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STUDIES OF RADIOACTIVITY IN FISH FROM WHITE OAK LAKE AND T[illegible] RIVER

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HEALTH PHYSICS DIVISION

STUDIES OF RADIOACTIVITY IN FISH FROM WHITE OAK LAKE AND THE CLINCH RIVER

by

Venus I. Knobf

JUL 9 195[illegible]

Date Issued

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CONTENTS

ABSTRACT

A survey of the extent of utilization of radioactive materials by various species of fish in the White Oak Creek drainage system was inaugurated by the Health Physics Division of the Oak Ridge National Laboratory in cooperation with the Fish and Game Branch, Division of Forestry Relations, Tennessee Valley Authority. That study disclosed that there were progressively smaller amounts of radioactive materials in the fish taken from the upper part of White Oak Lake and downstream as far as about seven and one-half miles below the outlet of White Oak Creek. The use of fish from White Oak Lake as food for human beings is not permitted. These studies show that such use would constitute a health hazard because as little as 2.5 ounces of flesh from these fish may contain sufficient radioactive material to exceed the present accepted maximum permissible dosage. Although fish from White Oak Creek below the dam were not nearly so highly contaminated as those from White Oak Lake, their use as food for human being is not recommended. The radioactivity in fish from the Clinch River below the mouth of White Oak Creek appears to be insignificant.

STUDIES OF RADIOACTIVITY IN FISH FROM WHITE OAK LAKE AND THE CLINCH RIVER

INTRODUCTION

All living organisms are able to concentrate certain elements in their cell structures. Age of the individual, type of organ or tissue, kinds of elements involved, and other factors may affect the rapidity of exchange and the rate of accumulation. The work of J.G. Hamilton[1] and his group using various isotopes in adult rats has contributed greatly to the information concerning the absorption of elements and their deposition within the body. However, no organism, in carrying on its metabolic activities, is capable of distinguishing between the stable and the radioactive isotopes of the various elements. The amounts of radioactivity concentrated within the organism are influenced by the relative abundance of stable and unstable isotopes and the biological requirements for those elements. Furthermore, the amount of one particular radioisotope deposited in tissues may be affected by changes in the concentration of some other element in the external environment. For example, Prosser, et. al.[2] concluded that an excess of calcium in the water limited the amount of strontium accumulated in goldfish.

The quantity and variety of radioactive isotopes discharged into White Oak Creek vary from time to time. Because of these changes in radioisotope content of the water and also because of the seasonal variations in the food habits of the fish, it is to be expected that the average amount of radioactivity found in fish may be different at different times.

A cooperative survey was planned between the Health Physics Division, Oak Ridge National Laboratory and the Fish and Game Branch, Division of Forestry Relations, Tennessee Valley Authority to study the radioactivity in fish in the White Oak Creek area and in other selected sites in the Clinch River drainage below the Oak Ridge National Laboratory. In addition, any significance from the standpoint of public health was to be taken into consideration.

The White Oak Creek drainage system has been adequately described elsewhere by Setter and Kochtitzky[3].

MATERIALS AND METHODS

Collection of fish

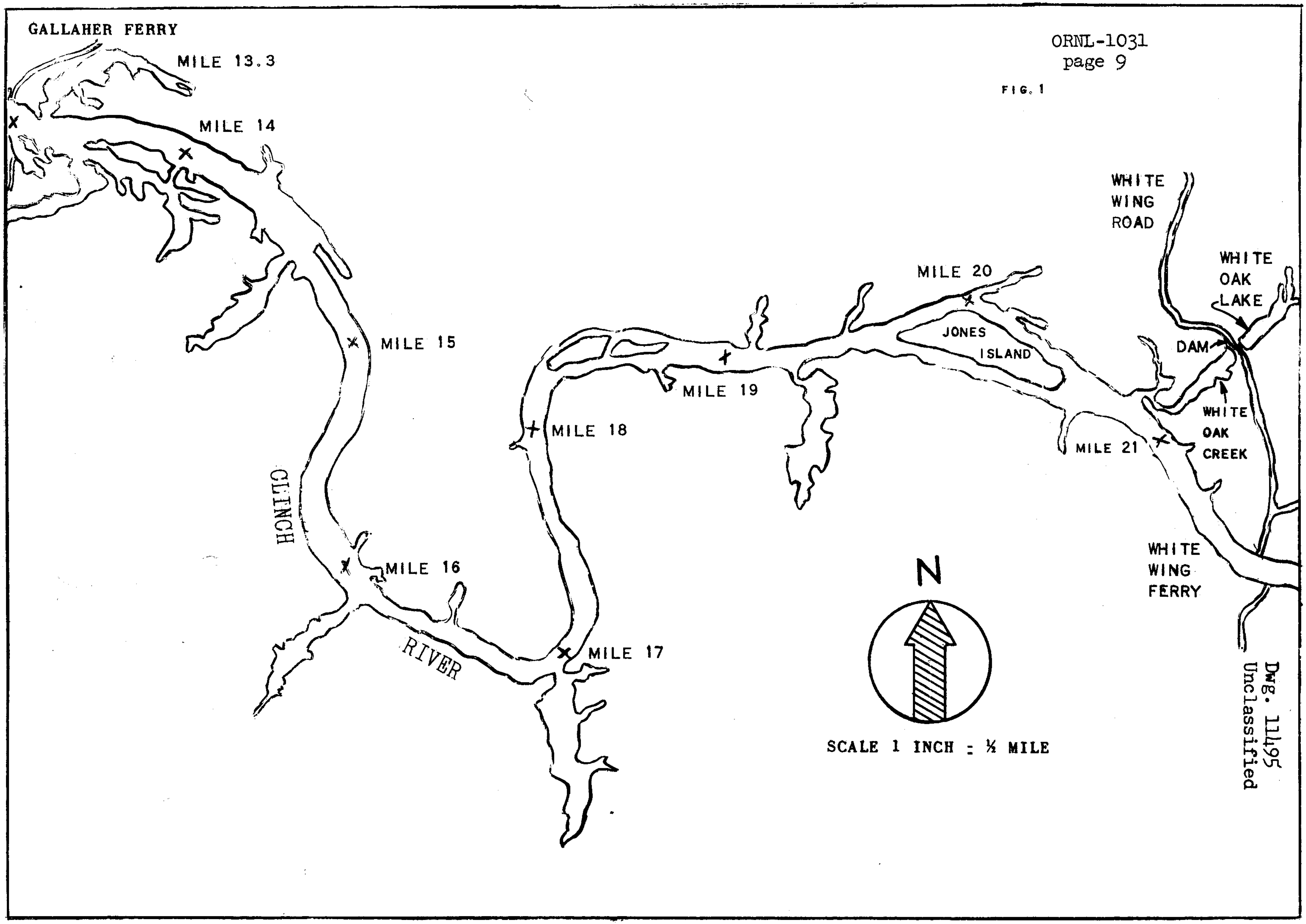
All fish collections were made under the supervision of Dr. R.W. Eschmeyer of TVA. Derris root (4.8 per cent rotenone) was mixed with water to form a thick paste and scattered over the water surface. Within an hour after the distribution of the derris root was completed, the incapacitated fish began to rise to the surface and were collected with nets. Altogether, four areas were sampled in this manner (Figures 1 and 2).

