9840	—	120	—
3/4	99	2080	60	50	3640	1450	1330	1470	1840	50	490	60	40	80	—	640	30	70	240	30	20	60	270	—	240
3/4	100	1980	100	60	3100	1400	1240	1530	1730	150	700	70	210	160	180	500	1330	1000	320	150	110	690	—	40	—
3/5	101	2870	170	110	3720	1690	1540	1710	2100	340	1050	150	1180	450	220	1040	330	580	600	240	130	25400	370	200	—
3/11	102	2840	190	60	4350	1940	1290	2040	2160	150	730	60	380	220	60	520	260	—	210	340	370	1660	30	10	—
3/12	103	2490	290	70	4270	1760	1840	1710	2260	180	940	80	230	120	940	650	—	450	160	220	—	1700	—	110	—
3/14	104	1900	220	140	2520	1220	1440	1620	1620	200	600	120	510	340	—	3720	410	540	360	430	100	440	—	—	440
3/18	105	1930	230	110	3710	1440	1400	920	1520	450	900	170	950	530	670	1050	60	80	370	430	220	1500	350	260	—
3/21	106	2730	220	70	3730	1670	1600	1680	2200	190	740	130	260	—	280	630	70	80	180	270	40	1080	100	90	—
3/21	107	2530	200	100	3060	1600	1260	1040	1750	450	1190	210	800	570	770	1800	130	390	710	630	350	1350	—	—	530
3/26	108	2560	130	70	3870	1750	1480	1610	1730	180	1040	140	360	350	300	970	200	300	110	300	—	580	—	—	370
3/27	109	2090	80	20	2830	1450	1230	1230	1490	110	730	40	260	160	—	580	—	150	310	260	20	2400	—	70	—
3/27	110	2500	120	40	3460	1960	1500	1690	2150	170	440	70	430	100	—	750	—	—	80	200	130	2720	—	60	—
3/31	111	450	30	30	2590	1390	900	1220	1200	70	650	80	250	90	190	1440	30	200	160	300	40	5930	—	—	30
4/1	112	2070	70	30	3500	1380	1420	1470	1760	20	560	80	100	150	80	240	—	290	20	—	90	250	130	30	—
4/1	113	2240	130	70	3160	1330	1580	1580	1810	190	840	90	840	340	230	550	60	30	270	220	210	1260	—	260	—
4/7	114	2420	160	90	2640	1740	1170	1410	1500	320	940	130	610	350	400	1500	800	410	340	—	140	2070	—	—	520
4/7	115	1980	70	10	2810	1590	1420	1560	1560	60	650	90	130	80	460	900	210	220	120	—	70	220	—	—	—
4/7	116	2320	20	40	4130	1740	1630	1560	2020	150	1060	90	380	200	—	1080	720	—	170	—	90	940	—	—	20

TABLE 39—(*continued*)

Date	Fish Number	Scales	Skin	Muscle	Compact Bone	Cancellous Bone	Dorsal Fin	Anal Fin	Other Fins	Gill Filaments	Gill Arches and Rakers	Eyes	Stomach and Pyloric Caeca	Intestine	Heart	Liver	Gall Bladder and Contents	Spleen	Kidney	Head Kidney	Central Nervous System	Contents of Digestive Tract	Adipose Tissue/or Stomach Contents[a]	Ovaries	Testes[b]
4/14	117	2540	220	110	3660	1500	1480	1670	1900	400	1160	130	760	380	—	1030	—	820	320	—	70	6530	—	450	—
4/14	118	2450	200	60	3970	1810	1550	1770	2130	190	1080	90	390	90	—	990	—	—	640	—	210	3590	—	60	—
4/15	119	2430	200	110	4170	1750	1810	1830	2240	350	1250	120	550	390	170	1280	300	800	490	—	150	2740	—	—	—
4/21	120	1950	80	40	2960	1070	1150	1360	1280	210	550	100	420	300	30	550	—	350	90	—	50	1600	—	—	280
4/21	121	2060	50	60	2540	1490	1330	1420	1440	190	890	80	610	150	40	740	150	—	350	—	220	8400	—	320	—
4/21	122	2310	180	60	3870	1660	1430	1670	1770	230	1200	160	510	410	350	670	310	300	340	—	160	1010	—	380	—
4/28	123	4370	410	350	5610	2430	2280	2580	3140	830	2370	320	1230	900	690	3320	720	900	1050	—	670	2710	—	—	1550
4/28	124	1730	120	70	3430	1490	1570	1800	1680	310	1110	100	700	410	330	940	—	460	310	—	360	1200	—	490	—
4/30	125	4480	470	320	5730	2880	2380	2650	3480	1280	2120	300	1590	1100	1270	2720	350	1530	980	—	540	5170	—	2700	—
5/6	126	3260	250	280	4740	2370	1880	1950	2450	530	1870	280	600	440	470	1290	450	670	670	—	360	780	—	—	800
5/6	127	2580	120	80	3220	1700	1520	1670	1770	260	1010	120	400	180	210	650	—	150	300	—	70	670	—	310	—
5/7	128	3200	310	190	3740	1900	1610	1590	2540	580	1320	210	720	610	340	1120	140	260	620	—	240	1550	—	720	—
5/13	129	3110	350	260	4840	2030	1510	1990	2670	760	2190	300	1030	650	730	1600	470	1240	870	1390	350	1600	—	—	1300
5/13	130	2230	360	180	4470	2280	1900	1800	2600	830	1690	230	1400	850	630	1010	210	690	900	1220	400	2300	—	1280	—
5/13	131	5010	380	220	8050	3990	2330	3270	3630	630	1770	250	700	540	390	1140	—	—	660	790	240	1280	—	—	830
5/19	132	2750	160	130	3600	2140	810	1520	1770	470	1570	210	880	630	160	1120	290	960	460	880	360	1080	—	1380	—
5/19	133	3120	250	190	3490	1670	2140	1700	2420	550	1310	230	980	720	540	1430	110	190	620	870	360	1380	—	900	—
5/19	134	2910	260	120	3590	2000	1730	1890	1630	600	1830	150	700	470	580	1100	150	280	490	610	260	860	—	420	—
5/26	135	2680	160	110	3870	2470	1920	2030	2080	440	1750	190	690	400	400	1450	—	—	470	550	260	580	260	—	580
5/26	136	2070	80	100	3740	1900	1350	1500	1520	320	950	140	250	280	760	1070	130	160	270	380	270	—	—	—	490
5/26	137	3340	300	200	3350	2180	1590	1990	2340	640	1350	210	710	350	470	1220	200	960	710	1110	240	900	580	—	860
6/3	138	4580	370	400	9260	4260	3230	3100	3280	600	2650	390	730	470	310	2420	620	700	870	1320	440	—	250	—	1180
6/3	139	3350	170	90	4160	2230	1660	2200	1880	240	1440	150	400	250	300	590	60	240	300	630	140	840	800	480	—
6/3	140	1510	140	90	2130	1100	670	1150	1150	270	1200	200	460	320	340	1380	80	210	280	720	180	1020	1140	—	480
6/10	141	5910	400	310	10300	5220	3300	4610	4510	620	3240	410	450	430	860	2100	420	540	820	300	500	790	—	—	950
6/10	142	3730	230	100	3560	2020	2010	1500	2390	460	1590	170	620	470	570	840	40	—	560	630	80	—	—	560	—
6/10	143	2970	190	130	3840	1920	1300	1830	2310	470	1710	190	460	380	810	1000	190	410	720	610	210	970	—	740	—
6/17	144	3030	140	110	3680	1700	1510	1910	2260	300	1530	160	540	370	370	550	120	290	330	470	210	740	290	660	—
6/17	145	4350	420	300	6080	3250	2490	2640	3120	700	2360	160	110	850	670	3450	1200	700	890	1800	420	1000	370	—	1310
6/17	146	3310	250	130	3930	2120	1730	2030	2270	380	1550	180	510	220	330	1240	50	460	330	640	200	370	430	—	420
6/24	147	10660	270	440	19620	8070	5400	5530	6770	690	4700	570	590	670	1420	2360	1150	100	970	1600	670	520	620	—	940
6/25	148	3590	30	70	3900	1850	1800	1990	2530	360	1790	260	660	500	1660	730	290	960	360	620	240	1100	700	580	—
6/25	149	3190	150	100	3990	2450	1670	2350	1660	280	1700	230	470	350	1100	1050	560	260	380	360	330	870	1050	—	300
7/1	150	8420	540	500	14420	5140	5150	5320	6460	—	4150	500	1000	670	1100	4500	800	1170	1170	2160	670	940	600	—	1960
7/1	151	3120	220	140	6050	2950	2190	800	2580	400	2020	220	700	670	430	1650	780	670	620	620	320	1820	1410	—	690
7/1	152	3110	240	120	5750	3220	2150	2320	2870	420	2160	230	530	510	510	1250	680	1110	690	970	430	820	390	—	810
7/8	153	4110	390	160	4760	2350	2140	2320	3270	430	2000	230	640	370	360	1060	400	—	320	560	270	940	910	400	—
7/8	154	6780	360	290	12730	6000	4750	4740	4830	490	3590	360	690	500	400	3230	450	1100	580	1380	330	550	250	—	640
7/8	155	16800	540	1030	30160	13340	8580	11100	13490	1830	10840	1150	1960	1790	2320	5120	800	2390	1620	2880	1400	2520	830	—	2460
7/15	156	4170	350	200	4410	2000	2150	2560	2880	560	1720	310	1210	710	1370	2240	230	980	640	1540	540	1960	1500	810	—
7/15	157	4430	300	150	3730	1350	2350	2470	3150	500	1950	190	790	320	420	1240	280	680	590	590	370	1860	1060	640	—
7/15	158	4230	330	270	6960	3170	2140	2840	3080	390	1600	200	470	490	920	2370	320	300	440	1270	300	670	460	—	480
7/22	159	4260	270	150	5000	2420	2560	2920	3010	550	2040	320	970	750	410	1480	190	1550	890	1070	380	1120	1200	760	—
7/22	160	3650	270	150	4010	2000	2000	2400	2620	570	1750	210	1020	670	440	1350	—	380	510	1300	300	1350	2430	760	—
7/22	161	5420	380	240	—	1700	2660	3270	3940	760	2470	300	1300	680	640	2000	440	980	880	1380	250	1380	1580	—	860
7/29	162	4340	250	130	4060	2020	2080	2160	2640	490	1590	240	730	620	510	1350	160	830	420	670	320	—	640	—	850
7/29	163	3930	290	160	5980	2960	2450	3240	3050	700	2810	290	1000	800	940	1930	160	1220	810	1270	410	1400	590	1360	—
7/29	164	5000	330	250	5850	1440	2770	2930	3910	650	2250	330	900	600	600	2830	260	1820	790	1100	570	890	380	—	1040
8/5	165	6420	190	290	9140	4740	3600	4020	5090	390	3110	290	740	320	370	2420	300	660	490	1380	370	1170	1110	480	—
8/5	166	5150	260	170	6190	3100	2450	3230	3120	550	2450	260	660	490	820	1650	450	1580	290	—	250	900	1200	—	260
8/5	167	4220	220	180	3790	2000	1930	2050	2880	580	2060	230	620	480	580	1180	260	—	420	560	450	760	820	1700	—
8/12	168	2850	110	60	4560	1700	2170	2300	2410	240	1450	160	400	260	240	1100	550	850	110	390	150	840	960	—	370
8/12	169	4290	220	210	4560	2480	2380	2100	3080	420	1680	200	400	370	230	980	80	720	460	440	360	1370	340	850	—
8/12	170	3530	270	80	3460	1890	2200	2430	2570	310	1630	160	500	340	520	660	610	60	440	600	350	1380	920	550	—

