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AN ECOLOGICAL SURVEY OF WHITE OAK CREEK, 1950 – 1953

By
Louis A. Krumholz

February 1954

Tennessee Valley Authority
Norris, Tennessee

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ORO-587(Vol. I)
HEALTH AND SAFETY

AN ECOLOGICAL SURVEY OF WHITE OAK CREEK

1950-1953

Prepared By

Louis A. Krumholz

Conducted by the Tennessee Valley Authority for the

Atomic Energy Commission under Contract AT(40-1)-221

February 1954

PREFACE

I was pleased when informed by Dr. Roth that the Division of Technical Information of AEC planned to print the 1954 Report on the Ecological Survey of White Oak Creek and Lake as an AEC document. Although several years have passed since the survey was completed, publication of the report seems to be in order for several reasons.

The 1954 report is not the final answer with respect to the effect of radioactive wastes upon the flora and fauna of the White Oak Lake area or in comparable situations in other localities. This is true especially with respect to the long-range effects because of the short period of time available for the study. The report, however, shows that an Atomic Energy facility can be operated without catastrophis effect upon the local biota--terrestrial and aquatic.

The 1954 report merits wider distribution than it has received to date because of the intrinsic value of the included data covering botany, limnology, and fisheries biology. Also no report on the effect of radioactive wastes upon the flora and fauna comparable in scope and character involving a fresh-water-terrestrial study unit has appeared in print. Several additional reasons may be mentioned. Ecological studies regarding the effect of atomic wastes upon organisms--plant and animal--are being continued at Oak Ridge and are in progress elsewhere. The extensive and reliable information--data and provisional conclusion of the 1954 report--may be profitably examined by these workers. A number of people who have seen published summaries of the report have requested the data upon which these summaries were based. The increased employment of atomic energy in industry and power production calls attention to the urgent need for additional efforts in this field in order that managers of atomic facilities may have available to them valid information regarding the effects of radioactive waste upon the biota of field and stream. It is the hope, therefore, that the data--in botany, limnology, and fisheries biology; the tentative conclusions; and the suggestions for future studies may serve as helpful guides to those already in this field and at the same time stimulate additional workers to enter this field.

The report should be of interest to all who study aquatic ecology and to many others including many laymen.

A. H. Wiebe
Tennessee Valley Authority (Retired)

Norris, Tennessee
October 3, 1962

FOREWORD

This report covers the biological work performed as part of an ecological survey of White Oak Creek, Oak Ridge, Tennessee.

The Ecological Survey of White Oak Creek was conceived in the minds of certain staff members of the Atomic Energy Commission, the Tennessee Valley Authority, and the U. S. Fish and Wildlife Service who felt that despite the claims that atomic wastes from the Oak Ridge National Laboratory could be contained, enough radioactive material in liquid form might be released into White Oak Creek and thence into Watts Bar Reservoir where it could have a deleterious effect upon the local flora and fauna. Another thought in the minds of these individuals was that if organisms manifested a certain degree of tolerance some economies in waste disposal might be effected.

The AEC requested the TVA to make this study because neither the Commission nor any of the private firms that had operating contracts at Oak Ridge were willing to conduct this type of work. Under these circumstances, TVA seemed to be the logical choice because of (1) its interest in stream sanitation, (2) its employment of properly qualified personnel, and (3) its geographic proximity to Oak Ridge.

It is not the object of this foreward to outline and dissect the contents of the report that follows. Suffice it to say that although it contains few definitive answers, it proves rather conclusively that the operation of the Oak Ridge Atomic Energy installation produced no catastrophic effect upon the flora and fauna of White Oak Creek, White Oak Lake, and the local watershed. Long-range effects could not be determined during a three-year study period. For this reason the report includes a number of suggestions for additional investigation--ecological in nature.

The report contains data of considerable volume and variety, some of which can be interpreted and applied immediately, and some of which will not make sense or find application until additional work has been performed. It has been the deliberate policy in the preparation of this report to include all data and observations regardless of their meaning at the moment. The desire was to make all available information a matter of record, and not to increase the size of the report. The volume, the variety, and the quality of the contents of this report speak well, not only of the ability of the people who did the work, but bear testimony to their industry as well.

After Contract AT(40-1)-221, TV-7699A, between AEC and TVA had been approved, the Authority's responsibilities were assigned to its Director of Health, who in turn delegated the responsibility for the biological aspects of the survey to the Director of Forestry Relations on a work-order basis. However, late in August 1953, when all the survey work except the clean-up of odds and ends and the preparation of the final report on biology had been completed, the delegation within TVA was transferred from the Division of Health and Safety to the Division of Forestry Relations.

This work was financed by the AEC. Some funds were budgeted direct to TVA--on reimbursable basis--and some were budgeted indirectly through Oak Ridge National Laboratory--this applies especially to funds to cover laboratory services.

INTRODUCTION

The Ecological Survey of White Oak Creek was established on January 1, 1950, as a cooperative program between the Tennessee Valley Authority and the Atomic Energy Commission 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. Under this agreement, the TVA was to set up a program of survey and study to determine the effects of radioactive waste materials, produced in the course of production operations, on the ecology of the flora and fauna of White Oak Creek and contiguous sections of the Clinch River. The scope of the problem is best outlined by a statement arrived at by the Advisory Committee at their meeting on January 27, 1950, as follows:

> "What radioactive elements have accumulated in living things in the stream; where have they accumulated; and what has been the effect on survival rates, population balances, and types of organisms?"

Accordingly, an ecological survey program was initiated to: (1) make a physical survey of the drainage area of White Oak Creek; (2) study the limnology of White Oak Creek and Lake below the point of entrance of radioactive wastes, and to make comparable studies on uncontaminated streams in the area; (3) to study the biology of the fish population of White Oak Lake; and (4) to study the accumulation and effects of radiomaterials on the biota, with particular reference to the fish life and its ecology.

Some time was required for recruiting suitable personnel and the actual field work did not get underway until June 1950. The field work of the overall survey program continued through June 30, 1953.

In setting up the survey, the study was divided into three parts:

1. Botany. The following studies were part of the botanical survey: (a) a collection of all the vascular plants and bryophytes in the area; (b) a study of the successional aspects of the vegetation; and (c) a study of the accumulation of radiomaterials in as many different plants as feasible, along with radiochemical or other such analyses as were required to determine which radionuclides were utilized by the plants.

2. Limnology. This phase of the program included: (a) a physical and chemical survey of the waters of White Oak Creek and Lake together with studies of the normal limnological biota; (b) the occurrence, magnitude, and duration of plankton pulses; and (c) a study of the accumulation of radiomaterials by the planktonic organisms and other invertebrates together with suitable analyses to determine which radioelements had been concentrated by the different organisms.

3. Fisheries Biology. This phase of the study was expanded to take in the studies on all vertebrates and included: (a) six semi-annual estimates of the size and composition of the fish population of White Oak Lake followed by the eradication of the existing fish population by using rotenone; (b) the dissection of fishes in an effort to establish the percentage composition, by weight, of the various tissues of the body; (c) the food habits of some of the fishes as determined by analyses of their stomach contents; (d) the accumulation and selective concentration of radiomaterials in the different tissues of fishes, amphibians, reptiles, shorebirds, waterfowl, and mammals;

(e) radiochemical analyses of selected samples to determine the amounts and kinds of radiomaterials accumulated by the different animals; and (f) the banding and releasing of migratory waterfowl in an effort to maintain some surveillance over the movements of such birds frequenting the area.

During the course of the survey, attached personnel kept records of the various kinds of animals observed in the field. In some instances, the animals were brought to the laboratory and identified; in others, the identity was recorded in the field. Thus, all members of the survey staff contributed to that list of animals which is included as an appendix to the Introduction. From this list, although it is known to be far from complete, and from the list of plants included in the report on Botany, it is evident that there are a great many individual biological factors contributing to the ecology of the area. Because of this vast array of flora and fauna, it was impossible, in the time alloted, to study any particular group in detail. Rather, those organisms and communities which were believed to best exemplify the overall picture were selected for study. It is felt that this report includes sufficient information on which to base general assumptions regarding the effects of radioactive waste materials on the flora and fauna of a selected area, and to suggest possibilities for future necessary research.

It is unfortunate that adequate time was not provided for a more complete and comprehensive analysis of the data gathered during the survey. No provision was made for time to review the related literature and to compare the data at hand with the findings of others. Consequently, this report includes only a compilation and analysis of the survey data, together with a documentation of the results and recommendations for studies to be undertaken in the future.

Description of the Area

The drainage area of White Oak Creek, which is 3,850 acres in extent, is tributary to the Clinch River and is located in Roane County, Tennessee. The topography of the area 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, 1952).

White Oak Creek rises from several sources between Chestnut and Haw Ridges and the main stream flows in a southwesterly direction across Bethel Valley over limestones of the Chickamauga group to Haw Gap just below the site of the Oak Ridge National Laboratory. The stream then 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.

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 above the Clinch River, which was in existence some time prior to the impoundment of the lake. In 1941, the highway fill was raised to its present level by the Tennessee Valley Authority and the present concrete culvert installed (Smith, 1945). During the summer of 1943, a coffer dam of interlocking steel sheet piling was driven in the form of a rectangle around the upstream side of the concrete culvert and the spillway was closed in October of that year. A vertical sliding gate, four feet by six feet, with a top elevation of 750 feet above mean sea level, is used to control the water level in the lake. Above that elevation, the water spills freely over the top of the piling. At full pool, the lake extends about a mile upstream from the dam and has an area of 44.19 acres (Fry, 1953).