1. October 4, 1948. One collection at mile 13.3 in the Clinch River, approximately seven and one-half miles downstream from the mouth of White Oak Creek. Of the fish collected, more than 500 gizzard shad were discarded. The remaining fish consisted of 133 gizzard shad, 3 redhorse, 25 carp, 2 buffalofish, 1 catfish, 59 crappies, 20 drum, 8 bass, 18 sunfish, and 2 pike; total of 271 individuals.

2. October 4, 1948. Collections were made from two small embayments at Cl. mile 18-19, two - three miles below the outlet of White Oak Creek. Two hundred gizzard shad were discarded and of the 491 specimens retained for study there were: 253 gizzard shad, 122 crappies, 34 drum, 34 carp, 17 pike, 10 buffalofish, 10 sunfish, 6 suckers, 4 bass, and 1 catfish.

3. October 26, 1948. Collection of fish from the White Oak Creek embayment near its mouth at Cl. mile 20.8. A number of gizzard shad were again discarded. Of the 164 fish saved for further study there were: 10 fingerling sunfish, 29 large sunfish, 1 minnow, 56 crappies, 2 bass, 3 suckers, and 63 gizzard shad.

FIG. 1



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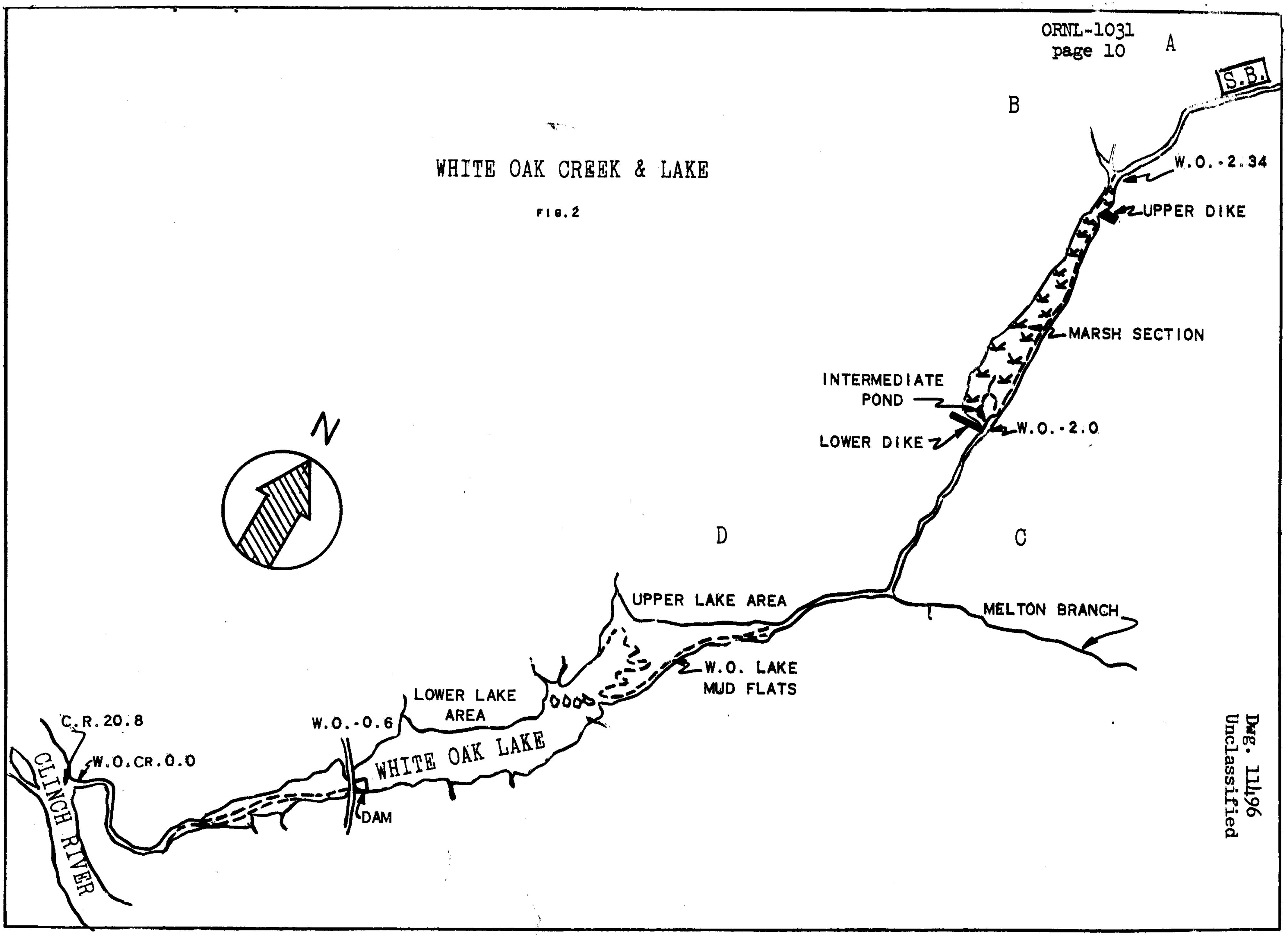