8/18	171	4680	100	130	4930	2620	2600	2850	3180	470	2140	250	480	320	370	1150	410	590	520	1000	410	590	620	850	—
8/18	172	4420	160	140	4740	2440	2570	2530	3250	530	2050	230	400	240	310	2040	250	—	510	780	340	640	—	—	550
8/18	173	4230	310	150	4470	2360	2360	2980	2700	620	2200	220	620	450	390	850	280	190	760	900	540	980	650	990	—
8/27	174	3980	270	90	4070	2140	2110	2370	2620	420	1720	150	550	440	450	2860	430	720	390	630	300	900	870	—	460
8/27	175	8290	480	280	11260	5010	5140	5190	7340	570	3710	300	770	620	—	1790	1030	1610	720	980	530	1980	560	630	—
8/27	176	9800	620	460	21760	8130	5880	7910	8970	1060	6630	790	860	780	2300	4870	740	2150	2800	1100	950	1370	890	2130	—
9/4	177	4000	200	130	3670	1740	1800	2140	2230	260	1460	160	470	450	560	700	210	40	430	350	140	5630	5340	370	—
9/4	178	5170	230	150	6330	2900	2610	3150	3700	360	1820	190	390	400	310	1630	960	580	890	320	250	7850	700	410	—
9/5	179	16270	670	830	23400	10070	9670	9680	12130	1410	6650	690	1450	890	1120	6660	290	1620	1770	3280	1140	5100	7170	1440	—
9/9	180	5670	230	150	8430	4160	3940	4430	4240	370	2450	260	530	320	1180	1360	—	1760	370	580	300	17500	8740	520	—
9/12	181	4470	220	130	5570	2880	2750	3030	3150	250	1720	70	540	410	840	1060	—	2520	170	740	340	1520	4350	560	—
9/12	182	5890	190	130	7400	3120	3030	3480	4530	350	2350	180	410	470	300	860	—	—	460	430	380	7160	5400	270	—
9/18	183	5340	220	90	5870	2350	2730	2730	4040	320	2110	170	520	310	550	1000	950	310	240	1180	900	3830	4030	490	—
9/19	184	4040	—	90	4690	2060	2120	2370	2940	210	1540	170	360	210	220	810	150	—	—	780	130	2120	1100	330	—
9/19	185	3530	60	80	3440	2160	1960	2500	2520	320	1340	130	400	130	630	820	—	—	—	—	50	3670	2330	350	—
9/23	186	6160	160	110	9420	4610	3910	4750	4830	370	2710	110	470	390	610	2060	—	490	780	750	240	2820	4600	—	680
9/24	187	3600	90	70	3920	1930	1890	2460	2500	230	1530	130	340	170	290	940	960	270	230	80	290	970	1310	750	—
9/24	188	5560	430	420	6290	3300	2810	3170	4370	1170	2730	380	1470	1280	930	4360	1050	1640	1150	1960	1940	1100	720	—	930
10/9	189	3140	70	30	3290	1820	1730	2040	2170	210	1640	80	270	200	130	810	—	90	440	480	160	1860	620	240	—
10/10	190	3160	90	70	3540	1780	2020	2290	2830	130	1440	120	370	140	—	440	—	—	300	670	230	550	—	180	—
10/13	191	4330	130	40	5670	2790	2500	3200	2810	110	1560	140	370	160	320	1120	—	1290	240	430	40	1090	830	270	—
10/13	192	4610	70	90	6180	2700	3250	3870	3700	360	2530	160	700	320	210	1370	—	600	480	760	140	1370	—	460	—
10/14	193	8070	290	340	10590	5040	4550	5820	4860	590	2790	380	1050	720	540	4770	550	1200	860	2080	340	9030	1680	—	1090
10/23	194	11370	370	450	16890	6780	6650	8020	7990	880	3730	460	870	520	720	3680	460	1120	960	2660	830	900	290	—	—
10/23	195	3960	110	50	3990	2430	2400	2640	2500	150	1240	110	440	120	240	680	—	—	—	320	170	1950	2870	240	—
10/24	196	4930	190	90	6420	3010	3210	3390	3570	240	1750	120	340	160	770	890	—	1400	950	910	210	700	—	320	—
10/27	197	3300	130	60	3960	1770	1910	2280	2030	240	1210	120	520	360	—	940	—	990	260	540	180	5600	3180	260	—
10/28	198	8770	620	580	14740	6370	5960	6960	6560	1060	4380	1500	840	620	840	8170	1030	700	1240	2420	680	630	—	—	1320
10/28	199	4080	10	50	6990	2830	2660	2870	3290	130	1280	100	460	190	560	1170	90	2110	250	240	200	1700	2050	120	—
11/5	200	2400	50	30	3570	1900	1550	1800	1600	270	1080	100	310	140	350	1750	210	310	330	350	200	3180	840	—	310
11/5	201	3430	40	40	3820	2040	2000	2340	2070	130	960	70	310	200	130	720	80	—	310	390	130	3580	—	150	—
11/5	202	9480	560	620	16020	6570	5670	6670	5230	1450	4050	520	1800	930	880	7420	370	1640	1420	2560	1150	1860	—	—	—
11/11	203	3830	80	60	6130	2510	2710	2940	2650	270	1190	130	300	200	530	600	410	220	100	260	80	260	—	160	—
11/12	204	2990	40	30	3820	1900	1830	2090	1690	160	1020	120	420	190	290	520	120	220	280	400	90	1080	—	170	—
11/12	205	3130	70	50	3490	1910	1780	2130	1950	250	1120	100	520	180	150	740	—	120	360	400	150	1080	—	220	—
11/18	206	4710	120	60	5950	3170	3080	3540	3400	110	1950	100	220	10	—	700	—	—	300	—	180	1350	—	—	—
11/18	207	8800	420	380	13250	6520	4880	5720	4770	1840	3110	490	1180	1040	—	3170	—	—	1130	—	740	1170	—	—	—
11/18	208	2410	0	70	2970	1570	1500	1300	1700	190	1000	70	150	130	—	260	—	—	190	—	160	1270	860	140	—
11/24	209	7090	320	440	12300	5860	5260	4910	3630	1120	3490	460	1500	800	—	4220	—	—	1230	—	780	—	—	—	—
11/24	210	6540	440	440	10380	5650	3850	4400	4490	1650	3650	420	2070	1220	—	2830	—	—	970	—	760	—	—	—	—
11/25	211	6180	250	250	10610	5020	4110	4700	4100	530	2410	290	600	450	—	2580	—	—	700	—	2280	—	—	—	—
12/2	212	2230	70	20	3790	2020	1810	2290	1980	190	1170	100	530	190	—	490	—	—	220	—	90	1880	—	170	—
12/2	213	4110	310	170	3670	2440	2090	2710	2800	1040	2160	280	1850	980	—	2190	—	—	1420	—	520	3780	—	690	—
12/2	214	3230	60	20	4160	2520	1380	2320	2310	150	1220	100	470	210	—	540	—	—	310	—	100	4420	—	140	—
12/9	215	3170	40	40	3260	1710	1560	1840	2630	130	1110	110	180	60	—	310	—	—	100	—	70	210	—	100	—
12/10	216	3280	90	30	3910	1830	1670	2220	1860	150	1060	80	290	170	—	620	—	—	—	—	50	1440	550	130	—
12/10	217	2620	60	10	3020	1500	1070	2090	1440	150	740	80	150	110	—	500	—	—	—	—	40	2820	1920	130	—
12/15	218	2860	120	50	3400	1770	1910	2140	2180	140	960	100	440	160	—	730	—	—	280	—	80	2270	—	130	—
12/15	219	6070	360	320	10920	5060	4070	4820	3730	620	3380	380	730	600	—	2450	—	—	780	—	190	760	—	620	—
12/16	220	2950	80	40	3890	2100	2050	2250	2280	150	1230	90	700	300	—	650	—	—	—	—	120	8620	6540	260	—
12/22	221	2930	30	10	3540	1510	1370	1670	1870	70	710	80	290	190	—	260	—	—	90	—	110	1970	2980	70	—
12/22	222	2900	50	30	4230	1910	1990	1990	2570	180	1080	80	2200	110	—	1420	—	—	170	—	140	660	290	70	—
12/22	223	2980	10	40	2570	1580	1520	1620	1970	100	690	60	220	260	—	320	—	—	100	—	90	760	—	90	—
12/31	224	3100	120	60	4480	2320	2020	2100	2140	320	1450	140	920	250	—	950	—	—	—	—	140	6360	—	160	—
12/31	225	3100	90	20	3700	1950	1870	1220	1870	130	1040	100	450	200	—	310	—	—	—	—	60	6320	—	130	—
12/31	226	3830	80	40	6400	3240	2640	2680	2780	280	1500	120	1340	560	—	1080	—	—	—	—	140	12800	14300	—	—
1953																									
1/6	227	3250	60	20	5080	2520	2550	3660	2750	100	920	100	180	110	—	690	—	—	—	—	70	330	330	—	—
1/6	228	4870	210	100	7250	3730	3800	4010	3310	470	1880	160	1530	510	—	1470	—	—	—	—	460	10450	2380	—	—
1/6	229	3200	120	170	7520	3760	3580	3600	4750	520	1620	230	430	350	—	2160	—	—	—	—	320	540	—	—	—