Inasmuch as the lake was constructed to serve as a final settling basin for the waste effluents from the Oak Ridge National Laboratory, it is rarely kept at full pool. Rather, the water level is maintained at an elevation of approximately 748, at which level the lake has an area of 35.87 acres. In this report, that pool level and acreage will be 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 is badly overgrown with willows and other woody plants, and many dead trees, flooded out by the impounded water, either remain standing or have toppled over. Old barbed wire fences are still present in parts of the lake along with a considerable amount of waterlogged debris which is scattered over much of the present lake bottom. The presence of this sunken debris has caused considerable difficulty in the setting and lifting of nets, in seining, and in other operations pertinent to the execution of an aquatic survey.

A series of two small earthen fills were placed across White Oak Creek at distances of 2.0 and 2.27 miles above the Clinch River (Setter and Kochtitzky, 1950) to impound water which would serve as preliminary settling basins to White Oak Lake. The construction of the lower fill caused the impoundment of water in a rather extensive marshy area which has been called the Intermediate Pond. Information supplied by Mr. J. S. Cheka of the Oak

Ridge National Laboratory places the time of construction for both fills either late in 1943 or early the following year. Both of those fills failed during a flood following the heavy rainfall of September 29, 1944 (Smith, 1945). However, much silt had already accumulated in the Intermediate Pond where it remains intact along with much of the original fill.

White Oak Creek receives the waste effluent from the Oak Ridge National Laboratory from a series of sources between 2.34 and 3.0 miles above the Clinch River (Setter and Kochtitzky, op. cit.). The principal source of effluent is from the Settling Basin which empties through a weir box directly into the creek at a point about 2.54 miles above the Clinch River. The average daily effluent from the Settling Basin, based on figures compiled by the Chemical Separations Department, Operations Division, Oak Ridge National Laboratory, amounted to about 650,000 gallons per 24-hour period during 1953, a decrease of approximately 11 percent 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 per day. The point of effluence from the Settling Basin serves, for purposes of this report, as a dividing line between the upper or uncontaminated portion of White Oak Creek and the lower contaminated section.

A considerable portion of the drainage area of White Oak Creek was used for agricultural purposes prior to 1942. According to Fry (1951), about 60 percent of the area was covered with forest at that time and the remainder, with the exception of the area used for laboratory operations, consisted of old fields in various stages of succession. Judging by the present cover types, some of the old fields have been abandoned for at least 50 years; some having stages of succession from weeds and grasses to mature pine and hardwoods in the overstory. In addition to the natural succession, there are several pine plantings placed by the Civilian Conservation Corps that are, about 20 years old.

During the course of the survey, there was considerable construction underway on the laboratory site. As a result, many denuded areas were formed, and this, coupled with the high annual rainfall, resulted in a considerable amount of silt being carried into the streams and ultimately into White Oak Lake. Consequently, the waters of the lake were almost constantly muddy during the early part of the survey. As soon as it was feasible, those denuded areas were seeded and mulched, and during the past year or so the waters of the lake have remained relatively clear.

The climate of the area is usually characterized by relatively mild winters and hot summers. The average annual rainfall is 52 inches and is fairly evenly distributed over the year. During the survey, exceptional periods of precipitation, drought, and low temperatures were recorded. The summer of 1950 was marked by unusually heavy rainfall which resulted in luxurious plant growth. The fall of 1950 was mild until the end of November when the lowest temperatures of the last 80 years were recorded and were accompanied by record snowfall. At that time, White Oak Lake was completely covered with ice which persisted for a period of 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 considerably. The fall and winter of 1951-1952 was drier than normal and 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 drought that year 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 close to normal, but by July 1 the signs of a drought, even more serious than the one of the preceding year, were in evidence.

Personnel

This list of personnel includes only those persons, employed by the Tennessee Valley Authority, who were directly concerned with the biological aspects of the Ecological Survey of White Oak Creek.

Dr. A. H. Wiebe, Chief, Fish and Game Branch, Division of Forestry Relations, was supervisor of the work in fisheries biology from the start of the program in June 1950. In April 1951, he assumed responsibility for the planning and execution of the entire biological program.

Mr. Felton R. Nease was in charge of the botanical investigations for the entire course of the survey from June 12, 1950 to August 1, 1952. Mr. Nease prepared the final report of the botanical section.

Mr. Richard C. Hodgson and Mr. Xen K. Motsinger assisted Mr. Nease during the summer of 1951.

Mr. Robert D. Ross was in charge of the limnological investigations from June 19, 1950, to June 30, 1951.

Mr. William T. Helm was in charge of the limnological investigations from October 1, 1951, until the completion of that phase of the survey, September 1, 1953. Mr. Helm was responsible for the preparation of the final report of the limnological section including the work performed by Mr. Ross.

Dr. Louis A. Krumholz was in charge of the fisheries biology investigations for the entire period of the survey from June 19, 1950, to February 28, 1954. Dr. Krumholz prepared the final report on the fish population studies for White Oak Lake and the accumulation of radioactive materials in fishes and other vertebrates. He was also responsible for the technical administration of the survey after April 1951, and for the final preparation of the overall report. Dr. Krumholz prepared all graphs, maps, and charts for the final report.

Mr. William T. Miller was fisheries biologist from August 1, 1951, until January 31, 1954. Mr. Miller prepared the final report on the food habits of fish in White Oak Lake, the collection and accumulation of radioactivity by the littoral bottom fauna of White Oak Lake, and the banding studies on waterfowl. Mr. Miller also collaborated with Dr. Krumholz in the preparation of the report on fish populations.

Mr. D. William Yambert, Jr., was fisheries technician from June 19, 1950, to February 1, 1951.

Mr. Edwin R. Eastwood was fisheries biologist from August 13, 1951, to January 31, 1954. He assisted Mr. Miller and other members of the survey staff with the laboratory and field work.

In addition to the above, the following persons were assigned to the survey by the Waste Disposal Research Section of the Oak Ridge National Laboratory:

Mr. A. H. Emmons, radiochemist, from July 1, 1950, to June 1, 1951.

Mr. Bernd Kahn, radiochemist, from August 1, 1951, to June 30, 1953.

Mrs. Venus I. Knobf assisted with many different phases of the laboratory work from July 1, 1950, to September 1, 1952, especially in the accumulation of radioactivity in waterfowl.

Mr. William A. Mills assisted with the laboratory work, and also in the field, from October 1, 1952, to June 30, 1953.

Acknowledgements

The Ecological Survey of White Oak Creek is indebted to the various members of the Advisory Committee for much of the preliminary planning and outlining of the study program, and for continued guidance throughout the period of the survey. Although the membership of the committee changed during the course of the study, the following persons served as members:

Dr. Elda E. Anderson, Oak Ridge National Laboratory

Mr. Robert N. Clark, Tennessee Valley Authority, Chattanooga

Mr. Charles M. Davidson, Tennessee Valley Authority, Chattanooga

Dr. T. F. Hall, Tennessee Valley Authority, Wilson Dam, Alabama

Mr. Elmer Higgins, U. S. Fish and Wildlife Service, Washington, D. C.

Mr. Joshua Z. Holland, U. S. Weather Bureau, Oak Ridge

Mr. F. W. Kittrell, Tennessee Valley Authority, Knoxville

Dr. Edward McCrady, Atomic Energy Commission, Oak Ridge

Dr. Karl Z. Morgan, Oak Ridge National Laboratory

Prof. Royal E. Shanks, University of Tennessee, Knoxville

Dr. Charles S. Shoup, Atomic Energy Commission, Oak Ridge

Dr. Gordon E. Smith, Tennessee Valley Authority, Wilson Dam, Alabama

Prof. Paris B. Stockdale, University of Tennessee, Knoxville

Dr. Forrest Western, Oak Ridge National Laboratory

Dr. A. H. Wiebe, Tennessee Valley Authority, Norris, Tennessee

In addition, Dr. O. M. Derryberry, Director, Division of Health and Safety, Tennessee Valley Authority, Chattanooga, served in an advisory capacity although not a member of the committee.

We are also indebted to the following members of the Technical Committee who served at various times during the study period:

Mr. Edwin R. Eastwood, Tennessee Valley Authority

Mr. A. H. Emmons, Oak Ridge National Laboratory

Mr. James M. Garner, Jr., Oak Ridge National Laboratory

Dr. Robert P. Geckler, Atomic Energy Commission

Mr. William T. Helm, Tennessee Valley Authority

Mr. Joshua Z. Holland, U. S. Weather Bureau

Mr. Bernd Kahn, Oak Ridge National Laboratory

Mr. F. W. Kittrell, Tennessee Valley Authority

Mr. O. W. Kochtitzky, Jr., Tennessee Valley Authority

Mrs. Venus I. Knobf, Oak Ridge National Laboratory

Dr. Louis A. Krumholz, Tennessee Valley Authority

Mr. William T. Miller, Tennessee Valley Authority

Mr. Roy J. Morton, Oak Ridge National Laboratory

Mr. Felton R. Nease, Tennessee Valley Authority

Mr. Robert D. Ross, Tennessee Valley Authority

Dr. Charles S. Shoup, Atomic Energy Commission

Mr. William F. Vaughan, Tennessee Valley Authority

Dr. A. H. Wiebe, Tennessee Valley Authority

Mr. D. William Yambert, Jr., Tennessee Valley Authority

We gratefully acknowledge the assistance and guidance furnished by personnel of the Division of Research and Medicine of the Atomic Energy Commission at Oak Ridge, especially Drs. Edward McCrady, C. S. Shoup, and R. P. Geckler, Mrs. Alice Mr. Corley, and Mr. H. J. McAlduff.