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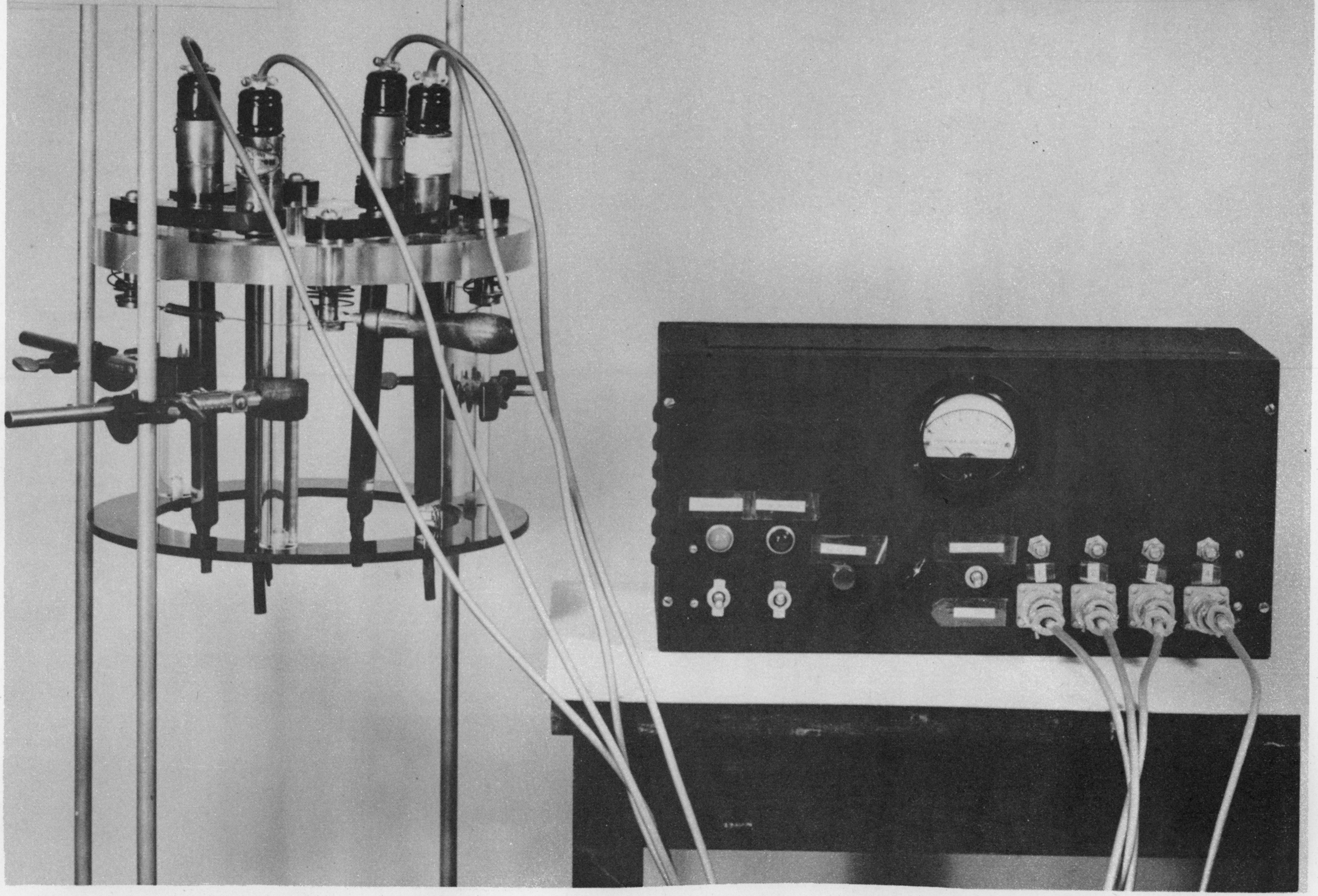
4. May 2-3, 1949. Collection of fish from White Oak Lake. These fish were collected from two areas designated (for this study) as Upper Lake and Lower Lake (Figure 2). A total of 254 fish were taken to the laboratory from the two areas as follows: Upper Lake - 115 fish consisting of 19 bluegills, 7 carp, 6 redhorse, and 83 gizzard shad; Lower Lake - 139 fish consisting of 2 largemouth bass, 1 crappie, 21 bluegills, 28 carp, 10 redhorse, and 77 gizzard shad. The remaining fish, mostly shad together with a few redhorse, were discarded. In addition to these, a largemouth bass found dead near the dam at the outlet of White Oak Lake was taken to the Laboratory. A resume of observations made by Dr. Eschmeyer at the time of the collection is included in the Appendix of this report.

<u>Scanning and Selection of Fish for Processing</u>

When handling such a large number of fish it became necessary to devise a rapid method for indicating the various levels of radioactivity in the different specimens. For the two collections of fish made October 4, 1948, measurements of radioactivity of scale samples were used as an indicator of total activity. Each fish was washed thoroughly. Samples of scales were taken, mounted on stiff paper cards, covered with cellophane, and counted on the first shelf of an end window GM tube counter. On the basis of these data it was decided that fish giving 10 counts or more per minute above background should be processed. In addition, 10 fish having fewer than 10 counts per minute were processed as a means of checking this method of scanning. There was such poor correlation between scanning data and the data obtained through processing that this method of scanning was considered unreliable for indicating various levels of activity. However, it appears that this method can be used as a rapid means of differentiating between fish of relatively high and those of relatively low activity.

Fish from White Oak Creek could not be selected for processing in the same manner as those from the two locations farther downstream because most of the White Oak Creek fish registered fairly high levels of activity when scanned. Scanning was done by suspending whole fish between the four tubes of a four channel GM tube rate meter (Figure 3) and recording the reading after subtracting the appropriate background value. Since it was impossible to process all of the fish before spoilage occurred, it was decided to process as many as possible and to correlate the scanning readings with the activity of bone as determined through processing. Accordingly, after processing was completed, a calibration curve was prepared for converting rate meter readings to

FIG. 3



FOUR CHANNEL G M TUBE AND RATE METER

counts per minute per gram of bone. Unfortunately, the scanner readings gave only a rough indication of activity in the bone of the 110 fish that were not processed.