[a] Data in this column are for adipose tissue prior to May 1, 1952, and for stomach contents thereafter.
[b] Fish No. 93 was a male, but the gonads were too small to provide an adequate sample.

TABLE 40

AMOUNTS OF RADIOACTIVITY (IN COUNTS PER MINUTE PER GRAM OF TISSUE) FOUND IN DIFFERENT TISSUES OF INDIVIDUAL WHITE CRAPPIES FROM WHITE OAK LAKE

Date Fish number	11/21/50 1	11/29/50 2	11/29/50 3	1/9/51 4	1/10/51 5
Scales	3220	2310	2520	1670	1760
Skin	250	190	—	70	45
Muscle	140	110	95	35	60
Compact bone	3370	2320	2640	2220	2290
Cancellous bone	1980	1300	1140	1000	1220
Dorsal fin	2240	2050	1920	1700	1170
Anal fin	1840	1920	1480	1470	1250
Other fins	1790	1900	1450	1250	1360
Gill filaments	370	290	230	180	80
Gill arches and rakers	1300	1830	970	1320	790
Eyes	150	170	190	100	140
Stomach and pyloric caeca	480	450	450	190	170
Intestine	350	360	330	220	250
Heart	700	—	440	190	300
Liver	260	550	390	280	180
Gall bladder and contents	520	—	—	190	55
Spleen	150	—	—	590	270
Kidney	550	500	—	60	—
Head kidney	—	440	440	120	—
Central nervous system	440	370	90	70	200
Contents of digestive tract	540	700	820	160	—
Adipose tissue	—	—	—	—	—
Ovaries	340	—	—	—	—
Testes	—	410	440	170	105

The data for the amounts of gross beta radioactivity found in the samples of tissues from all the individual fish dissected during the entire study are listed in tables 38–45.

Those data for the individual black crappies and bluegills used to determine the presence of any seasonal changes in accumulation of radiomaterials were grouped for each week, and the average amounts of radioactivity present were determined. Then those weekly averages were treated with a moving average of five in order to smooth out the curves to show any seasonal changes that might have taken place.

The amounts of radioactivity accumulated in five different tissues from black crappies, as indicated by a moving average of five applied to the weekly averages, are presented graphically in figure 6. Similar curves for the same tissues from bluegills are shown in figure 7. From these figures it is obvious that there are marked seasonal differences in the amounts of radiomaterials accumulated by both the soft and the hard tissues of both species of fish, and that the same seasonal changes are reflected in all tissues represented in the figures. These particular tissues were selected for demonstration because of their relatively high concentration of radiomaterials. All other tissues showed the same seasonal fluctuations although they had not accumulated such large amounts of radiomaterials.

The curves for the black crappies (fig. 6) are considerably smoother than those for the bluegills (fig. 7). The most plausible explanation for the relative smoothness of the curves for the black crappies, and the lack of that quality in those for the bluegills, probably lies in the extreme differences in the diets. Each of the food organisms accumulated various concentrations of radiomaterials which in turn were concentrated in the various tissues of the fish. It has already been

TABLE 41

Amounts of Radioactivity (in Counts per Minute per Gram of Tissue) Found in Different Tissues of Individual Largemouth Bass from White Oak Lake

Date Fish number	7/28/50 1	11/9/50 2	11/27/50 3	1/16/51 4	8/2/51 5
Scales	1500	1110	125	1000	640
Skin	30	55	25	5	45
Muscle	25	70	40	50	60
Compact bone	1960	770	170	1150	820
Cancellous bone	1200	690	120	660	540
Dorsal fin	730	540	65	700	350
Anal fin	—	670	55	660	320
Other fins	—	780	80	660	380
Gill filaments	50	65	45	—	50
Gill arches and rakers	1020	370	130	150	420
Eyes	—	60	20	30	40
Stomach and pyloric caeca	10	45	35	—	40
Intestine	80	50	35	—	55
Heart	120	7	15	130	110
Liver	170	75	85	130	70
Gall bladder and contents	—	30	15	100	60
Spleen	45	50	45	530	60
Kidney	45	—	100	110	140
Head kidney	—	—	30	—	90
Central nervous system	—	50	10	150	50
Contents of digestive tract	100	70	80	—	150
Adipose tissue	—	—	—	—	75
Ovaries	—	—	40	—	—
Testes	110	120	—	—	—

TABLE 42

Amounts of Radioactivity (in Counts per Minute per Gram of Tissue) Found in Different Tissues of Individual Carp from White Oak Lake

Date Fish number	11/10/50 1	1/16/51 2	1/17/51 3	2/8/51 4	2/9/51 5
Scales	1100	1600	1090	610	940
Skin	115	150	20	20	30
Muscle	100	220	70	35	30
Compact bone	1380	3350	1360	1100	1050
Cancellous bone	660	1430	780	680	660
Dorsal fin	380	1580	540	400	460
Anal fin	380	1630	570	570	590
Other fins	960	2200	610	260	310
Gill filaments	750	510	360	160	740
Gill arches and rakers	950	1580	740	860	910
Eyes	15	55	—	40	30
Intestine	530	160	190	90	180
Heart	25	120	70	100	—
Liver	360	120	85	25	50
Gall bladder and contents	15	420	40	30	45
Spleen	50	260	285	40	100
Kidney	75	350	210	140	240
Head kidney	—	150	200	100	130
Central nervous system	120	90	45	25	40
Contents of digestive tract	1070	210	430	270	440
Adipose tissue	—	—	—	—	—
Ovaries	—	—	60	—	—
Testes	200	—	—	20	35