We are deeply indebted to Dr. Karl Z. Morgan, Director, Health Physics Division, Oak Ridge National Laboratory, for providing office, laboratory, and counting room facilities during the entire period of the survey. Dr. Morgan and members of his staff also served to expedite the use of facilities on a laboratory-wide scale. Of those staff members, Dr. Forrest Western, Associate Director, who helped coordinate the activities of the survey with those of the laboratory; Dr. E. E. Anderson, Chief, Education and Training Section, who replaced Dr. Western in a liaison capacity and who offered advice in the preparation of manuscripts; Mr. R. J. Morton, Chief, Waste Disposal Research Section, in whose section the laboratory work was done; Mr. J. C. Hart, Chief, Applied Health Physics Section, and members of his section including Messrs. A. D. Warden, Jr., H. H. Abee, J. C. Ledbetter, and the various field men who frequently were of invaluable assistance; Mr. C. E. Haynes, Assistant to the Director; Mr. P. E. Brown, in charge of counting room facilities; and Dr. H. P. Yockey, Technical Assistant to the Director, are to be especially thanked. Many other persons attached to the Health Physics Division, as well as other divisions of the Oak Ridge National Laboratory assisted in many ways.

Personnel of other groups attached to various projects in the Oak Ridge area were very helpful. Dr. C. P. Straub and Mr. M. W. Carter of the Public Health Service provided technical data and advice. Dr. C. L. Comar, Laboratory Director, UT-AEC Agricultural Research Program, and members of his staff provided technical assistance. Lt. Col. J. H. Rust, Veterinary Corps, U. S. Army, gave technical assistance in the preparation of histological material, and collaborated with Dr. Krumholz in the publication of a paper on the occurrence of an osteogenic sarcoma in a muskrat caught near White Oak Creek.

Mr. Willis M. Baker, Director, and Mr. Richard Kilbourne, Assistant Director, Division of Forestry Relations, Tennessee Valley Authority, Norris, Tennessee, showed genuine interest in the progress of the study, and gave needed encouragement and advice. Dr. A. H. Wiebe, Chief, Fish and Game Branch, supervised the study during its entirety and contributed many valuable suggestions and criticisms. Without his personal interest and knowledge of the problem, the success of the survey would have been much more limited. Mr. Andrew C. Hair willingly assisted in the procurement of materials and equipment. Messrs. C. J. Chance, O. F. Haslbauer, D. E. Manges, and Earl R. Cady helped during the rotenone study as well as in some of the other field work. The final copy of this report was typed by Mrs. Cordelia B. Pointer. Other members of the division also helped on numerous occasions.

ABSTRACT

The ecological survey was established to determine the effects of radioactive wastes on the flora and fauna indigenous to the drainage area of White Oak Creek. The field work of the survey extended from mid-June 1950 to the end of June 1953.

The biological phase of the program was divided into three sections: botany, limnology and invertebrate biology, and vertebrate biology. The botanical studies extended from June 1950 until September 1, 1952, whereas the studies on the faunal aspects continued for the entire three-year period.

All samples of tissues were prepared for radioassay by a modification of the nitric acid wet digestion method developed specifically for this program by L. A. Krumholz and A. H. Emmons. A paper describing that method in detail was published in the open literature.

Botany

Any attempt to interpret the present flora is difficult because of the recent history of the area under consideration. The effects of fire, grazing, and other disturbing influences have not been adequately investigated. For these, and perhaps other reasons as well, it cannot be said that all the normal elements of this portion of the Ridge and Valley Province are present. In fact, there is good evidence that some species of plants may have already been eliminated from the study area. Between August 1950 and June 1952, 38 species of bryophytes, referable to 31 genera

and 19 families, together with 392 species of vascular plants referable to 258 genera and 91 families were collected and identified. Individual specimens of each of those different plants were placed in the collections at each of the following institutions, U. S. National Herbarium, Washington, D. C.; University of Tennessee, Knoxville; and Duke University, Durham, North Carolina, as indicated in Appendix I to the section on Botany.

The general survey of the area revealed no unusual conditions in the vegetation. The morphology of plants growing in the areas most heavily contaminated with radiomaterials appeared normal in every respect. The ecological succession among the various species of plants around White Oak Lake and Creek showed no noticeable differences from similar sites near other reservoirs in the Tennessee Valley.

The only unusual plant was collected from a clone of broad-leaved cat-tail (*Typha latifolia*) which had a variegated leaf pattern. That plant was growing in the Settling Basin at the Oak Ridge National Laboratory. Such a pattern of coloration is extremely rare in that species and it is believed that it was induced by its long period of exposure to the radiation from waste materials in the basin. However, when portions of that clone of cat-tail were transplanted to other areas, the variegated color pattern was lost.

In order to determine the extent of accumulation and the locations of the primary areas of deposition of radiomaterials in the various plants throughout the study area, several methods, both qualitative and quantitative, were used. Autoradiograms were prepared from various tissues of a selected group of plants to ascertain in which tissues the greatest concentrations of radioelements were deposited. Samples of the various tissues of different plants from large numbers of individual samples, collected over a wide area at all seasons of the year, were assayed for gross beta radioactivity. Groups of samples from each of ten plants of the same species, growing in a limited area, were similarly assayed to determine the extent of variation between individual plants. In addition, radiochemical and spectrographic analyses were made on selected samples in order to identify which radionuclides were concentrated.

The general results from the autoradiography are three-fold:

1. The amounts of radiomaterials accumulated in all plants were progressively smaller in amount from the Settling Basin to the mouth of White Oak Creek. Samples of plants collected just below the basin provided good autoradiograms after an exposure of 24 hours, those from White Oak Lake after an exposure of 72 hours, whereas those collected below the dam showed no darkening of the film following an exposure of seven days.

2. The highest concentration of radiomaterials in the trees growing along White Oak Creek was in the bark. Although the samples used in those autoradiograms contained wood that was formed by the trees before the area became contaminated with radiomaterials, there was no detectable gradient of radioactivity from the central part of the sections toward the outer edge. There was, however, a decrease in the amounts of radioactivity accumulated from the lower parts of the tree towards the top.

3. The greatest concentration of radiomaterials in the forbs and grasses was in the leafy portions of those plants.

The results from radiochemical and spectrographic analyses indicated that all living plants selectively concentrated specific radionuclides. The following radioelements were most common among those specifically concentrated: strontium, cesium, ruthenium, rare earths, and zirconium. In only one instance, however, was enough radiomaterial concentrated to cause apparent damage to the plant. The plant in question was an American elm tree (*Ulmus americanus*) that selectively concentrated enough ruthenium to cause the edges of the leaves to curl and die. Microscopic sections of those leaves indicated that there was a sharp line of demarkation between the normal and injured tissue. The injured tissue was considerably reduced in thickness apparently as a result of shrinkage of the palisade and mesophyllous cells. There was no apparent injury to the normal cells of the damaged leaves. In that tree there was a consistent increase in the amounts of ruthenium on the twigs between late October and early May, providing good evidence that solutes were continually absorbed throughout the winter months.

It was found that there was no apparent correlation between the amounts of radioactivity in the soil and the amounts concentrated by the vegetation growing in it. However, it was found that parts of dead plants that had fallen in water contaminated by radiomaterials accumulated considerable amounts of radioactivity. Such accumulation is thought to have taken place primarily by adsorption with the lattice structure of the plant acting as a sort of sponge. Analyses of living plants in a particular area indicated that they selectively concentrated certain amounts of specific radionuclides. Dead portions of those same plants that had fallen into the water contained similar amounts of the same radioelements that were present in the living plants, plus an accumulation, in approximately the same proportions, of the various radiomaterials present in the water that were not selectively concentrated by the plants.

After separating the mineral and organic fractions of soil from the lake bottom it was found that the organic fraction was capable of adsorbing considerably greater amounts of radiomaterials than the mineral portion. It was further determined that a mixture of dead tree leaves and Conasauga shale was an effective filter for the removal of strontium 90 and cesium 137.

Radioanalyses of samples from individual specimens of the same species of plant from the same location indicated that there were considerable variations in the amounts of radioactivity concentrated from plant to plant.

Limnology

Physico-chemical data including determinations for chemical composition, dissolved oxygen, free carbon dioxide, total alkalinity, total hardness, ammonia nitrogen, nitrites, nitrites plus nitrates, hydrogen ion concentration, total phosphorus, percent of light transmitted, turbidity, temperature, and gross beta radioactivity were collected routinely.

At times during the survey, usually during periods of algal blooms, the dissolved oxygen in the water reached or exceeded saturation.

Similarly, at times the nitrate nitrogen reached a concentration of as much as 10 ppm. Such concentrations of nitrogen may well have been one of the major causative factors for the tremendous algal blooms that occurred periodically in White Oak Lake. In general, the following conclusions may be drawn from the physico-chemical data:

1. Sufficient amounts of nutrient materials were present at all times for the growth of plants, and occasionally there was a decided surplus of nitrate nitrogen.

2. Although relatively few determinations were made for ammonia nitrogen, there was no apparent problem of organic pollution.

3. Values for total alkalinity, total hardness, and hydrogen ion concentration fell within the expected range.

4. Enough bicarbonates were present to provide a continuous and adequate supply of free carbon dioxide for plant growth.

5. At no time was free carbon dioxide present in amounts large enough to be detrimental to the aquatic fauna.

6. Temperature profiles taken at various times throughout the year showed the formation and disappearance of the thermocline over relatively short periods of time.