Some species, taken as a group, have comparatively high levels of activity in the flesh whereas other species have high levels in the bones and scales. The shape and size of the fish determine, to a large extent, the distance from the source to the sensitive areas of the counter tubes as well as the angle of incidence of radiations. Furthermore, any self-absorption of beta activity is affected by the topography of the fish concerned. For these reasons it would appear to be essential that the scanned fish be grouped according to species and sizes to obtain the best values.

Each of the 255 fish collected from White Oak Lake, May 2-3, 1949, was thoroughly washed in tap water, wrapped in cellophane, and scanned for gross beta activity. The four channel GM tube rate meter was used for scanning the first 20 fish. After that time it was not used because it had become contaminated. Scanning of this group of fish was completed with a single tube probe counter and scaler. This preliminary scanning served as a means of indicating the levels of activity in fish of any particular species that were not processed. None of the fish were grouped according to level of radioactivity, as were the fish from the White Oak Creek collection, because of the debatable reliability of the single tube counter. There was no representative sampling of this group of fish for processing, but for ease in handling and dissection, only large fish were chosen. Here, again, the limited correlation between scanner reading and specific activity of tissue as determined by processing did not justify the use of scanner readings in estimating specific activities in individual fish.

The numbers of fish of each species from each of the collections that were scanned during this study are listed in Table I.

Processing

During this study, a total of 198 fish from the five collection sites were processed for measurements of radioactivity (Table I). Samples of bone, scale, and flesh were taken from each fish that was processed. In addition to those samples, 19 of the fish from White Oak Lake were dissected and samples of the tissue from gills, heart, liver, kidney, and gonads were prepared for processing.

Each sample was placed in a weighed porcelain evaporating (counting) dish having an inside depth of one centimeter and an area of 13.8 square centimeters and weighed. The samples were then

Table I

Number of Individual Fish of Each Species From Each Collection, Together With the Totals for Each Species and Each Collection, That Were Scanned (no parentheses) and Processed (parentheses) During the Present Study

Number of Fish Studied

Site and date of Collection	Largemouth Bass	Sunfish	Crappie	Pike	Carp	Redhorse	Gizzard Shad	Sucker	Drum	Minnow	Buffalo-fish	Catfish	Totals
Clinch River mile 13.3 October 4, 1948	8	18	59 (12)	2	25 (8)	3	133 (11)		20		2	1	271 (31)
Clinch River mile 18-19 October 4, 1948	4	10	122 (14)	17	34		253 (42)	6 (5)	34 (1)		10	1	491 (62)
White Oak Creek October 26, 1948	2 (2)	39** (14)	56 (20)				63 (15)	3 (3)		1			164 (54)
Upper White Oak Lake May 2-3, 1949		19			7 (3)	6 (4)	83 (6)						115 (13)
Lower White Oak Lake May 2-3, 1949	2* (2)	21 (6)	1 (1)		28 (18)	10 (10)	77						139 (38)
Totals	16 (5)	107 (20)	238 (47)	19	94 (29)	19 (14)	609 (74)	9 (8)	54 (1)	1	12	2	1180 (198)

*In addition to these two bass, a third bass, found dead near the dam was scanned and processed.

**This group consisted of 29 large sunfish and 10 fingerlings.

dried in an oven at approximately 100°C. and weighed again. After they had been dried, the samples were digested with from one-half to four milliliters of concentrated nitric acid along with from two to six drops of concentrated sulfuric acid. They were then dried under infra-red lamps, as described in another report(4) and ashed in a muffle furnace at about 550°C. When necessary, the residue in the dishes was distributed over the bottom more evenly by spreading with distilled water and a stirring rod. After re-drying and weighing, each sample was counted on the second shelf of an end-window Geiger-Mueller counter.

Corrections of Counting Data

All counts were corrected for background, coincidence loss, and geometry (to 10 per cent of actual disintegrations). No counts were corrected for backscattering.

In the studies of fish from the Clinch River and White Oak Creek no corrections were made for self-absorption. However, following a study of self-absorption in flesh, bone, and scales to determine a basis for correction, self-absorption corrections were made on all counting data for samples of fish from White Oak Lake. For this study of self-absorption, 74 separate samples of flesh, bone and scale were prepared and processed in the same manner as for other counting measurements throughout these studies and self-absorption curves were run for these three tissues. In addition, aluminum absorption curves were run on samples of flesh, bone, scales, gills, heart, kidney, liver and gonads, to determine the correction curves that were most applicable. Absorption corrections were based on the ashed weight. Specific activity was based on the natural weight.

RESULTS

Gross Beta Activity

In general, there was a progressive increase in the radioactivity in the samples of flesh, bone, and scales of fish caught from mile 13.3 of the Clinch River upstream through White Oak Creek to the upper part of White Oak Lake (Table II). The data presented for the Clinch River and White Oak Creek are not true averages for the fish population as a whole because the methods for choosing the fish to be processed were highly selective. In these collections only the fish that showed a relatively high activity were used. Had there been no such selectivity in the choice of specimens to be processed, there is little doubt that the values given in Table II would have been considerably lower. For the fish from White Oak Lake, on the other hand, the only basis for selection of fish to be processed was size for ease in handling and dissection. So far as we know at the present time size alone is not a selective factor for radioactivity. Thus it is apparent that the fishes inhabiting the area nearer the source

Table II

Average Counts per Minute per Gram of Samples of Flesh, Bone, and Scale, From Fish Taken at Five Collection Sites Downstream, From the Upper Part of White Oak Lake, Together With the Numbers of Fish From Each Collection That Were Processed

Site of Collection	Number Processed	Average Counts per minute per gram of sample: Flesh	Bone	Scale
Clinch River mile 13.3	31	2	13	39
Clinch River mile 18-19	62	5	51	92
White Oak Creek	54	27	525	1204
Lower White Oak Lake	38	134	1264	1971
Upper White Oak Lake	13	423	2290	2901

of contamination generally utilize larger amounts of radioactive isotopes in their metabolic processes than do those farther away.