TABLE 43

AMOUNTS OF RADIOACTIVITY (IN COUNTS PER MINUTE PER GRAM OF TISSUE) FOUND IN DIFFERENT TISSUES OF INDIVIDUAL REDHORSE FROM WHITE OAK LAKE

Date	11/22/50	1/4/51	1/5/51	1/20/51	2/13/51	2/14/51	2/17/51	8/17/51
Fish number	1	2	3	4	5	6	7	8
Scales	1440	1350	1000	640	970	820	1180	1460
Skin	70	100	50	10	40	35	45	35
Muscle	120	290	100	10	80	40	80	50
Compact bone	1810	1850	1000	1230	1330	780	1600	1940
Cancellous bone	800	1140	610	760	740	520	900	910
Dorsal fin	820	940	630	590	650	480	560	710
Anal fin	1130	1310	1030	870	710	520	610	910
Other fins	1400	590	630	570	720	540	1050	1120
Gill filaments	430	1260	150	210	160	200	360	330
Gill arches and rakers	810	1950	480	550	420	460	680	730
Eyes	85	220	70	30	50	30	70	110
Intestine	250	190	100	95	65	60	150	90
Heart	180	840	370	80	90	50	160	70
Liver	260	260	110	25	75	50	150	100
Gall bladder and contents	60	400	1120	20	60	60	120	35
Spleen	270	970	170	150	35	10	320	340
Kidney	340	300	310	70	120	100	230	140
Head kidney	290	1320	150	80	95	55	150	140
Central nervous system	150	740	75	20	35	55	120	45
Contents of digestive tract	1620	390	420	150	125	360	240	370
Adipose tissue	—	300	150	5	85	85	40	50
Ovaries	140	300	—	120	—	—	90	70
Testes	—	—	65	—	65	35	—	—

TABLE 44

AMOUNTS OF RADIOACTIVITY (IN COUNTS PER MINUTE PER GRAM OF TISSUE) FOUND IN DIFFERENT TISSUES OF INDIVIDUAL YELLOW BULLHEADS FROM WHITE OAK LAKE

Date	8/23/50	1/11/51	2/13/51	2/13/51
Fish number	1	2	3	4
Skin	55	150	20	60
Muscle	130	175	70	110
Compact bone	2180	1600	1230	1480
Cancellous bone	1500	1120	1020	550
Dorsal fin	—	1280	1340	880
Anal fin	—	360	340	400
Other fins	—	450	270	240
Gill filaments	90	100	15	55
Gill arches and rakers	610	1140	640	480
Eyes	—	100	10	65
Stomach	100	90	20	60
Intestine	450	85	25	65
Heart	—	150	10	130
Liver	160	75	15	40
Gall bladder and contents	20	10	10	25
Spleen	85	130	0	210
Kidney	180	160	65	300
Head kidney	690	75	45	200
Central nervous system	60	190	25	15
Contents of digestive tract	4300	380	170	90
Adipose tissue	50	110	0	20
Ovaries	120	—	60	—
Testes	—	110	—	75

TABLE 45

AMOUNTS OF RADIOACTIVITY (IN COUNTS PER MINUTE PER GRAM OF TISSUE) FOUND IN DIFFERENT TISSUES OF INDIVIDUAL GIZZARD SHAD FROM WHITE OAK LAKE

Date	12/28/50	1/20/51
Fish number	1	2
Scales	725	650
Skin	5	15
Muscle	20	40
Compact bone	1400	830
Cancellous bone	740	670
Dorsal fin	360	390
Anal fin	260	220
Other fins	410	590
Gill filaments	130	80
Gill arches and rakers	310	260
Eyes	50	15
Stomach	50	35
Intestine	50	20
Heart	30	60
Liver	100	60
Gall bladder and contents	50	—
Spleen	20	70
Kidney	160	80
Head kidney	110	90
Central nervous system	50	—
Contents of digestive tract	90	35
Adipose tissue	—	0
Ovaries	80	30
Testes	—	—

pointed out that the amounts of radioactivity in the contents of the bluegill stomachs had a much greater range of values than those for the contents of the black crappie stomachs. In essence, the bulk of the crappie diet consisted of the larval forms of various midges along with microcrustaceans, whereas the diet of the bluegills was tremendously varied. It is believed that the sample of three black crappies per week was adequate for determining the seasonal trends in accumulation of radiomaterials, whereas such a sample of bluegills was inadequate. Perhaps a sample of as many as 10 bluegills per week would have yielded more satisfactory results.

In all poikilothermous animals, the body temperature is largely controlled by the temperature of the environment. Also there is a direct relationship between metabolic rate and temperature in such animals; as the temperature increases the metabolic rate increases and vice versa. Certainly the increase in the concentration of radiomaterials, as shown in figures 6 and 7, was closely related to the rise in water temperature in the spring. Based on temperatures of the water recorded from White Oak Lake, it appears that the spring increase in the accumulation of radiomaterials by both species of fish began when the water temperature reached about 55° F., and the accumulation of radiomaterials by mid-June had more than doubled the amounts carried during the winter months. The mid-

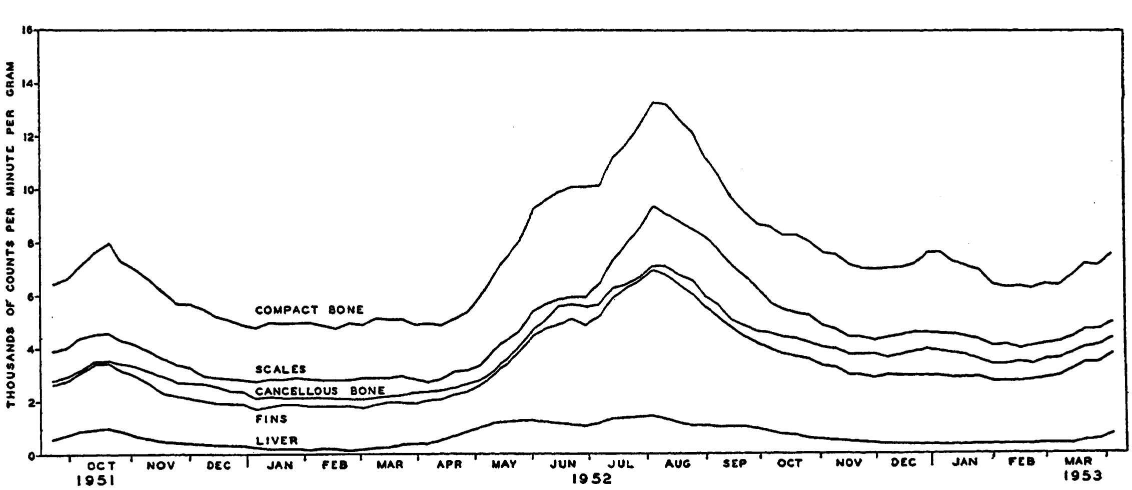

FIG. 6. Average values for radioactivity accumulated in five tissues taken from black crappies from White Oak Lake, arranged to show the seasonal variations in such accumulation.

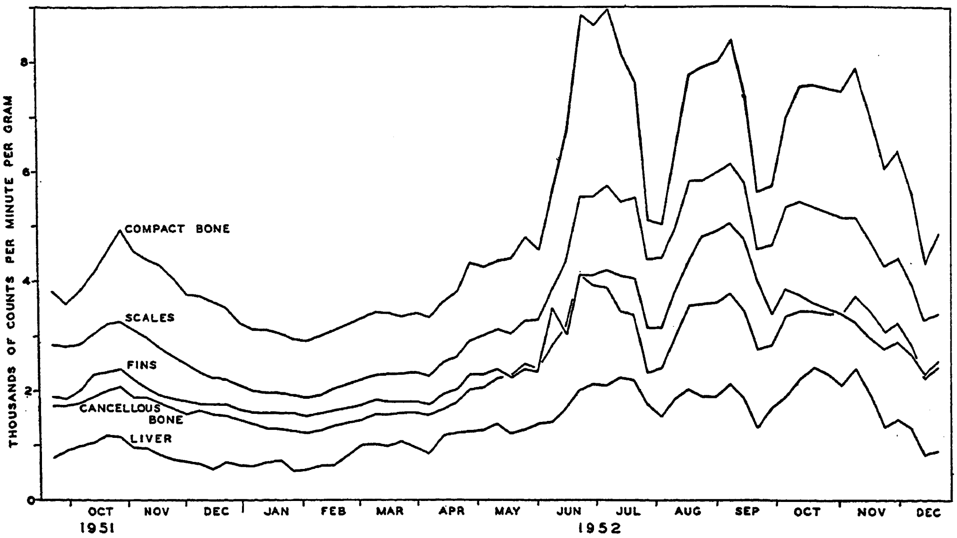

FIG. 7. Average values for radioactivity accumulated in five tissues taken from bluegills from White Oak Lake, arranged to show the seasonal variations in such accumulation.