7. Turbidity of the water in White Oak Lake was caused primarily by suspended particles of clay. During the first two years of the survey, the lake was almost constantly turbid because of extensive earth moving in conjunction with construction in parts of the watershed. The lake was relatively clear during

the third year, following the cessation of construction and the seeding and mulching of large denuded areas. Turbidity was a limiting factor in the production of rooted aquatic plants and attached filamentous algae, but apparently did not affect the reproduction and growth of planktonic forms.

8. The amount of radioactivity per unit volume of water gradually increased during the entire survey period although there were occasional relatively great fluctuations from that line of increase. The amount of radioactivity in the water generally decreased from the upper end to the lower end of the lake. In the deeper part of the lake, the amount of radioactivity usually increased from the surface to the bottom.

During the course of the survey a total of 185 species of invertebrate animals referable to 12 phyla were collected and identified. That list includes all zooplankters and bottom fauna as indicated in the appendix to this section.

Variations in the volume of total plankton in White Oak Lake followed the expected pattern of a bimodal curve with peaks in the spring and in the fall. The species composition of the plankton in the lake was similar to that found in nearby impoundments which had not been contaminated with radiomaterials.

The populations of some of the plankters were characterized throughout the survey period by tremendous, but usually short-lived, pulses. Such pulses lasted from two days, as in the case of *Chlamydomonas*, to more than a month, as in Volvox. Some pulses were local in nature, covering only a few acres, whereas others were more generally dispersed over the entire lake. Each organism manifested its own characteristic pattern of pulse formation and those distinguishing features did not differ appreciably from year to year. Organisms referable to the following genera were predominant among those causing plankton pulses:

Pandorina	Pteromonas	Cryptomonas
Volvox	Euglena	Chroomonas
Chlamydomonas	Trachelomonas	Difflugia
Carteria	Oscillatoria	

The most spectacular pulses were those formed by Volvox. About mid-May 1952 samples contained upwards of 700,000 colonies per liter. During such periods the entire lake was deep green in color and was noticeably streaked with even greater concentrations of Volvox. Following such pulses, the zygotes of Volvox were so numerous that the lake became orange-red in color and on one occasion windrows of zygotes were observed piled up along the windward shores.

Pulses of Euglena were nearly as spectacular as those of Volvox. In such cases, however, the water was first a bright green color, and, in turn, was followed by a yellow, then a dirty yellow-brown, and finally a very deep brown that was almost black. The last stage produced a film on the water not unlike one formed by used crankcase oil.

The most abundant filamentous alga was Spirogyra, which frequently covered much of the bottom in the shallow upper end of the lake.

The littoral bottom fauna was abundant and varied. The littoral zone of the lake, which included the bottom under less than three feet of water, was divided into five different types. Each type of bottom supported much the same types of organisms irrespective of its location in the lake. Larval dragon flies, damsel flies, and other aquatic insects, together with adult aquatic coleopterans and hemipterans were common in the littoral zone. There was a direct correlation between the size of the various organisms and the productivity of the particular type of littoral zone. Midge larvae (Tendipedidae) were perhaps the most abundant organisms in the littoral zone but were also present in large numbers in the sublittoral zone.

The sublittoral bottom fauna consisted primarily of three species of organisms: Tubifex, larval Tendipes, and larval Chaoborus. Tubifex occurred in greatest abundance in the soft putrescent muds of the shallow portion of the lake, whereas Chaoborus and Tendipes were more abundant in the deeper regions.

The bottom fauna of White Oak Creek below the Settling Basin supports a moderate population of benthos consisting primarily of Tubifex and larval Tendipes, along with limited numbers of may fly, caddis fly, and other dipterous larvae, and a few molluscs. In White Oak Creek above the source of contamination, however, there were nearly twice as many genera represented in the collections. From such observations it is apparent that White Oak Creek, even in its lower reaches, is potentially a productive stream, but the effects of heavy siltation and waste effluents from the Oak Ridge National Laboratory have inhibited that productivity.

Data from radioassay of samples of the various invertebrate bottom organisms indicate that there is a good correlation between the type of bottom and the amount of radioactivity accumulated. Furthermore, there was a progressive decrease in the amounts of radioactivity in the organisms from the upper end of the lake towards the dam.

The greatest amounts of radioactivity were accumulated by the filamentous algae. The maximum amounts of radioactivity found in Spirogyra was 15,800 counts per minute per gram fresh weight, for Oscillatoria 6,900 counts per minute per gram, and for a mixture of Oscillatoria and Oedogonium 15,650 counts per minute per gram. Radiochemical analysis of one sample of a large mat of Spirogyra, which covered much of the upper end of the lake, indicated that about 42 percent of the radioactivity was emitted by radiophosphorus, 38 percent by the rare earths, and 22 percent by radiostrontium.

Phytoplankters did not accumulate as much radioactivity as the filamentous algae, the maximum amounts accumulated by Volvox was 2,800 counts per minute per gram, Pandorina 5,700 counts per minute per gram, and Euglena about 2,000 counts per minute per gram. In each of these organisms, well over half of the radioactivity was emitted by radiophosphorus.

In most of the zooplankters and bottom fauna radiophosphorus was selectively concentrated in greater amounts than any other radioelement. However, radiostrontium, radioactive rare earths, and small amounts of others, were also selectively accumulated.

Vertebrate Biology

Individuals of 228 species of vertebrate animals referable to five classes were identified as follows: 23 species of fish, 14 species of amphibians, 17 species of reptiles, 158 species of birds, and 16 species of mammals. These different animals are listed in the appendix to this section. Although such a list appears to be rather comprehensive, it is by no means complete.

Six semi-annual estimates of the size and composition of the fish population of White Oak Lake were made by the mark and recapture method according to the formula derived by Schnabel (1938). The following species were considered in those estimates: bluegills, black crappies, white crappies, largemouth bass, carp, bullheads, and redhorse. No estimates were made for the gizzard shad because that species is so delicate it cannot withstand the necessary handling. During these studies, only those fish large enough to be retained by the nets were considered. No attempt was made to estimate the numbers of small fish present.

Those estimates indicated that, in general, the fish population under study exhibited fluctuations in abundance and total weight well within the expected range. The total weight of the fish population decreased during the winter months but that lost weight was usually regained during the ensuing summer. Also, there was evidence from these netting studies that two species of fish, the white crappie and the redhorse, were gradually disappearing from the population.

Another aspect of these studies revealed that the black crappie was more than twice as vulnerable to hoopnetting as the bluegill.

Immediately following the last semi-annual netting study, the lake was treated with rotenone and all dead fish recovered insofar as possible. Approximately two-thirds of all the fish marked during the netting study just completed were recovered during the rotenone study. From these data it was estimated that the total fish population consisted of approximately

392,000 individuals that weighed about 35,500 pounds. Such a large number of fish indicates that White Oak Lake is a very productive body of water. On a unit basis, there were about 11,000 fish per acre that weighed nearly 1,000 pounds.

No white crappies and only 17 redhorse were recovered during the rotenone study, thus corroborating the earlier evidence from the netting program that these two species were gradually disappearing from the lake. The reason for the gradual disappearance of two species from the lake is not immediately obvious. Perhaps the most reasonable explanation is to be found in some slight change in the environmental conditions. Such a change would not have been drastic or the population would have been wiped out at once. Rather, the change was one to which neither species could quite completely adapt itself and thus could not maintain healthy populations.

The rate of growth of all species of fish in White Oak Lake was noticeably slower than that in nearby TVA reservoirs insofar as could readily be determined. In addition, the life spans of the black crappies and largemouth bass, and perhaps all other species as well, were as much as 25 percent shorter than the fish of the same species in nearby waters. The slower growth rate among the fishes of White Oak Lake may have resulted from overcrowding. However, there is good evidence that the shortening of the normal life span was caused by the constant exposure to both internal and external irradiation from the radioactive waste materials present. It may be that such radiation damage may have been one of the primary causative factors in the disappearance of the white crappie and redhorse from the fish population.

The data on growth from the netting studies, as well as from the scale readings, indicate that the fish in White Oak Lake increased in length during the winter months. This information corroborates data collected by Krumholz (unpublished) for fish in experimental ponds in northern Indiana. It was also found from these data that the time of annulus formation for all species involved in this study was similar to that for nearby TVA waters.

Length-frequency data for all species of fish, except the white crappie and the redhorse, indicated that that characteristic of the populations was as expected. Similarly, the relationship between length and weight was much the same as for other waters in all species concerned.

Thus, with the exception of the foreshortened life span, and perhaps the slower growth rate as well, the fish population of White Oak Lake is believed to be essentially the same as that of any comparable body of water in the region.

Several individuals of each species of fish large enough to be caught in the nets in White Oak Lake were dissected and the various component tissues weighed so that a series of standard weights for each particular tissue could be obtained. Each of the following tissues was weighed in its entirety: 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, abdominal fat, gonads, and contents of the digestive tract. The percentage of the total weight was then determined. From this information it is obvious that in general: (1) the skin of the bullhead contributes approximately the same percentage of the total body weight as the combined scales and skin of the centrarchids studied; (2) the weights of the combined bony structures varied from species to species, presumably because of differences in structural requirements; and (3) the percentage of the total body weight made up by muscle tissue was approximately the same for all species.