There are, however, considerable variations from such a general pattern. For instance, the three suckers that were taken from White Oak Creek were less radioactive than those taken from mile 18-19 of the Clinch River. Such an unusual difference may have been a result of the natural migratory habits of that species. The suckers in the White Oak Creek embayment may have come downstream in the Clinch River above the confluence with White Oak Creek and entered that embayment only a short time before they were killed. Those taken at mile 18-19 may well have followed much the same pattern of migration, having left White Oak Creek only shortly before being captured farther downstream. Further, they may have spent a considerable period of time in the White Oak embayment.

From the data in Table III it is evident that there is great variation in the average radioactivity between the different species. In comparing the average radioactivity for the three tissues listed of the crappie with those for the shad it is evident that the shad at mile 13.3 were more radioactive than the crappie whereas at mile 18-19 the crappie were more radioactive. Still, at White Oak Creek the average radioactivities of the two species for each of the three tissue are identical. Any extraordinary cause

Table III

Average and Maximum Levels of Radioactivity in Samples of Flesh, Bone, and Scale in Counts Per Minute Per Gram From Different Species of Fish From Three Different Collection Sites Below White Oak Lake, Together With the Number of Fish Processed in Each Instance

Species of Fish	Number Processed	Flesh		Bone		Scales	
		Average	Maximum	Average	Maximum	Average	Maximum
Clinch River - Mile 13.3							
Crappie	12	3	20	14	77	26	208
Shad	11	1	6	16	139	62	318
Carp	8	1	2	8	30	26	85
Clinch River - mile 18-19							
Crappie	14	9	27	60	234	123	629
Shad	42	4	19	47	454	83	703
Sucker	5	6	16	56	145	79	84
Drum	1	4	4	43	43	126	126
White Oak Creek							
Crappie	20	28	67	520	1429	1323	3670
Shad	15	28	65	526	1755	1320	2858
Sucker	3	2	5	8	20	24	55
Sunfish	14	24	49	657	2759	1236	5213
Bass	2	56	111	426	689	707	1130

for such variation is not obvious. Certainly the natural range of differences that occur could easily embrace such differences as are manifest here.

A comparison of the average and maximum counts per minute per gram for any particular species for which there were several individuals showed that the differences between the individuals within a species were as great or greater than corresponding differences between the different species. Here, again, such differences could fall within the natural range.

A comparison of the data for the individual fingerling sunfish that were collected from White Oak Creek as listed in Table IV points up the differences. Those sunfish had apparently spent their entire lives in that particular area, still the individual differences in radioactivity are remarkable. The radioactivity measurements for those sunfish were made for the entire fish and were not separated into the different tissues. Rather, the whole fish was assayed as a unit all of the tissues being grouped together.

The average count per minute per gram of flesh, bone, and scale together with the mean radioactivity indicated by scanning the whole fish are listed for each species in Table V. A comparison of these values using the activity of flesh (c/m/g) for each species is shown graphically in Figure 4. The activity

Table IV

Individual Levels of Radioactivity in Fingerling Sunfish Taken From White Oak Creek, in Counts Per Minute Per Gram of Total Body Weight

Specimen Number	Body Weight Grams	Counts Per Minute Per Gram of Body Weight	Counts Per Minute Per Gram of Fixed Solids
1	5.7	485	8,100
2	6.3	475	8,530
3	5.9	330	6,130
4	0.7	320	6,780
5	1.0	90	2,050
6	1.5	85	2,050
7	8.8	52	1,020
8	1.2	30	645
9	1.5	30	585
10	7.3	3	55