summer peak in temperature was reached almost simultaneously with the peak in accumulation of radiomaterials (August 1). At that time the water temperature reached a high of about 80° F., which was less than twice the average winter temperature, whereas the fish had very nearly tripled the amounts of radiomaterials concentrated over the winter period. After August 1, the amounts of radiomaterials in the fish samples fell off rather rapidly, while the water temperatures decreased gradually over the next two or three months but did not drop below 55° F. until about the middle of October. If the rate of accumulation of radiomaterials by the fishes of White Oak Lake is directly correlated with their metabolic rate, and there is little doubt that it is, the sharp decrease in accumulation during August and September, 1952, when the temperature of the environment remained relatively high, indicates that there must have been a marked change in the metabolic processes at that time. If temperature were the only controlling factor, the metabolism of radiomaterials should have continued throughout the periods of high temperature and should not have

TABLE 46

MINIMUM, AVERAGE, AND MAXIMUM AMOUNTS OF RADIOACTIVITY (IN COUNTS PER MINUTE PER GRAM, FRESH WEIGHT) ACCUMULATED IN SAMPLES OF SELECTED TISSUES OF BLACK CRAPPIES, FOR TWO DIFFERENT THREE-MONTH PERIODS AND ONE ONE-MONTH PERIOD, WHITE OAK LAKE

Tissue	January–March, 1952			June–August, 1952			January, 1953		
	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Compact bone	2650	5000	6750	5550	11500	19600	4890	6650	10600
Scales	2200	3000	4950	4050	7500	12900	2600	4300	5500
Vertebral bodies	1300	2200	3150	2450	6350	10650	2250	3650	5250
All fins	1300	1950	2550	2550	5900	9900	1950	2900	3900
Liver	35	270	620	670	1350	1870	110	410	860
Muscle	16	35	50	110	240	450	7	25	50

fallen off as rapidly as it did. However, it is obvious that temperature is not the only factor that controls the rate of metabolism. It seems plausible to assume that the fish underwent some marked physiological changes and entered a period of summer dormancy. The physiological changes that are believed to accompany such periods of estivation could adequately explain the rapid decrease in the accumulation of radiomaterials.

The minimum, average, and maximum amounts of gross beta radioactivity, for six selected tissues from black crappies and bluegills, assayed during January, February, and March, 1952, and January, 1953, as compared with similar data for June, July, and August, 1952, are listed in tables 46 and 47, respectively. From these data it is obvious that there was more than twice as much radioactivity in all tissues during the summer than during the winter. It is also obvious that there were significantly greater amounts of radioactivity in the fish during the second winter than during the first. Data compiled by the Area Monitoring Group of the Applied Health Physics Section of the Oak Ridge National Laboratory showed that during January and February, 1953, there was about a five-fold increase in the amount of radioactivity that passed over the dam of White Oak Lake over that spilled in the same period in 1952.

In addition, it is readily apparent from these same data that the crappies accumulated considerably greater amounts of radiomaterials in the hard tissues than the bluegills, whereas among the soft tissues the reverse was generally true. These differences are presented graphically for two selected tissues for each species in figure 8. The reasons for such differences are not obvious. It may be that the differences in diet are a contributing factor. Also it may be that the physiological demands for the elements accumulated are quite different for the two species of fish involved. If such differences in physiological requirements for certain elements are so great between two species so closely related as the bluegill and the black crappie, any prediction of the relative amounts of radiomaterials that might be accumulated by unrelated species of fish would be pure speculation.

The average amount of radioactivity in the water of White Oak Lake, as determined by the Area Monitoring Group, was 4.5 counts per minute per milliliter during July, 1952. Radiochemical analysis of the July sample of water by that same group showed that about 24 per cent of the radioactivity was emitted by radiostrontium. The maximum amount of radioactivity detected in the bones of black crappies caught on July 29, 1952, was approximately 19,000 counts per minute per gram. From these data it is apparent that there is a concentration factor of about 20,000 to 1 for radiostrontium from the lake water to the bones of the black crappie. Similar data for the bluegills caught on July 8, 1952, showed a concentration factor of more than 30,000 to 1 in selected individuals.

TABLE 47

MINIMUM, AVERAGE, AND MAXIMUM AMOUNTS OF RADIOACTIVITY (IN COUNTS PER MINUTE PER GRAM, FRESH WEIGHT) ACCUMULATED IN SAMPLES OF SELECTED TISSUES OF BLUEGILLS, FOR TWO DIFFERENT THREE-MONTH PERIODS AND ONE ONE-MONTH PERIOD, WHITE OAK LAKE

Tissue	January–March, 1952			June–August, 1952			January, 1953		
	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Compact bone	2050	3250	4900	2100	7150	30400	3700	5750	7500
Scales	950	2100	2850	1600	5000	16800	3100	3550	4900
Vertebral bodies	1000	1400	1950	1100	3250	13400	1950	2900	3750
All fins	1150	1650	2250	1150	3650	13600	1850	2950	4750
Liver	180	810	3700	550	1850	5150	300	1100	2150
Muscle	10	55	150	65	220	1050	20	70	170

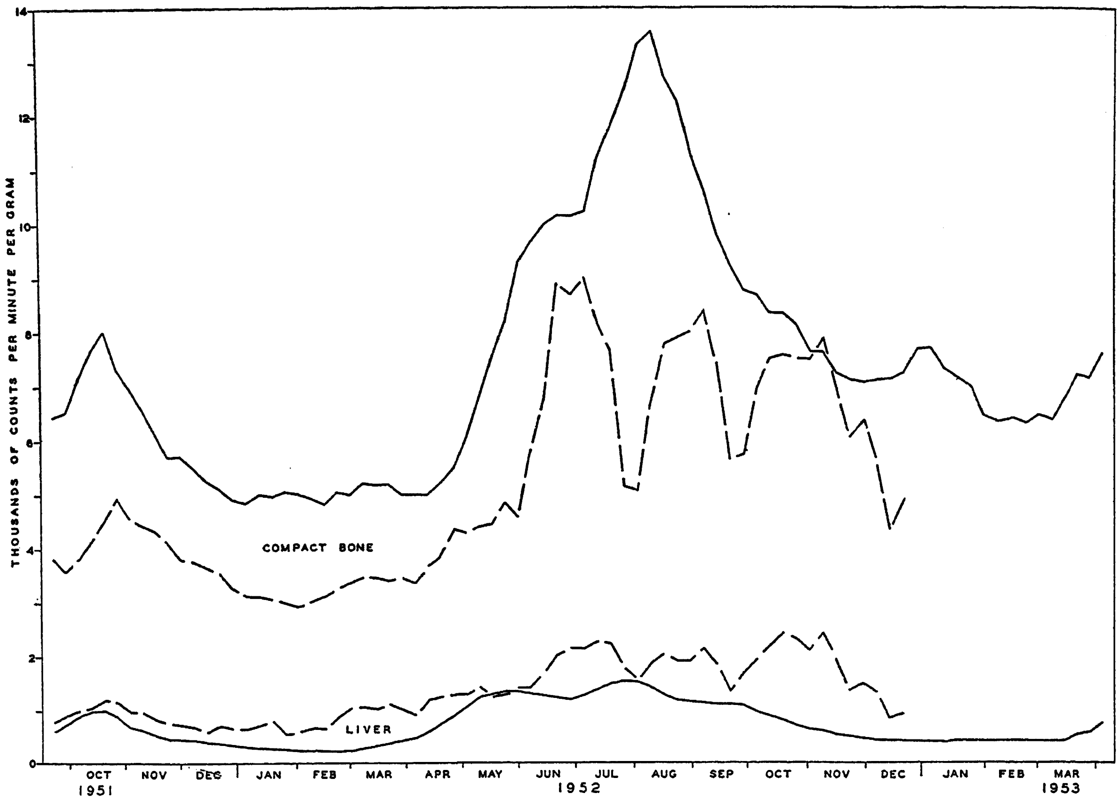

FIG. 8. Comparison of values for radioactivity accumulated in two tissues from black crappies (solid lines) and from bluegills (broken lines) from White Oak Lake.