The food habits of the black crappies and bluegills were quite different. The black crappies fed primarily on those macroplankters and bottom fauna which appear 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. On an annual basis, 43 percent of the total volume of 106 stomachs of black crappies consisted of larval Chaoborus, an additional 20 percent was made up of copepods and cladocerans, and 12 percent was larval midges. Thus, about three-quarters of the food of black crappies in White Oak Lake consisted of small invertebrate organisms, and only about 8 percent was made up of small fish. The bluegills fed primarily along the littoral zone and the food items found in 100 stomachs, on a year-round basis, indicates that they will eat practically anything. Actually, there appeared to be very little preference shown for any particular kind of food. Although 43 percent of the annual total volume consisted of algae and the remains of vascular plants, it is believed that a large fraction of that material was eaten inadvertently. The four items which made up three-quarters of the diet of the black crappies, made up less than one-quarter of that of the bluegills.

Radioassay of the contents of the stomachs of the black crappies and bluegills indicated the food organisms had accumulated significant amounts of radioactivity. In the crappies the range was from about 100 to 1,800 counts per minute per gram whereas those from the bluegills ranged from 250 to 14,350. The average for the full crappie stomachs was 960 counts per minute per gram and that for the bluegills was 1,250. The greater amounts of radioactivity in the contents of the bluegill stomachs was traceable primarily to the relatively large quantities of filamentous algae present.

Radiochemical analysis of the organisms which were most frequently found in the stomachs, indicated that most of the radioactivity was emitted by phosphorus 32, with smaller amounts from the radioisotopes of the rare earths, strontium, and cesium.

Radioassay of the tissues from black crappies and bluegills, on a year-round basis, indicated: (1) there were definite seasonal fluctuations in the concentration of radiomaterials by all tissues; (2) the primary radioelement concentrated by the soft tissues was cesium; (3) the primary radioelements concentrated by the hard tissues was strontium and, to a lesser extent, phosphorus; (4) the black crappies generally concentrated considerably greater amounts of radioactivity in the hard tissues than the bluegills; (5) the bluegills concentrated greater amounts in the soft tissues than did the crappies; and (6) in both species of fish the amounts of radiomaterials accumulated in the hard tissues was considerably greater than that in the soft tissues.

The seasonal variation in the accumulation of radiomaterials in the fish tissues was largely governed by seasonal changes in temperature which in turn controlled the metabolism of the animals in question. However, after the peak concentration had accumulated by midsummer, there was a sharp decrease in the amounts of radiomaterials retained in the tissues even though the water temperatures remained relatively high. Thus it appears that there is good preliminary evidence that the fish in White Oak Lake enter a period of aestivation during August, and that period continues until late September or early October. During the winter months the amounts of radioactivity in each of the tissues remained fairly constant at a level about one-third to one-half that of the summer peak.

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 proportion of the amount concentrated in the fish tissues, whereas strontium, which was present in the food organisms in only relatively small quantities, was concentrated in large amounts in the fish skeletons. Furthermore, although the contents of the bluegill stomachs contained much more radioactivity than those of the crappies, the crappies accumulated considerably greater amounts of radiomaterials in the hard tissues than did the bluegills. Both species of fish selectively accumulated radiostrontium in concentrations twenty or thirty thousand times as great as those in the environment.

From these and other data it is obvious that there are marked interspecific differences in the accumulations of radiomaterials in fishes, even between closely related species. It may be that the physiological requirements for the elements represented are different for the two species involved. If such differences in physiological demands for certain elements are so great between two such closely related species of fish, any prediction of the relative amounts of radiomaterials that might be accumulated in the tissues of unrelated species would be pure speculation.

Tissues from other vertebrate animals, including 2 amphibians, 9 reptiles, 50 migratory waterfowl, 6 water birds, and 11 mammals, were prepared for radioassay and, in some instances, analyzed radiochemically. All of these animals had been feeding on food of their own choice that was native to the area.

Neither of the bullfrogs assayed had accumulated very great amounts of radiomaterials. All of the turtles had concentrated relatively large amounts of radiomaterials in the various parts of the skeleton. The various tissues of the snake contained only small amounts of radioactivity.

Although the herons and the kingfisher spent much of their time searching for food and feeding at White Oak Lake, none of the tissues contained large amounts of radiomaterials. However, the migratory waterfowl which fed primarily at the lake accumulated a total body burden of at least five microcuries of radioactivity. Practically all of the radioactivity that was concentrated in the edible parts of the bird, the muscle, skin, and giblets, was emitted by phosphorus 32.

Among the mammals, the muskrats and woodchuck accumulated more radiomaterials than the raccoons or squirrel. One of the muskrats concentrated more than one microcurie of strontium 90 and its yttrium daughter per gram of bone in the entire skeleton, a total body burden of nearly 100 microcuries. That animal had developed an advanced osteogenic sarcoma at the proximal end of the right tibiofibula which had metastasized to both kidneys and both lungs. The woodchuck, although only a few months old, had accumulated such large amounts of radioactivity in its tissues that it is believed it would have suffered the same fate as the muskrat if it had been allowed to continue living in the area.

A program for banding migratory waterfowl was inaugurated in September 1952 in order to obtain information on the movements of such birds that visited White Oak Lake. During the ensuing season, a total of 649 waterfowl were banded and released as follows: 390 mallards, 137 wood ducks, 96 black ducks, 17 coot, 6 pintails, 1 gadwall, 1 baldpate, and 1 green-winted teal. From these data and from general observations it was estimated that upwards of 6,500 migratory waterfowl visited the lake during that season.

Information on bands from ducks killed by hunters during that season was received from Tennessee, Kentucky, Alabama, Louisiana, and Texas. One of the banded birds was found dead in Haliburton County, Ontario, Canada, in April 1953.

RECOMMENDATIONS FOR FUTURE STUDIES

The findings of the ecological survey included in this report can serve as a starting point for more complete and comprehensive studies of the effects of radioactive wastes on the flora and fauna of the drainage basin of White Oak Creek and contiguous areas. Many of the data indicate possible trends in the physiology of certain plants and animals observed. However, inasmuch as a great many edaphic and biological factors contribute to the ecology of such an area, it is virtually impossible to isolate sufficient data from such a survey on any particular organism on which to base accurate conclusions.

On the basis of the information gathered by the survey, several future studies are suggested:

1. A determination of the relationship between the accumulation of hazardous radionuclides in food plants and the animals that utilize them as part of their regular diet. One of the most hazardous nuclides concentrated in large amounts by plants is radiostrontium. It is recommended that a study be made of the amounts of such hazardous nuclides that can be concentrated by plants under natural conditions, and the amount of those plants that must be eaten by an animal in order for it to accumulate its maximum permissible concentration. In this same study the amount of radiomaterial present in the plant that would be incorporated into the tissues of the animal could be determined.

2. Determine the amounts of airborne radiomaterials accumulated in the tissues and on the surface of plants in

the area of contamination. This should be followed by studies to ascertain the amounts of such materials that are incorporated into the tissues of animals which feed on the plants under observation.

3. A study of the viability of seeds from plants that have accumulated various amounts of radiomaterials and the survival of seedlings from those seeds. Indications of possible genetic changes could be ascertained from such a study.

4. Inasmuch as there is already some indication of morphological changes in some of the plankton organisms, a thorough classification of all phytoplankton and zooplankton should be undertaken to find any morphological differences that may exist between the forms indigenous to White Oak Lake and "normal" forms from other areas.

5. Determine the role of phytoplankters in the accumulation and selective concentration of radionuclides. Of particular interest are those forms which irrupt into pulses at various seasons of the year and which serve primarily as food organisms for zooplankters and bottom organisms. This should include studies designed to show the amounts of radiomaterials that are transferred from the phytoplankters to the zooplankters.

6. Determine the role of zooplankters and bottom fauna in the accumulation and selective concentration of radiomaterials and the relationships between those organisms and others in the aquatic, or even the terrestrial, food chain. Such a chain might

entail: phytoplankter → zooplankter → zooplankter → bottom organism → amphibian → fish → reptile → bird → mammal, or any variation of that pattern.

7. Make year-round observations on occurrence and causative factors leading up to phytoplankton pulses and pursue the effects of such irruptions on the populations of the various zooplankters.

8. Determine the amount of irradiation necessary to damage plankton organisms. It may be that the population as a whole can tolerate relatively tremendous amounts of radioactivity only because the life span of the individuals in the population is normally very short and their reproduction potential very great. For instance, even if a population comprised of billions of organisms, such as Euglena, were to be decimated to as little as one-tenth, or even one-twentieth, of its original size, the remainder would probably be capable of irrupting again in a few days to a level as great as the previous one.

9. Study the differences in the biotic composition of the bottom fauna of the lake according to the different types of bottom and the presence or absence of water currents. Study the transfer of radiomaterials from the larval and pupal stages to the imago in the aquatic insects in the lake which serve as food for fishes and birds, depending on the life stage.

10. Determine the ability of non-planktonic algae to accumulate and selectively concentrate radionuclides and the role such plants play in the food chain of various animals frequenting White Oak Lake, particularly migratory waterfowl.

11. Complete the anatomical studies begun during the survey regarding the relative amounts of the total body weight made up by the various tissues and organs. Descriptions of the soft anatomy of the various fishes under consideration would constitute a valuable and much-needed contribution to the literature in that field.

12. Prepare histological sections and slides of the various tissues of plants and animals known to have concentrated large amounts of radioactivity in order to determine what changes in the cellular structure have been caused by long exposure to low levels of irradiation. In conjunction with this project, a series of reference slides from normal tissues of the same species would have to be prepared for comparison.

13. Determine the accumulation and selective concentration of hazardous nuclides in the various aquatic, terrestrial, and arboreal vertebrates in the area on a seasonal basis. Here, special emphasis should be placed on the food organisms which serve as primary items in the diet. For instance, the larvae of certain aquatic insects, such as *Chaoborus*, serve as a primary item in the diet of some fishes whereas the adult insects are important food items for some birds.