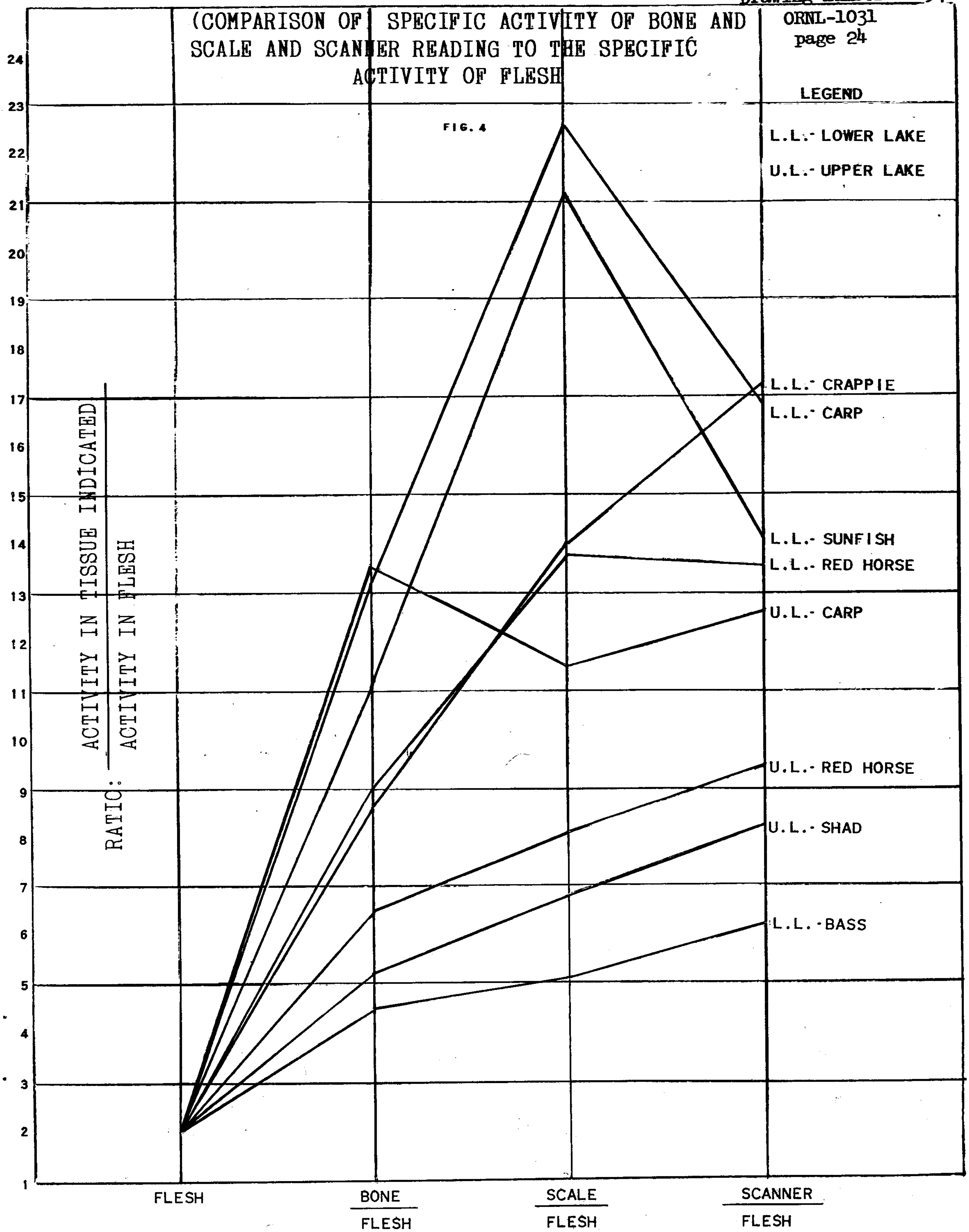

(COMPARISON OF SPECIFIC ACTIVITY OF BONE AND SCALE AND SCANNER READING TO THE SPECIFIC ACTIVITY OF FLESH
FIG. 4
LEGEND
L.L.- LOWER LAKE
U.L.- UPPER LAKE
L.L.- CRAPPIE
L.L.- CARP
L.L.- SUNFISH
L.L.- RED HORSE
U.L.- CARP
U.L.- RED HORSE
U.L.- SHAD
L.L.- BASS
RATIO: ACTIVITY IN TISSUE INDICATED / ACTIVITY IN FLESH
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
FLESH
BONE / FLESH
SCALE / FLESH
SCANNER / FLESH

Table V

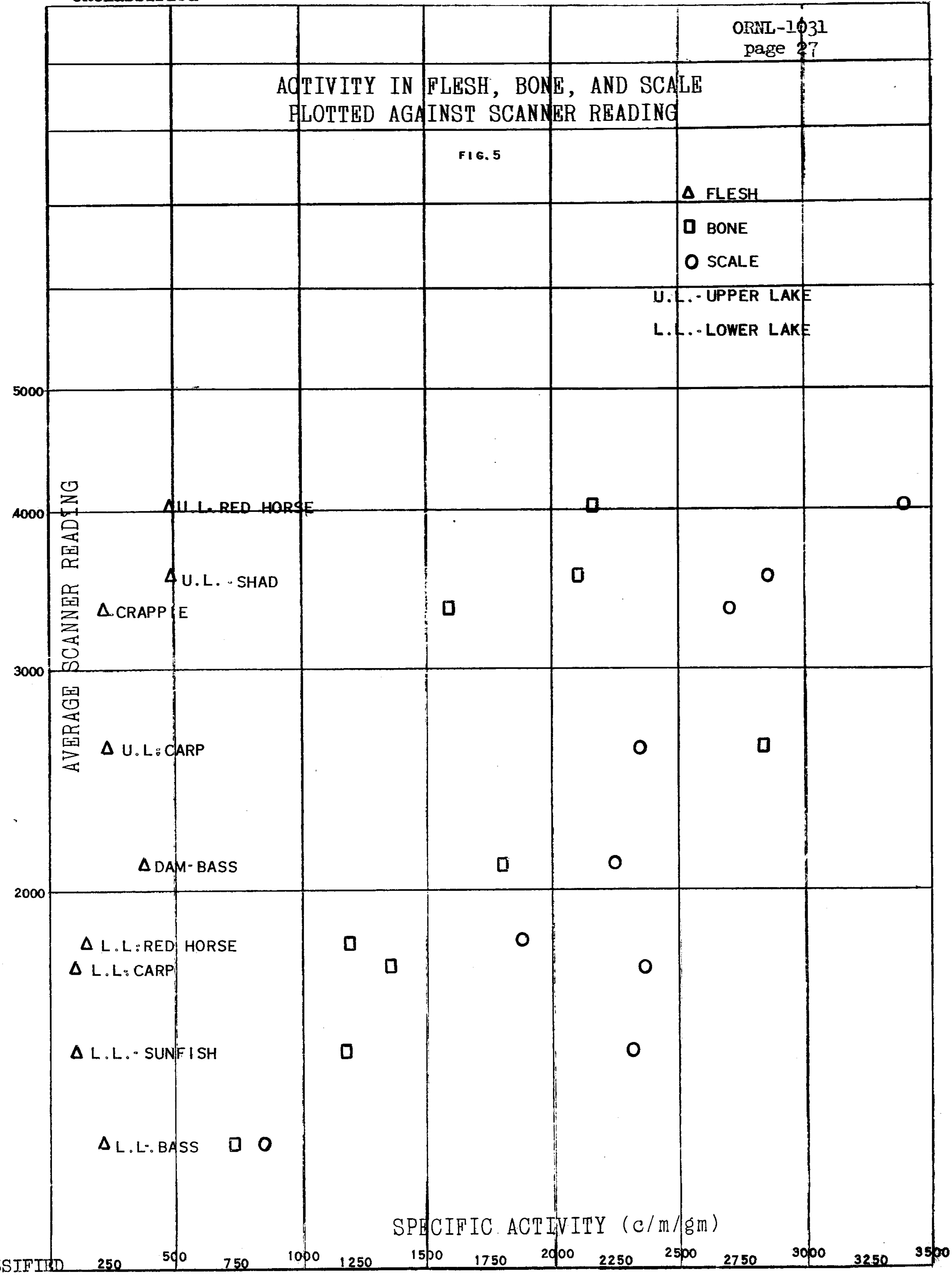
Average Activity Present in the Various Species from White Oak Lake