RADIOCHEMICAL ANALYSES OF FISH TISSUES

Radiochemical analyses of the composite samples of the various tissues of the black crappies and the bluegills revealed the presence of the following radionuclides: strontium 89, strontium 90 and its yttrium 90 daughter, cesium 137, cerium 144-praseodymium 144 and other rare earths, ruthenium 106, cobalt 60, phosphorus 32, iodine 131, zirconium 95, and niobium 95. However, each of those radioelements was selectively concentrated by separate tissues; the hard tissues concentrated primarily strontium and phosphorus, whereas the soft tissues generally concentrated cesium in greater amounts than any of the other elements. Among the black crappies, representative hard tissues (compact bone, cancellous bone, scales, and dorsal fin) contained the same percentages of radioelements consistently at all seasons of the year, irrespective of the actual amounts of radiomaterials accumulated. Approximately 85 per cent of all the radioactivity in each of these tissues was emitted by radiostrontium and its daughter products, and about 10 per cent by phosphorus 32. The remaining 5 per cent consisted of small amounts of the various other elements mentioned above. Among the same tissues in the bluegills, much the same pattern of accumulation was found. There, about 82 per cent of the radioactivity in the bones was emitted by radiostrontium and its daughter products, about 10 per cent by radiophosphorus, and the remainder by various amounts of the other elements mentioned.

Among the soft tissues of both species of fish, the main source of radioactivity was from cesium 137, as indicated by Knobf (1951), together with smaller amounts of radioruthenium, radioactive cerium-praseodymium, radioniobium, and radiozirconium. The amounts of radiocesium ranged from about 50 per cent to 90 per cent, with an average of about 75 per cent. The greatest amount of ruthenium detected comprised about 10 per cent of the total. None of the other elements were ever found to have contributed more than about 3 per cent, with the single exception of cobalt 60. In one instance, the livers of several bluegills were found to be highly radioactive (more than 8000 counts per minute per gram). Radiochemical analysis revealed that nearly all the radioactivity in these organs was emitted by cobalt 60.

DISCUSSION

There is little doubt from the foregoing presentation of data that the fish from White Oak Lake selectively accumulated radiomaterials in the various tissues of the body. Although radiophosphorus was generally accumulated in much greater amounts than any other radioelement by the organisms that served as food for the fish, that element made up only a small portion of the total radiomaterials concentrated in the fish tissues, whereas radiostrontium, which was present in the food organisms in only relatively small quantities, was accumulated in high concentrations in the fish skeletons. Furthermore, although the contents of the bluegill stomachs contained more radioactivity, on the average, than those of the black crappies, the crappies accumulated considerably greater amounts of radiomaterials in the hard tissues than the bluegills did. The bluegills, on the other hand, accumulated more radiomaterials in the soft tissues than the black crappies. Both species concentrated radiostrontium in quantities 20,000 to 30,000 times as great as those in the water in which they lived.

Based on the data presented for the percentage of the total body weight contributed by the various tissues, and on the data for the amounts of radiomaterials accumulated in the samples of these tissues, it was estimated that during the summer of 1952 the average total body burden of radioactivity carried by a black crappie 7 inches long, which weighed 116 grams, was well over a microcurie. Of that amount of radioactivity, approximately 0.9 microcurie was emitted by radiostrontium and its daughter products that had been concentrated in the hard tissues of the body. During the winter months, however, the total body burden of radiostrontium was reduced to about one-third of a microcurie. The average total body burden of radioactivity carried by a bluegill 6 inches long, which weighed 120 grams, was slightly less than that for the crappies for both seasons.

CONCLUSIONS

IN AN UNDISTURBED ANIMAL COMMUNITY, there is often a tendency towards a more or less stable equilibrium, from year to year, among the various components of the population. There are, however, natural seasonal fluctuations in population size, especially among the cold-blooded forms. Each of the various components of the population serves as a check and balance against the other components and, in turn, is acted upon by them. Many factors, such as space, climate, type of habitat, characteristics of the soil, and so forth, act as the physical limiting factors in the make-up of the population.

The indefinite survival of any particular segment of any population depends largely on the ability of that segment to adapt itself to changing conditions. For example, if the climate of an area becomes more and more moist, the xerophytic organisms must either adapt themselves to the increased moisture, move elsewhere, or perish. In a terrestrial community, such a move may be, although it ordinarily is not, feasible because of geographical and/or climatological barriers. In an aquatic environment, where the boundaries are sharply defined and the animal in question is unable to survive out of water, that animal must either adapt itself to any slight change in environmental conditions, whether they are changes in the hydrogen-ion concentration, average temperature, degree of radiation, turbidity, total alkalinity, or others, or it will be unable to survive.

Among those animals that have a very short life span and reproduce very rapidly, such as the various zooplankters, it is difficult to determine through field studies alone whether or not any particular factor, such as the constant exposure to low levels of radiation, has any effects on the populations as a whole. Among such organisms, when conditions are suitable, a relatively few individuals can erupt into a tremendous pulse within a few days. Similar eruptions among the phytoplankters can be even more spectacular. Such increases in population size are usually rather short-lived, primarily because of the limitations imposed by the environment. In the normal course of events, the organisms decrease in abundance until only the residual population remains. This residual population is only a very small fraction of the size of the peak pulse population.

Such tremendous fluctuations in numbers are not common among the larger animals. Under normal conditions, there is apparently a fairly good inverse correlation between the average length of the reproductive cycle and the amplitude of the fluctuations in population size; populations of animals with a long reproductive cycle (e.g., ungulates) very seldom erupt into large numbers, whereas those of animals with a very short reproductive cycle (e.g., rotifers) may erupt several times each year.

Although there were unusually large pulses of both zooplankters and phytoplankters in White Oak Lake each year of the study period, no studies were made of the biotic potentials of these organisms. It has been pointed out previously that White Oak Lake is an unusually fertile, and consequently a highly productive, lake. Plankton pulses are commonplace in very productive lakes. However, it is not known whether or not a lake of such high productivity as White Oak Lake in this latitude might not produce even more spectacular plankton pulses if the environment were not contaminated with radioactive materials or did not contain any toxic chemical substances. Without any detailed information on the fecundity of the adults, the viability of the zygotes, and the other vital statistics of the populations of the different plankters, it was virtually impossible to determine whether or not there were any effects from the constant exposure of the population to radiation. Pulses of these organisms which serve as food for the fishes would, in all probability, continue to occur as conditions warranted such occurrence, even though the over-all fitness of the populations was deteriorating.

To a certain extent, the fluctuations in the sizes of the populations of planktonic organisms affect the well-being of the populations of the fishes that utilize them as food. If there is a relatively constant supply of food, these larger predatory organisms will usually maintain their populations satisfactorily. Conversely, if these food organisms were to be wiped out by some extraordinary factor, the fishes that feed on them would suffer from that lessened food supply.

Each estimate of the size and composition of the fish population of White Oak Lake as revealed by the mark-and-recapture method, when compared with that from the rotenone study, indicates that the mark-and-recapture method, as used in this study, is quite fallible. The data from these netting studies did not provide quantitatively accurate data on the sizes of the populations of all the various species of fish present. However, they did provide what appear to be reasonably good estimates of the sizes of the populations of black crappies, bullheads, and redhorse each spring and fall of the study period. When it is considered that the size of the population of gizzard shad was not estimated during the netting studies, it is apparent that the netting studies yielded reasonably good estimates for only half of the species present in the lake. In only one instance (fall, 1951) did the estimate of the size of the bluegill population by the mark-and-recapture method even approach the size of the population revealed by the rotenone study. Then, too, when it is considered that the population of fishes in a body of water is usually larger in the fall than it is in the spring because of the seasonal fluctuations in population size, the estimate for the bluegills in the fall of 1951 seems even less accurate. In no instance during the six semiannual netting studies was there a reasonably good estimate of the sizes of the populations of the carp and the largemouth bass.

The netting studies were of value in that they yielded qualitative information on the relative abundance of the different species, on the seasonal fluctuations in the sizes of the various species components of the total fish population, and on the comparative vulnerability of the different species to netting. In addition, the routine gathering of data on the relationship between length and weight and the length-frequency distributions, along with the data on age and growth as determined from the scale samples, did assist materially in the appraisal of the well-being of the various segments of the population as well as that of the population as a whole.

The estimate of the size of the total fish population in White Oak Lake, as revealed by the data from the rotenone study, indicates that the productivity of the lake was very high. The lake had received relatively large quantities of nutrient materials from the sewage plant at the Oak Ridge National Laboratory, and in all probability that added fertilizer caused the production of an unusually high standing crop of fishes. The extant population in late April, 1953, was nearly 1000 pounds of fish per acre. Such a large standing crop is believed to be very high for this region of the United States.

As pointed out above, the netting studies indicated that the white crappie and the redhorse were gradually disappearing from the lake during the three-year study period. These indications were verified by the data from the rotenone study. Concurrent with the netting studies, field observations and sampling indicated that there were no cyprinids other than the carp and the goldfish in White Oak Lake. The reasons for the absence of these smaller minnows, which were relatively abundant in near-by Watts Bar Reservoir, and the gradual disappearance of the white crappie and the redhorse from the fish population are not immediately obvious.