14. Study the processes which enable fishes to accumulate more radioactivity during the spring and early summer months than they do during the winter, and determine why they fail to continue such an accumulation during the latter part of the summer. If the accumulation of radiomaterials is a direct

result of metabolic processes, and no doubt it is, that accumulation should continue throughout the summer. However, the fish not only fail to accumulate radiomaterials during the latter part of summer but, during that period of supposed high metabolic activity, they lose virtually all they gained during the spring and early summer, and approach the same level of concentration of the previous winter. The fact that these animals are able to rid their tissues of the relatively large amounts of radioactivity accumulated during the summer months, may be one of the reasons why no anatomical defects were noted in the dissection of more than 600 specimens. Even though their life span may be foreshortened as a result of long exposure to external and internal irradiation, there was no evidence of any morphological or genetic changes.

15. Study the viability of eggs and the early embryology of the various species of fish in White Oak Lake in order to determine any differences from the normal pattern. Inasmuch as there were some deformities among the young-of-the-year carp in 1953, it may be that those anomalies were induced by external irradiation of the fertilized ova. Such a study would probably yield information on possible reasons for the disappearance of the white crappies and redhorse from White Oak Lake during the survey period.

16. Determine the differences in the structure of bones among the cold-blooded vertebrates and correlate with seasonal changes in accumulation of radiomaterials. It is known that the

concentration of radioactivity in the fishes varies from season to season whereas among the other poikilothermous vertebrates there are indications to the contrary. However, all amphibians and reptiles in the lake become dormant during the winter months. It is possible to collect turtles throughout the winter inasmuch as they usually bury themselves in the soft bottom muds. In so doing, the external irradiation would be increased because the bottom muds of White Oak Lake contain much more radioactivity than the water.

17. Determine which routes and by which methods and foods the fishes can most efficiently utilize and assimilate the hazardous nuclides. If there are such small amounts of radiostrontium in Chaoborus larvae as the preliminary work indicates, and that organism makes up less than 43 percent of the total annual diet of the black crappies, where did those fish obtain enough radiostrontium in a matter of a few months to more than triple the total radiostrontium in the skeleton? It may be that there is a tremendous physiological demand for that element even in the presence of large amounts of calcium. If there is so much phosphorus in the ingested food, what is its fate in the metabolic processes of the fish?

18. Perform controlled experiments on the effects of induced radiation damage to the reproductive potential, viability of fertilized eggs, and length of life span to such fishes as Gambusia, which can be readily handled in aquaria and whose normal life habits are well known.

19. Continue and expand the research on the pattern of migration of waterfowl that frequent White Oak Lake. In order to give adequate information, that particular phase of the project should be continued for at least another seven or eight years.

20. Determine the physiological differences in the accumulation of radiophosphorus in the muscle of migratory waterfowl as well as other birds. In conjunction with this, comparable studies should be made on the lack of such an accumulation in the other vertebrates of the area, both aquatic and terrestrial.

It is not intended that this list is exhaustive. Rather, these are suggested lines of research of general interest from the general biological viewpoint. There are a great many other individual problems that merit consideration.

LIST OF FAUNA FOR THE DRAINAGE AREA

APPENDIX

The following taxonomic list includes all of the animals identified during the three-year period of the survey. All forms were identified, wherever practicable, to phylum, class, genus, and, in a limited number of instances, to species. For further convenience, the subclasses of crustacea, and the orders of insects and birds have been included. For the vertebrates, the classes along with either the orders or families referable to them, have been listed. The spiders (Arachnoidea) were collected by Dr. R. P. Geokler of the Research and Medicine Division of the AEC. Dr. Geckler's classification is based on that of Chamberlin and Ivie Spiders of the Georgia Region of North America [Bull. Univ. Utah, 35(9):1-267(1944)] All other animals were identified by members of the survey staff. This is not intended as a complete faunal list for the area.

Protozoa
- Mastigophora
  - *Peronema*
  - *Phacus*
- Sarcodina
  - *Difflugia*
- Ciliata
  - *Paradileptus*
  - *Prorodon*
  - *Paramecium*
  - *Stentor*
  - *Tintinnidium*
  - *Vorticella*
  - *Opercularia*
  - *Carchesium*
  - *Rhabdostyla*
  - *Scyphidia*
  - *Ophrydium*
- Suctoria
  - *Dendrosoma*
  - *Acineta*

Porifera
    Demospongiae
        _x_ (member of Spongillidae)

Coelenterata
    Hydrozoa
        Hydra carnea Agassiz

Platyhelminthes
    Turbellaria
        Curtisia foremani (Girard)
        Catenula

Gastrotricha
        Chaetonotus

Rotatoria
    Digononta
        Rotaria
        Philodina

    Monogononta
        Lacinularia
        Trochosphaera solstitialis Thorpe
        Conochilus
        Pompholyx
        Filinia
        Pedalia
        Cephalodella
        Scaridium longicaudum (Müller)
        Eosphora
        Notommata
        Synchaeta
        Polyarthra
        Asplanchna
        Brachionus (4-5 species)
        Platyias
        Mytilina
        Euchlanis
        Keratella
        Cyrtonia
        Trichocerca
        Limnias
        Floscularia
        Testudinella

Nematoda
    Phasmidia
        Panagrolaimus

    Aphasmidia
        Ethmolaimus
        Monhystera

Chromadora
Achromadora

Tardigrada

x (not identified beyond Phylum)

Bryozoa

Phylactolaemata

Pectinatella magnifica Leidy
Plumatella repens Linnaeus

Annelida

Oligochaeta

Chaetogaster
Tubifex tubifex (O.F.M.)
Branchiura sowerbyi Bedd.
x (member of Lumbriculidae)

Hirudinea

Helobdella
x (member of Glossiphoniidae)

Arthropoda

Crustacea

Cladocera

Pseudosida bidentata Herrick
Daphnia pulex (de Geer)
Daphnia longispina (O.F.M.)
Ceriodaphnia reticulata (Jurine)
Moina micrura Kurz
Scapholeberis mucronata (O.F.M.)
Simocephalus exspinosus (Koch)
Kurzia latissima
Pleuroxus denticulatus Birge
Alonella dentifera Sars
Leydigia quadrangularis (Leydig)
Chydorus sphaericus (O.F.M.)
Alona guttata Sars
Alona monacantha Sars
Alona costata Sars
Alona rectangula Sars
Ilyocryptus sordidus (Lieven)
Macrothrix laticornis (Jurine)

Copepoda

Eucyclops agilis (Koch)
Diaptomus
Bryocamptus hiemalis (Pearse)

Ostracoda

x (one genus not identified)

Isopoda

Lirceus fontinalis Rafinesque

Amphipoda
    Crangonyx

Decapoda
    Cambarus

Insecta
    Collembola
        Hypogastrura
        Podura

    Plecoptera (Nymphs)
        Acroneuria
        Isoperla
        Alloperla
        Allocapnia
        Isogenus
        x (one genus not identified)

    Ephemeroptera
        Siphlonurus
        Blasturus
        Ameletus
        Ephemerella (2 species)
        Stenonema
        Oreianthus
        Caenis
        Ephemera
        Baetis
        Habrophlebiodes
        Habrophlebia

    Odonata
        Agrion
        Nasiaeschna pentacantha (Rambur)
        Cordulegaster
        Orthemis
        Anax junius
        Boyeria
        Pachydiplax longipennis (Burm.)
        Pantala
        Libellula
        Didymops
        Perithemis domitia Drury
        Dromogomphus
        Agrion
        Enallagma
        Argia
        Ischnura
        Amphiagrion saucium (Burm.)
        Anomalagrion hastatum Say
        Plathemis lydia (Drury)
        Lanthus

Hemiptera

- *Hydrometra*
- *Notonecta*
- *Buenoa*
- *Ranatra*
- *Belostoma*
- *Benacus*
- *Trichocorixa*
- *Gerris*

Megaloptera

- *Sialis*
- *Chauliodes*

Trichoptera

- Tascobia
- *Rhyacophila ledra*
- *Polycentropus*
- *Psilotreta*
- *Agapetus*
- *Neophylax*
- *Cheumatopsyche*
- *x* (member of Hydropsychidae)
- *x* (member of Psychomyiidae)
- *x* (member of Limnephilidae)

Coleoptera

- *Peltodytes*
- *Haliplus*
- *Laccophilus*
- *Celina*
- *Hydroporus*
- *Dytiscus*
- *Acilius*
- *Cybister*
- *Gyrinus*
- *Tropisternus*
- *Berosus*
- *Hydrophilus*
- *Psephenus herricki* (DeKay)
- *Helichus*
- *Hydrobius*
- *Helophorus*
- *x* (member of Elmidae)
- *x* (not identified beyond order)

Diptera

- *Tabanus*
- *Tendipes*
- *Metriocnemus*
- *Chaoborus*

Tipula
Psychoda
Stratiomyia
Antocha
Simulium
Culex
Anopheles
Aedes
Psorophora
x (member of Ceratopogonidae)

Arachnoidea
Agelenidae
Agelena

Argiopidae
Argiope aurantia (Lucas)
Epeira foliata (Fourcroy)
x (4 other species of Epeira)
Mangora maculata (Keyserling)
Mangora gibberosa (Hentz)
Marxia stellata (Walckenaer)
Micrathena gracilis (Walckenaer)
Micrathena mitrata (Hentz)
Micrathena sagittata (Walckenaer)
Tetragnatha seneca Seeley
Tetragnatha elongata Walckenaer
x (2 other species of Tetragnatha)
x (9 other species unidentified)

Attidae
Metacyrba taeniola (Hentz)
Phidippus sp.
Thiodina iniquies (Walckenaer)
x (9 other species unidentified)

Clubionidae
x (3 species of Anyphaena)
Anaphaenella sp.
Chiracanthium inclusum (Hentz)
x (2 species of Clubiona)
x (4 other species unidentified)

Ctenidae
Anahita animosa (Walckenaer)

Dictynidae
Dictyna sp.