Species 1	Collection Point 2	Number Processed 3	Mean Scanner Value 4	Specific Activity (a) per Gram Natural Weight: counts/min/gm 5	μc/gm 6	counts/min/gm 7	μc/gm 8	counts/min/gm 9	μc/gm 10	MDIP (b) Fish Flesh in ounces 11
Bass	L.L. (b)	2	1264	203	91.4×10^{-5}	727	327.5×10^{-5}	844	380.2×10^{-5}	5.7
	Dam (c)	1	2101	370	166.7×10^{-5}	1789	805.8×10^{-5}	2231	1004.9×10^{-5}	3.2
Crappie	L.L.	1	3333	206	92.8×10^{-5}	1588	715.3×10^{-5}	2696	1214.4×10^{-5}	5.7
Sunfish	L.L.	6	1490	114	51.4×10^{-5}	1171	527.4×10^{-5}	2305	1038.2×10^{-5}	10.4
	U.L.	0	----	---	-----------	----	-------------	----	-------------	----
Carp	L.L.	18	1740	109	49.1×10^{-5}	1348	607.2×10^{-5}	2364	1064.8×10^{-5}	10.4
	U.L.	3	2580	222	100.0×10^{-5}	2829	1274.3×10^{-5}	2349	1058.1×10^{-5}	5.4
Redhorse	L.L.	10	1828	146	65.8×10^{-5}	1192	536.9×10^{-5}	1878	845.9×10^{-5}	7.9
	U.L.	4	4033	475	214.0×10^{-5}	2161	973.4×10^{-5}	3382	1523.4×10^{-5}	2.5
Shad	L.L.	0	----	---	------------	----	------------	----	-------------	---
	U.L.	6	3554	489	220.3×10^{-5}	2106	948.6×10^{-5}	2856	1286.4×10^{-5}	2.5

(a) Activity is given in counts per minute at 10% geometry (or 10% of total disintegrations).
(b) L.L. - Lower lake area.
U.L. - Upper lake area.
MDIP - Maximum daily intake permitted.
(c) This fish was found at the dam and had been partly destroyed.

in the flesh ranged from 109 c/m/g for carp from the lower lake area to 489 c/m/g for shad from the upper lake area. Figure 5 shows a comparison between the average activity found in each of the three tissues, bone, flesh, and scale and the mean scanner reading for the species concerned.

So far as fish from White Oak Lake were concerned, there was no conclusive evidence that radioactivity was lost from volatilization by muffle furnace ashing of bone and scale. However, there were indications that some loss occurred (approximately 6 per cent) in flesh samples and those counts were corrected accordingly[4]. A few studies were made to determine the loss of activity by ashing the internal organs. Such losses of activity within one week after collection in a number of samples of various organs ranged from 2 to 35 per cent, most losses falling within the 10 to 20 per cent range. The amount of loss in particular organs was quite inconsistent. The liver, gills, and kidneys usually lost large amounts from both decay and volatilization. Since adequate data were not obtained to determine the loss due to each of the two factors, decay and volatilization, and the per cent of loss varied greatly in like samples of internal organs of different fish, no corrections for losses due to decay and volatilization were made for those tissues.


ACTIVITY IN FLESH, BONE, AND SCALE
PLOTTED AGAINST SCANNER READING
FIG. 5
Δ FLESH
□ BONE
○ SCALE
U.L.- UPPER LAKE
L.L.- LOWER LAKE
AVERAGE SCANNER READING
5000
4000
3000
2000
U.L. RED HORSE
U.L. - SHAD
CRAPPIE
U.L. CARP
DAM-BASS
L.L. RED HORSE
L.L. CARP
L.L. - SUNFISH
L.L. BASS
SPECIFIC ACTIVITY (c/m/gm)
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500

Chemical Analysis

Radiochemical analyses were made on samples of flesh, bone, and scales. These analyses were run on June 22 and July 13, 1949, the fish having been caught from White Oak Lake the previous May 2 and 3.

Strontium^{89} with a half-life of 55 days would have decreased during that period before analysis. It was determined that 8 to 10 per cent of the strontium activity present at the time of separation was strontium^{89} and the remainder was strontium^{90} having a 25 year half-life. In equilibrium with strontium^{90} is yttrium^{90} with a half-life of 62 hours. Cesium^{137}, found in the flesh of fish, has a half-life of 33 years. Because of the long half-lives of cesium and strontium-yttrium^{90}, the activity due to them would not have changed appreciably in the time between collection and chemical analyses. The results are shown below:

Fish Bones	Fish Scales	Fish Flesh
52% of activity Sr^{89} and Sr^{90}	53.5% of activity Sr^{89} and Sr^{90}	96.8% of activity due to Cs^{137}
48% of activity Y^{90}	46.5% of activity Y^{90}	1.7% of activity due to Sr^{89} and Sr^{90}
		1.5% of activity due to Y^{90}

DISCUSSION

Fish Habits

The food habits of the different species of fish found in the Clinch River are extremely varied. Fingerlings generally feed in shallow water on plankton, algae, and insects, whereas older fish usually live in deeper water but may frequently feed in shallow water. Bluegills feed principally on plankton and insects. Crappie eat plankton and algae while small but after reaching larger sizes feed chiefly on small fish (shad) and insects. Carp, redhorse, and buffalofish are "rough fish" and root in the bottom and shore muds in quest of food materials[6].

The distances covered by fish in quest of food depend largely on the feeding habits as shown by the various sunfishes - bluegills have a rather limited range, whereas crappie range over greater distances and one tagged largemouth bass was known to have travelled upstream from Norris Dam for a distance of over 120 miles in a single season.

Fish may be affected by fluctuation in water elevation. If the water level falls slightly they may seek deeper water and if the level rises they move into embayments or estuaries of small streams for protection or for food. The level of water in White Oak Creek is subject to frequent fluctuation. This may result in the fish population being slightly more transient than in other areas.

Many small fish and some adults are consumed by predators. Some fish, snakes, turtles, birds, and mammals feed on dead fish. Thus the radioactive contamination of water may result in possible distribution of certain radioactive isotopes on land and water by means of biological life cycles. With the existing evidence, it is impossible to evaluate the effect of minute quantities of radioactive materials spread in this manner on the natural ecological balance in streams.

Permissible Levels of Radioactivity

The amounts of some radioactive elements permissible for ingestion have been calculated for standard man (70,000 gms). These and other values upon which calculations are now being based were agreed upon at the Chalk River Conference on September 29 and 30, 1949[5].

Values for $cesium^{137}$ were not established at this conference and were calculated for this study. The values used for calculating the permissible amount of $cesium^{137}$ which could be consumed per day are listed below:

0.3 rep per week level of maximum permissible exposure
1 rep = 93 ergs/gram in tissue
30,000 grams muscle (standard man)

The above values were agreed upon at Chalk River Conference (see above).