It may be that the white crappies, which utilized much the same kinds of food as the black crappies, were crowded out through direct competition by the black crappies which were better able to adapt themselves to the gradually changing environment. Such a crowding out of the white crappies solely on the basis of competition with the black crappies for food does not seem realistic, because there was ample food present for both species. Certainly the black crappies were not more adept at catching *Chaoborus*, or any of the other forms for that matter, than the white crappies. Still the fact remains that the white crappies gradually disappeared from the lake. It seems much more reasonable to assume that the white crappies were less able to adapt themselves to the changing environment. Then, too, it may be that there was some interspecific population pressure which worked to the disadvantage of the white crappies.

So far as the redhorse were concerned, it is feasible to assume that they were unable to reproduce successfully because of the continued or increased pollution of the waters over their spawning grounds by excessive amounts of chemical wastes. However, those waters were almost constantly populated with small bluegills, small largemouth bass, and other fishes. Here, too, it seems reasonable to assume that the population of redhorse was unable to adapt itself to the changes in the environmental conditions.

This same inability to become adapted to the changing conditions of the environment is the most plausible explanation for the absence of small minnows from White Oak Lake. Many of these small fishes require a clear-water habitat and this was not available. There were many different kinds of small cyprinids and other small fishes present in the upper uncontaminated reaches of White Oak Creek and Melton Branch throughout the study period. However, the cyprinids were primarily creek forms which would not ordinarily live in lakes.

The data from the scale readings of the fishes from White Oak Lake showed that the time of annulus formation was similar to that of fishes of the same species from near-by reservoirs of the Tennessee Valley Authority. It was also shown that some of the fishes, notably the black crappie, probably failed to form an annulus each year, a corroboration of the findings of Reid (1950) in Florida. However, the rates of growth of the fishes in White Oak Lake were noticeably slower, and the lengths of the life spans were markedly shorter, than those of fishes of the same species from near-by reservoirs. This slow growth rate and short life span cannot readily be explained by the differences in the natural environment. If the temperature of the environment is the controlling factor in the metabolic processes, the fish in White Oak Lake should have grown more rapidly than those elsewhere in the region, because the average summer temperature of White Oak Lake was generally higher than that in near-by waters. Moreover, it has been pointed out by Hile (1936) and others that slowly growing fish usually live longer than rapidly growing ones. In view of the fact that White Oak Lake was probably a much more fertile body of water than any of the near-by reservoirs, and hence had a much higher productivity, it would indicate that the fish, if they had a shorter life span, should have grown more rapidly than those in near-by reservoirs. Conversely, if they grew more slowly, which seems unlikely in view of the high fertility of the lake, a longer life span would have been expected.

Actually the black crappies in White Oak Lake grew more slowly than those in the near-by reservoirs at all times during their lives, with the possible exception of the first year. The rapid growth during that first year may suggest that there was an abundance of food for the fishes of that size and a relative scarcity of food for the older fishes. It was pointed out by Dendy (1946) that one of the principal items in the diet of the black crappies in Norris Reservoir was small fish, especially during the winter months. There was an abundance of small fishes in White Oak Lake at all times during the study period covered by this report. Yet the stomach of only one of the 289 black crappies collected each week for 18 months, which included two winter periods, that were dissected for radioassay contained a fish. From this information, it is obvious that small fish were not a preferred item in the diet of the black crappies in White Oak Lake.

In all probability, White Oak Lake was overpopulated with bluegills. The data for age and growth indicated that they were growing even more slowly than in the near-by reservoirs. Furthermore, the length-frequency distributions from the different netting studies indicated that there was no line of demarcation between the various year classes. The overpopulation, as pointed out above, probably resulted in a stunting of the entire bluegill population.

The information from the netting studies, particularly the length-frequency data, showed that individuals of all species of fish increased in length during the winter months in White Oak Lake. The data for the black crappies (fig. 2) indicate that many more fish of the 1950 year class were taken in the spring of 1951 than in the fall of 1950. The same holds true for members of the 1951 and 1952 year classes in the spring of 1952 and the spring of 1953, respectively. This over-winter growth does not seem unlikely in White Oak Lake where the winters are relatively short and not extremely cold. However, it does corroborate the observations of the author in ponds in northern Indiana and southern Michigan (Krumholz, 1948a).

Studies of the food habits of the black crappie and the bluegill in White Oak Lake indicated that black crappies fed primarily on larval *Chaoborus* at all seasons of the year. That organism made up approximately 43 per cent of the total annual diet and was followed in order by copepods (13.4%), larval Tendipedidae (12%), cladocerans (8%), and *Corixa* (6%). The bluegills, on the other hand, were quite omnivorous and showed little preference for any particular kind of food. The black crappies generally sought their food in the pelagic zone of the lake, whereas the bluegills obtained most of their food along the littoral zone.

One of the primary objectives of this study was to determine which radioelements had accumulated in the biota of White Oak Lake, in which tissues of the various organisms they had accumulated, and whether or not such an accumulation had any effects on the well-being of the different individual organisms and their populations.

It is pointed out above that each of the organisms in the entire food chain concentrated some radiomaterials in its tissues. Some animals selectively concentrated one radioelement and some concentrated another. Here it is not intended to imply that one organism concentrated only one radioelement. Rather each organism, through its own peculiar physiological processes, utilized and concentrated the various elements necessary for its own life processes. The fact that the particular element that was concentrated in relatively large amounts happened to be radioactive was incidental so far as the normal physiological processes were concerned. All the radiomaterials ingested and concentrated by the various organisms in White Oak Lake were taken into the body as part of the natural life processes.

Most of the plankton organisms selectively concentrated radiophosphorus in greater amounts than any other radioelement. In addition to this high concentration of radiophosphorus, smaller amounts of other radioactive elements such as strontium, ruthenium, cesium, cerium, and so forth, were also accumulated. For example, one sample of *Chaoborus* contained 95 per cent radiophosphorus, 2 per cent radioactive rare earths, 0.5 per cent radiostrontium, and 1.1 per cent radiocesium (table 36). Other organisms contained different percentages of these same radioelements. In general, the majority of the zooplankters concentrated radiophosphorus in greater amounts than any other radioelement, whereas among the filamentous algae the radioactive rare earths were concentrated in amounts almost equal to those of the radiophosphorus.

All organisms did not contain the same amounts of radioactivity. Some contained many times the amounts concentrated by others. For example, the samples of larval *Tendipes* collected from the lake ranged in radioactive content from 150 to 2770 counts per minute per gram.

No attempt was made to determine which tissues of the plankton organisms had concentrated the various radioelements. Among the fishes, however, each tissue was assayed for radioactivity, and chemical analyses were made in order that the elements present could be identified. In addition, several individual fish were dissected so that the percentage composition, by weight, of each kind of tissue in the body could be determined. Thus it was possible to assess the total amount of radioactivity in each of the tissues and also in the entire animal.

Radioassay of the various tissues of the fish indicated that the hard tissues of the body concentrated much more radioactivity than the soft tissues. Among the hard tissues, the compact bone concentrated the largest amounts and was followed in order by the scales, fins, and cancellous bone. Among the soft tissues, the liver generally concentrated larger amounts of radioactivity than the others. Only relatively little radioactivity was accumulated in the flesh.

The hard tissues selectively concentrated large quantities of radiostrontium and smaller quantities of radiophosphorus and other radioelements. The soft tissues, on the other hand, selectively concentrated radio-iodine, radiocobalt, radiocesium, the radioactive rare earths, and other radionuclides to a lesser degree.

Of particular interest in this study were the seasonal changes in the accumulation of radiomaterials in all the different tissues of the fish. An intensive study of the seasonal changes in the accumulation of radioactivity of black crappies and bluegills showed that an increase in concentration in the tissues began in April when the surface temperature of the water reached about 55° F. That increase in concentration continued until midsummer (August 1), by which time the concentration of radiomaterials was about three times that carried in the tissues in midwinter. Then, even though the water temperature remained higher than 55° F. until about the middle of October, the amounts of radioactivity in the tissues decreased very rapidly after August 1. This rapid loss of radiomaterials was obviously a manifestation of some radical change in the physiology of the fish, and it is believed that the fishes of White Oak Lake entered a period of summer dormancy which lasted through August and September.

The rapid loss of radioactivity by the tissues of black crappies and bluegills indicates that the metabolism of the fish was not affected by the changes in temperature alone. Rather it is believed that the metabolic rate of the fish increased to an upper threshold which was reached at the peak of the summer water temperature on August 1 (80° F.). Once that threshold was reached, the metabolism of the fish underwent a profound change. If the fish had continued to concentrate radiomaterials during August and September at the same rate they did in June and July, there would have been an increase in the concentration of radiomaterials of nearly five times that of the preceding winter by October 1. However, the fish, instead of continuing to concentrate the radiomaterials, began actively to disperse those already present in the tissues.