Linyphiidae
Ceraticelus alticeps (Fox)
Linyphia marginata C. Koch

Linyphia coccinea (Hentz)
x (1 species unidentified)

Lycosidae

Lycosa aspersa Hentz
Pardosa sp.
Pirata sp.
x (1 species unidentified)

Pisauridae

Pisaurina mira (Walckenaer)

Theridiidae

Latrodectus mactans (Fabricius)
Rhomphaea lacerta (Walckenaer)

Thomisidae

Misumenoides formosipes (Walckenaer)
Synema varians (Walckenaer)
x (1 species not identified)

Mollusca

Gastropoda

Ferrissia
Physa
Lymnaea
Gyraulus
Menetus
Hydrobia
Plerocera
Pomatiopsis
Helix

Chordata

Osteichthyes

Dorosoma cepedianum (LeSueur)	Gizzard shad
Ictiobus bubalus (Rafinesque)	Smallmouth buffalofish
Moxostoma aureolum (LeSueur)	Northern redhorse
Catostomus commersonnii (Lacepede)	Common sucker
Cyprinus carpio Linnaeus	Carp
Carassius auratus (Linnaeus)	Goldfish
Semotilus atromaculatus (Mitchill)	Creek chub
Nocomis biguttatus (Kirtland)	
Rhinichthys atratulus (Hermann)	
Rhinichthys cataractae (Valenciennes)	(Southern red-
Chrosomus erythrogaster (Rafinesque)	bellied dace)
Hyborhynchus notatus (Rafinesque)	Bluntnose minnow
Campostoma a. anomalum (Rafinesque)	
Ameiurus nebulosus marmoratus (LeSueur)	Brown bullhead
Ameiurus n. natalis (LeSueur)	Yellow bullhead

Gambusia a. affinis (Baird and Girard)	Mosquitofish
Hadropterus maculatus (Girard)	Black-sided darter
Boleosoma n. nigrum (Rafinesque)	Johnny darter
Micropterus salmoides (Lacepede)	Largemouth bass
Lepomis m. macrochirus Rafinesque	Bluegill
Pomoxis annularis Rafinesque	White crappie
Pomoxis nigro-maculatus (LeSueur)	Black crappie
Cottus b. bairdii Girard	Muddler

Amphibia

Triturus v. viridiscens	
Ambystoma maculatum	Spotted salamander
Desmognathus fuscus	
Eurycea bislineata	
Bufo americanus	American toad
Bufo fowleri	Fowler's toad
Hyla crucifer	Spring peeper
Hyla v. versicolor	Tree frog
Rana sylvatica catabrigensis	Wood frog
Rana catesbiana	Bullfrog
Rana clamitans	Green frog
Rana pipiens	Leopard frog
Rana palustris	Pickerel frog
Acris gryllus	Cricket frog

Reptilia

Sceloporus biseriatus	Fence lizard
Eumeces fasciatus	Blue-tailed skink
Cnemidophorus sexlineatus	Six-lined lizard
Opheodrys vernalis	Green snake
Coluber constrictor	Blue racer
Elaphe obsoleta	Pilot blacksnake
Storeria dekayi	DeKay's brown snake
Natrix sipedon	Water snake
Pituophis sayi	Bullsnake
Thamnophis sirtalis	Garter snake
Sternothorus odoratus	Stink-pot
Chelydra serpentina	Snapping turtle
Terrapene carolina	Wood terrapin
Graptemus geographica	Map turtle
Pseudemys troosti	Cumberland turtle
Chrysemys belli	Painted turtle
Amyda ferox spinifera	Soft-shell turtle

Aves

Colymbiformes

Podilymbus podiceps podiceps	Pied-billed grebe

Ciconiiformes

Ardea herodias	Great blue heron
Casmerodius albus egretts	American egret
Florida caerulea caerulea	Little blue heron
Butorides virescens virescens	(Eastern) green heron
Nycticorax nycticorax hoacti	Black-crowned night heron

Anseriformes

Branta canadensis	Canada goose
Anas platyrhynchos platyrhynchos	Mallard
Anas rubripes	Black duck
Chaulelasmus streperus	Gadwall
Mareca americana	Baldpate
Dafila acuta tzitzihoa	Pintail
Nettion carolinense	Green-winged teal
Querquedula discors	Blue-winged teal
Spatula clypeata	Shoveller
Aix sponsa	Wood duck
Nyroca americana	Redhead
Nyroca collaris	Ring-necked duck
Nyroca valisneria	Canvas-back
Nyroca marila	Greater scaup duck
Nyroca affinis	Lesser scaup duck
Charitonetta albeola	Buffle-head
Lophodytes cucullatus	Hooded merganser
Mergus merganser americanus	American merganser
Mergus serrator	Red-breasted merganser
Erismatura jamaicensis rubida	Ruddy duck

Falconiformes

Cathartes aura	Turkey vulture
Coragyps atratus	Black vulture
Accipiter striatus velox	Sharp-shinned hawk
Accipiter cooperii	Cooper's hawk
Buteo jamaicensis	Red-tailed hawk
Buteo platypterus platypterus	Broad-winged hawk
Buteo lagopus s.johannis	American rough-legged hawk
Haliaeetus leucocephalus	Bald eagle
Buteo lineatus	Red-shouldered hawk
Circus cyaneus hudsonius	Marsh hawk
Pandion haliaetus carolinensis	Osprey
Falco sparverius	Sparrow hawk

Galliformes

Bonasa umbellus	Ruffed grouse
Colinus virginianus	Bob-white

Gruiformes

Rallus elegans	King rail
Porzana carolina	Sora
Gallinula chloropus cachinnans	Florida gallinule
Fulica americana	Coot
Rallus limicola limicola	Virginia rail

Charadriiformes

Charadrius hiaticula semipalmatus	Semipalmated plover
Charadrius vociferus vociferus	Kill deer
Philohela minor	Woodcock
Capella gallinago delicata	Wilson's snipe
Tringa solitaria solitaria	(Eastern) solitary sandpiper
Actitis macularia	Spotted sandpiper
Totanus flavipes	Lesser yellow-legs
Larus argentatus	Herring gull
Larus delawarensis	Ring-billed gull

Columbiformes

Zenaidura macroura	Mourning dove

Cuculiformes

Coccyzus americanus americanus	Yellow-billed cuckoo
Coccyzus erythrophthalmus	Black-billed cuckoo

Strigiformes

Otus asio	Screech owl
Bubo virginianus	Great horned owl
Asio flammeus flammeus	Short-eared owl
Aegolius acadica acadica	Saw-whet owl

Caprimulgiformes

Caprimulgus carolinensis	Chuck-will's widow
Caprimulgus vociferus	(Eastern) whip-poor-will
Chordeiles minor	Nighthawk

Micropodiformes

Archilochus colubris	Ruby-throated hummingbird
Chaetura pelagica	Chimney swift

Coraciiformes

Megaceryle alcyon alcyon	(Eastern) belted kingfisher

Piciformes

Colaptes auratus	Flicker
Hylatomus pileatus	Pileated woodpecker
Centurus carolinus	Red-bellied woodpecker
Melanerpes erythrocephalus erythrocephalus	Red-headed woodpecker
Sphyrapicus varius varius	Yellow-bellied sapsucker
Dendrocopus villosus	Hairy woodpecker
Dendrocopus pubescens	Downy woodpecker

Passeriformes

Tyrannus tyrannus	Eastern kingbird
Sayornis phoebe	Eastern phoebe
Contopus virens	Wood pewee
Myiarchus crinitus	Crested flycatcher
Iridoprocne bicolor	Tree swallow
Riparia riparia riparia	Bank swallow
Stelgidopteryx ruficollis serripennis	Rough-winged swallow
Petrochelidon pyrrhonota albifrons	(Northern) cliff swallow
Progne subis subis	Purple martin
Cyanocitta cristata	Bluejay
Corvus brachyrhynchos	Crow
Parus atricapillus	Black-capped chickadee
Parus carolinensis	Carolina chickadee
Parus bicolor	Tufted titmouse
Sitta carolinensis	White-breasted nuthatch
Certhia familiaris	Brown creeper
Troglodytes aëdon	House wren
Troglodytes troglodytes	Winter wren
Thryomanes bewickii	Bewick's wren
Thryothorus ludovicianus	Carolina wren
Mimus polyglottos polyglottos	(Eastern) mockingbird
Dumatella carolinensis	Catbird
Toxostoma rufum rufum	(Eastern) brown thrasher
Turdus migratorius	Robin
Hylocichla mustelina	Wood thrush
Hylocichla guttata faxoni	(Eastern) hermit thrush
Hylocichla fuscescens	Veery
Hylocichla ustulata	Olive-backed thrush
Sialia sialis	Eastern bluebird