100% absorption from ingestion
45% accumulation in muscles, principal organ of retention
15 days half time in the body for cesium

Values of J.G. Hamilton(1).

The average energy for cesium^{137} was calculated (1/3 of 0.55 Mev beta + 0.66 Mev gamma or 0.84 Mev).

By using the above values, the maximum permissible daily intake of cesium^{137} was computed as 2.7 μc.

At the Chalk River Conference the maximum permissible concentration of Sr^{90} - Y^{90} in water was established as 2×10^{-6} μc/cc, the amount of water intake per standard man per day as 2,200 cc. This would result in a maximum permissible daily intake of 4.4×10^{-3} μc of Sr^{90} per day.

By comparison of the amounts of Cs^{137} and Sr^{90} permitted, the critical radioactive component is Sr^{90} even though it comprises only 3% of the activity in fish flesh. Since cesium accumulates principally in the flesh and strontium in the bone, the amount of fish flesh which might be eaten by a human being would depend upon the isotope in which the maximum permissible intake was first exceeded.

By using the value for strontium as explained above the amounts of fish flesh which might be permitted to be eaten per day were calculated to be 36 pounds from mile 13.3 based on the average for the higher 11 per cent; 14.4 pounds from mile 18-19 based on the higher 13 per cent; and 2.7 pounds from White Oak Creek based on the somewhat higher 33 per cent. The amounts of different species of fish from White Oak Lake which might be eaten are listed in ounces in Table 5, column 11.

CONCLUSIONS

The fish survey program as an exploratory project served two principal purposes: (1) it gave a better understanding of the problems concerned with the consumption of fish from waters directly below Oak Ridge National Laboratory; and (2) it suggested improvements in methods and procedures which could be applied in future survey work.

Some fish were found to have measurable amounts of radioactivity as far downstream as mile 13.3 or almost seven and a half miles from the mouth of White Oak Creek. However, except for fish from White Oak Creek and White Oak Lake, the public health hazard appears insignificant. "No Fishing" signs have been posted at White Oak Lake since 1944. Although not recommended, it is possible that fish from White Oak Creek might be eaten by human beings without adverse effects. With increasing knowledge of human physiology, in relation to isotopes and radiation damage, values for calculating maximum permissible dosage will possibly change. Levels that now appear safe may or may not be considered hazardous in the future.

By using present values for calculating tolerance levels the following amounts of fish might be consumed per day from the respective locations: mile 13.3, 36 pounds; mile 18-19, 14.4 pounds; White Oak Creek, 2.7 pounds, White Oak Lake from 2.5 to 10.4 ounces (varying with species - see column 11, Table V).

Any survey in the future should be planned and organized in such a way that sufficient qualified personnel will be available to prepare and count samples as soon after collection as possible. This would not be so important, however, if only measurements of gross activity in flesh, bone, and scale were desired, because the activity in these tissues was found by chemical analysis to be very largely from long-lived isotopes. Either all fish caught should be analyzed or a representative number from each group (or species) should be selected. The total catch should be evaluated as to its representation of a fair sampling of fish from the area.

ACKNOWLEDGEMENTS

The studies described in this report constitute one phase of a broad cooperative program of survey studies and numerous agencies and individuals have assisted in them. The project was initiated during the summer of 1948 largely through the efforts and under the general supervision of Dr. L.R. Setter, then on full-time loan from the Health and Safety Division of the Tennessee Valley

Authority to the Health Physics Division, Oak Ridge National Laboratory. The author has had the primary responsibility for preparation and radioassay of the samples, assembly and analysis of the data, and drafting of the report.

The extensive work required in the field collections, the laboratory measurement and processing of specimens, and the development of equipment and techniques for the studies has involved more or less the entire staffs of the Fish and Game Branch of TVA and of the Radioactive Waste Disposal Research Section of the Health Physics Division, ORNL. The TVA assisted particularly in providing boats and sampling equipment and in planning and executing the collections of fish. Other Health Physics groups helped by constructing the scanning instrument, by counting room service and by frequent consultations. Mr. Sam A. Reynolds and Mr. T.H. Handley of the Analytical Chemistry Group performed the radiochemical analyses. Dr. Louis A. Krumholz, fisheries biologist of the Ecological Study Group, gave valuable assistance in the editing and revision of the manuscript.

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APPENDIX

Notes submitted by Dr. R.W. Eschmeyer with reference to the samplings of fish from White Oak Lake on May 2 and 3, 1949.

Lower Sampling - May 2

Largemouth bass were represented by three large adults, no young fish. Some younger bass had been expected. No other bass taken.

Crappie were represented by a very few yourg and one adult. More were expected. The presence of young suggests that reproduction was successful, at least to some extent.

Shad were abundant as expected, and at least three year classes (one, two, and three year olds) were well represented. Reproduction had apparently been excellent each year for several years.

Carp, like the shad, were abundant and various age groups were well represented indicating that reproduction was successful.

Bluegills were present in moderate numbers and various age groups were represented. No other species of sunfish were observed.

Redhorse were numerous. Except for one adult female (ripe), the fish all represented one age group - presumably the one-year-old group.

In this locality a few bullheads or catfish were expected but aside from this, and the absence of young bass, the population appeared to be about as anticipated. The fish were in good condition and the size of the one-year-old fish suggests that the growth rate was good. The young shad had a decided red coloring under the lower jaw while dying and some had bloody spots on the skin. The latter may have been due to some disease. One adult bass had gills which were more brilliant red than I recall having seen before and the gill filaments also appeared to be abnormal.

Of the above species, the bass, crappie, and bluegills are nestbuilders; the other species spread their eggs on the vegetation or on the bottom.

Upper Sampling - May 3

This sampling consisted chiefly of adult shad, which were extremely abundant. The remainder of the take consisted of carp, bluegills, and redhorse, though these species were not abundant. Year-old shad were also represented.

The decided concentration of adult shad may have been associated with spawning. Their extreme abundance here may explain the scarcity of other fish. When one species tends to concentrate in some locality the competing species seem to tend to move elsewhere.

Of the species observed in the lake, carp, shad, redhorse, and crappie probably range widely in the lake. The bluegills probably tend to remain in local areas.

No minnows in the catch is also unusual.

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6-2-51