It has been pointed out by Comar and coworkers (1952) that osteoid tissue is normally quite avid for calcium and other bone-seeking elements and that there is a very close similarity between calcium and strontium in normal bone deposition. Radiostrontium consumed by mammals can be found in the crystalline bone within a few hours after ingestion. Furthermore, once it has been incorporated in the bone, there is only a small but significant level of strontium maintained in the blood as the bone is resorbed. It is shown above that radiostrontium was accumulated in large amounts in the bony tissues of the fishes of White Oak Lake early in the summer. However, the process by which it is rapidly dispersed from the bone over a relatively short period is not understood. Although the structure of fish bone is different from that of mammalian bone, it seems unlikely that the radiostrontium is not incorporated in the bone lattice of the fish in much the same manner as in the mammals. If it is, then the fish has some sort of metabolic mechanism by which it can release the radiostrontium from the lattice. Such a release of relatively large amounts of radiostrontium from bone into which it had already been incorporated is quite unusual and would require some special physiological mechanism to control such a rapid turnover.

It must be kept in mind, however, that there was residual radiostrontium in the bone of the fishes of White Oak Lake during the winter months. That residual level was about one-third of the peak summer concentration. It may be that the radiostrontium was incorporated in the bone in two different ways: one transitory in nature and the other fixed. Thus the fraction of the radiostrontium that manifested itself as the increased concentration during the early summer may have been merely adsorbed to the outside of the lattice, whereas that which remained with the fish over the winter months had actually been incorporated into the lattice. If this were true, the adsorbed radiostrontium would be much more easily dispersed from the bone than that which was actually incorporated in the lattice structure. Further research is necessary to increase our very limited understanding of the physiology of the deposition and release of bone-seeking elements in the skeletons of fishes.

It is shown above that certain individual black crappies and bluegills concentrated radiostrontium in their skeletal systems in amounts 20,000 to 30,000 times as great as those in the water in which they lived. Also it is shown that during the summer of 1952 the average total body burden of radioactivity carried by a black crappie 7 inches long was well over a microcurie, and that, on the average, a 6-inch bluegill carried only slightly less.

The total radiation dose received by any of the organisms in White Oak Lake is unknown. However, Dr. K. Z. Morgan (personal communication) estimated that, if the average concentration of radioactivity in the water of White Oak Lake is 10^{-3} microcuries per milliliter, and the average effective energy is 0.3 million electron volts, the external dose rate is 1.1 rep (roentgen equivalent physical) per week. Thus the fish in White Oak Lake received the equivalent of more than 57 roentgens of external irradiation from the surrounding water each year during their entire lives. Although no attempt was made to estimate the internal dosages received by the fishes that carried a total body burden of one microcurie, it can safely be assumed that the internal dose was several times that of the external dose. Thus in addition to the 1.1 rep of external irradiation, the fish may well have received as many as 5 rep, or perhaps even more, of internal irradiation per week. If these assumptions are valid, the fish in White Oak Lake received a total radiation dose of as much as 300 rep per year.

It has been shown experimentally by Foster *et alii* (1949) that exposure to X rays produced marked deleterious effects on rainbow trout (*Salmo gairdnerii*) in all stages of development from the fertilized egg to the adult. They found that ova obtained from adults that had received a dosage of 500 or more roentgens sustained a significantly greater mortality than ova from control parents. Furthermore, there was a direct correlation between the dosage to which the parents had been exposed and the frequency of occurrence of malformations in the offspring. Among the offspring that survived hatching, it was found that the growth during the first year of life was directly proportional to the amount of irradiation received by the parents. The growth of the progeny that had received 100 roentgens was slightly less than normal, whereas that of the progeny of fish that had received 500 roentgens was noticeably impeded.

The mutagenic effects of irradiation to the genetic material was first described by Muller (1927) for animals and by Stadler (1928) for plants. Since then many workers have used radiation in one form or another to induce mutations and to make further studies on the genetic material. Muller (1950, 1952) summarized the genetic effects of irradiation on the individual as well as on the population as a whole. Spencer and Stern (1948), in a study of the linear relationship between exposure to radiation and the frequency of gene mutation, stated that low dosages of X rays produce mutations which are as drastic in their effects, and are in the same proportion to the dosage, as those produced by higher dosages, and that there is no tolerance dose below which mutations are not induced.

Because the study of the fish population of White Oak Lake extended over only a three-year period, there is no chance to report on the long-term changes in the biota. If there had been any genetic effects on the populations of aquatic organisms, they were not recognized as such. However, many important changes were observed to be taking place in the various segments of the fish population.

It is pointed out above that the fish in White Oak Lake not only grew more slowly than the fishes of the same species in near-by reservoirs, but that they also had shorter life spans. Usually these manifestations of growth do not occur together, even in populations that are known to be stunted; slowly growing fish usually live longer than rapidly growing ones, and rapidly growing fish usually have shorter life spans than slowly growing ones. It is difficult to explain such growth phenomena on the basis of the ordinarily accepted knowledge of the ecology of fishes.

Two of the classical effects of exposure of a population of animals to radiation are a slowing down of the growth rate and a shortening of the life span. Although the evidence is not unequivocal that the slowed growth rate and the shortened life span of the fishes of White Oak Lake were brought about as the result of the continuous exposure to radiation alone, it can hardly be denied that such a constant exposure may have been a strongly contributing factor. In fact, it is difficult to believe that any fish in White Oak Lake, which may well have received as much as 1000 rep during its lifetime, would not have suffered some deleterious effects.

It was also observed that two species of fish, the white crappie and the redhorse, although relatively common in the lake in 1950, had apparently been unable to maintain their populations and had gradually disappeared from White Oak Lake during the three-year study period. By April, 1953, all the white crappies were gone, and fewer than 40 redhorse remained. Furthermore, even though some of the redhorse were still present in the lake when it was treated with rotenone, there had been no successful reproduction of the species since 1949.

It is well known that the exposure of an animal population to radiation will result in a decreased fertility of the breeding stock. Thus, although the disappearance of white crappies and redhorse from White Oak Lake can reasonably be accounted for on the basis of natural ecological processes, the constant exposure to radiation may have contributed to their inability to maintain their populations.

It would be of considerable assistance in the appraisal of the effects of radioactive wastes on naturally occurring populations if studies similar to the one undertaken at White Oak Lake could be made. Such studies, however, should ideally be set up on a long-term basis and should include intensive studies of all segments of the biota.

SUMMARY

A THREE-YEAR STUDY of the fish population of White Oak Lake, Roane County, Tennessee, was made in 1950–1953. That lake received the radioactive waste effluent, the chemical waste effluent, and the primary-treated sewage effluent from the Oak Ridge National Laboratory.

Six semi-annual estimates of the size and composition of the fish population were made by the mark-and-recapture method. Immediately following the last semi-annual netting study, the lake was partially drained and treated with emulsifiable rotenone. Approximately 60 per cent of the fish that had been marked during the last semi-annual netting study were recovered following the treatment with rotenone. The estimated total weight of the fish population was approximately 985 pounds per acre.

The data from the mark-and-recapture studies were not quantitatively sound but did provide good qualitative information on the composition of the fish population. They indicated that white crappies and redhorse were gradually disappearing from the population; these findings were corroborated by the data from the rotenone study.

Age and growth data, supplemented by data on length frequencies, indicated that the fish of White Oak Lake grew more slowly and did not live so long as fish of the same species in near-by reservoirs of the Tennessee Valley Authority.

Dissection of fishes provided data on the percentage composition, by weight, of the various tissues in the body.

A year-round study of the food habits of the black crappie revealed that it fed primarily on larval *Chaoborus* and other midges and to a certain extent on copepods and cladocerans. The bluegill, on the other hand, was very omnivorous and showed no such preference for certain food items.

Radioassay of samples of the various tissues of the black crappie and the bluegill indicated that radiomaterials were selectively concentrated in all tissues of the body. The hard tissues selectively concentrated radiostrontium in amounts 20,000 to 30,000 times that of the water in which they lived. Some radiophosphorus was also concentrated in the hard tissues. The soft tissues selectively concentrated cesium and the rare earths. The total body burden carried by a 7-inch black crappie during the summer of 1952 was more than a microcurie, whereas that for a 6-inch bluegill was only slightly less.

There were definite seasonal changes in the accumulation of radiomaterials which corresponded, to some extent, with the seasonal changes in water temperature. However, the accumulation of radiomaterials stopped when the temperature of the water reached its maximum about August 1. The rapid loss of radiomaterials during August and September indicated that both species of fish probably entered a period of summer dormancy during that time.

The total radiation dose received by the fish in White Oak Lake was estimated to be at least 57 rep per year from external irradiation and was probably several times that amount from internal irradiation. As a result of this irradiation, it is believed that the fish population of White Oak Lake may have suffered deleterious effects, as manifested by the shortened life span, the slowed growth rate, and possibly the decreased fertility of the breeding stock of the redhorse.

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