Polioptila caerulea caerulea	Blue-gray gnatcatcher
Regulus satrapa satrapa	(Eastern) golden-crowned kinglet
Regulus calendula calendula	(Eastern) ruby-crowned kinglet
Bombycilla cedrorum	Cedar waxwing
Lanius ludovicianus	Loggerhead shrike
Sturnus vulgaris vulgaris	Starling
Vireo griseus	White-eyed vireo
Vireo flavifrons	Yellow-throated vireo
Vireo virescens	Red-eyed vireo
Mniotilta varia	Black and white warbler
Protonotaria citrea	Prothonotary warbler
Vermivora ruficapilla ruficapilla	Nashville warbler
Parula americana	Parula warbler
Dendroica petechia	Yellow warbler
Dendroica magnolia	Magnolia warbler
Dendroica tigrina	Cape May warbler
Dendroica caerulescens	Black-throated blue warbler
Dendroica coronata coronata	Myrtle warbler
Dendroica virens	Black-throated green warbler
Dendroica fusca	Blackburnian warbler
Dendroica dominica	Yellow-throated warbler
Dendroica pennsylvanica	Chestnut-sided warbler
Dendroica castanea	Bay-breasted warbler
Dendroica striata	Black-poll warbler
Dendroica pinus	Pine warbler
Dendroica kirtlandii	Kirtland's warbler
Dendroica discolor	Prairie warbler
Seiurus noveboracensis	Northern water-thrush
Seiurus motacilla	Louisiana water-thrush
Geothlypis trichas	Yellow-throat
Icteria virens virens	Yellow-breasted chat
Wilsonia canadensis	Canada warbler
Setophaga ruticilla	American redstart
Passer domesticus domesticus	House sparrow
Sturnella magna	Meadowlark
Agelaius phoeniceus	Red-wing
Icterus spurius	Orchard oriole
Icterus galbula	Baltimore oriole
Quiscalus versicolor	Bronzed grackle
Molothrus ater ater	(Eastern) cowbird
Piranga rubra rubra	Summer tanager
Richmondena cardinalis	Cardinal
Passerina cyanea	Indigo bunting
Spinus tristis tristis	Common goldfinch
Pipilo erythrophthalmus	Towhee

	Junco hyemalis	Slate-colored junco
	Spizella passerina passerina	(Eastern) chipping sparrow
	Spizella pusilla pusilla	(Eastern) field sparrow
	Passerella iliaca iliaca	(Eastern) fox sparrow
	Melospiza melodia	Song sparrow
	Pooecetes gramineus gramineus	(Eastern) vesper sparrow
	Spizella arborea arborea	(Eastern) tree sparrow
	Zonotrichia leucophrys	White-crowned sparrow
	Zonotrichia albicollis	White-throated sparrow
	Melospiza georgiana	Swamp sparrow
Mammalia		
Marsupialia		
	Didelphis virginiana	Opossum
Insectivora		
	Scalopus aquaticus	Common mole
Chiroptera		
	Myotis lucifugus lucifugus	Little brown bat
Carnivora		
	Procyon lotor lotor	Raccoon
	Mustela vison	Mink
	Mephitis mephitis	Striped skunk
	Vulpes fulva	Red fox
	Urocyon c. cinereoargenteus	Gray fox
Rodentia		
	Marmota monax	Woodchuck
	Tamias striatus	Eastern chipmunk
	Sciurus carolinensis	Gray squirrel
	Peromyscus leucopus	White-footed mouse
	Oryzomys palustris	Rice rat
	Ondatra zibethica	Muskrat
Lagomorpha		
	Sylvilagus floridanus	Cottontail
Primates		
	Homo s. sapiens	Man

BOTANY OF THE DRAINAGE AREA

The work of the Botanical Section of the survey was directed toward the determination of the kinds and amounts of fission products assimilated by the various plants growing in the area, and whether or not such accumulated radiomaterials had produced any noticeable ecological, morphological, or genetic effects. In order to achieve that goal, the effort was divided into the following parts:

1. A collection and identification, together with field studies, of all species of bryophytes and vascular plants growing in the area.
2. An assessment of the accumulation of fission products by the various plants by direct radioassay and radiochemical analyses, by autoradiography, by decay and absorption curves, etc., and any physiological and genetic responses of the plants due to the radioactivity accumulated.
3. A study of soil contamination and the ability of soil particles to adsorb radiomaterials.
4. Studies on the successional aspects of the flora of the area.

Plant Collections and Field Observations

A program of collection and identification of all the bryophytes and vascular plants growing in the White Oak Creek drainage area was begun in August 1950 and continued until late spring 1952. Any attempt to interpret the present flora would be difficult because of the past history of the area. The effects of fire, grazing, and other disturbing influences have not been adequately investigated in this part of Tennessee. For these, and perhaps other reasons as well, it cannot be stated that all of the normal elements of this part of the Ridge and Valley Province should be present. Observations in other parts of the Oak Ridge Controlled Area indicate that some species may have been eliminated from the present study area.

The maintenance of roads and grounds near the Oak Ridge National Laboratory introduces new species from time to time. These new plants, with the succession occurring in the numerous habitats, indicate that the plant collections should not be considered complete. Approximately 40 species of bryophytes and 400 species of vascular plants were collected and identified (Appendix I). The identities of these plants have been checked with specimens in the Herbarium of the University of Tennessee, and, with one exception, no unusual nor abnormal differences were found. Duplicate sets of the collection are to be deposited with the United States National Museum, Duke University, and the University of Tennessee.

The general survey of the study area did not reveal any unusual condition in the vegetation. Plants observed growing in the most heavily contaminated places appeared normal in every respect. The succession around White Oak Lake showed no significant differences from similar sites observed on various reservoirs throughout the Tennessee Valley.

The only unusual plant was collected from a clone of broad-leaved cat-tail which showed a variegated leaf pattern. Specimens collected from that clone were checked by personnel of the National Herbarium and by Mr. Neil Hotchkiss of the U. S. Fish and Wildlife Service. Those were the first instances in which such a color pattern in the leaves of that species of plant had been observed by either person. This indicates that the variegated color pattern must be extremely rare under natural conditions. Consequently, it is felt that the alteration of the color pattern of the clone of cat-tail was induced by its exposure to the radiation from the Settling Basin where the plant was growing.

Accumulation of Radioactive Fission Products by Plants

One of the principal objectives of the botanical studies was to determine whether or not any observable changes had occurred in the ecological succession around White Oak Lake and in the abandoned fields along White Oak Creek. This included a survey of the flora for genetic and morphological changes which might be attributed to radiation damage. A second objective was to find out whether any plants were able to concentrate fission products to a level which might be deleterious either to the plant itself or to an animal which might feed upon it. By the end of 1950, it became evident that there were no marked changes in the morphology or ecology of the plants in the contaminated area. Because of this lack of positive evidence of radiation damage as shown by plant succession and gross morphology, the emphasis of the survey was shifted toward an investigation of the assimilation and concentration of radioactive fission products by the plants.

In order to determine the extent of accumulation of radioactive fission products by the various plants throughout the study area, several methods, both qualitative and quantitative, were used. Autoradiograms were made from a selected group of plants, or tissues taken from them, in order to find out where the highest concentrations of radiomaterials had been deposited. Radioassays were performed on samples of different tissues of plants from large numbers of individual samples, collected over a wide area and at all seasons of the year, in order to determine the actual amounts of gross beta radioactivity present. Groups of samples from each of 10 plants of the same species growing in the same limited area, were assayed for gross beta radioactivity in order to find the range of accumulation by the different tissues of different individuals of the same species. Radiochemical and spectrographic analyses were made, along with absorption and decay curves, for representative samples to determine which of the radionuclides had been assimilated.

Autoradiography. All autoradiograms were prepared from Eastman X-ray film exposed in a constant temperature and constant humidity room. The films were developed in constant temperature solutions, in order to furnish comparable results in relation to exposure time. The general results of this part of the survey indicate that the greatest concentration of radiomaterials occurs in plants nearest to the outlet from the Settling Basin. From the samples collected just below the Settling Basin, excellent autoradiograms were obtained from an exposure of 24 hours. Autoradiograms were obtained from plants from White Oak Lake after 72 hours of exposure, whereas plants collected from the embayment below White Oak Lake Dam showed no darkening of the film following an exposure of one week.

Autoradiograms prepared from transverse and longitudinal sections of the wood taken from several species of trees growing along White Oak Creek indicated that the highest concentration of radioactive fission products was in the bark. Although the wood samples used for making those autoradiograms was much older than the length of time that the area had been contaminated, there was no detectable gradient of accumulated radioactivity in any of the sections.

Many different species of plants were checked by autoradiography. Some radioactivity was detected in all plants that were collected from the contaminated area. There was, however, a wide range in the amounts of radioactivity concentrated by the plants examined. The concentration of radiomaterials in non-woody materials appeared to be related to the mass of the tissues rather than to the physiological activity. The similarity between the amounts of radioactivity in the leaves of woody and herbaceous plants is illustrated by comparing the autoradiograms from fog-fruit leaves and elderberry leaves as pictured in Figures 1 and 2 respectively.

The presence of rather large amounts of radioactive materials in the fruit of the elderberry (Figure 3), in the achenes of the sedge Cyperus (Figure 4), and in the flowers and seeds of the false nettle (Figure 5), indicate that some genetic modification might result from radiation.

Autoradiograms prepared from plants grown in a solution containing radiophosphorus (Eleventh Semi-annual Report, AEC) indicated that the primary concentration was in the younger parts of the plants. During the spring of 1952, a large number of autoradiograms was prepared from plant material which was actively growing to determine whether or not the radioactive fission products present in the contaminated area were being concentrated in the younger tissues. However, there was no evidence of any physiological gradient found in any of these autoradiograms. The concentration of fission products apparently followed the same pattern in the young plants as in the more mature individuals.

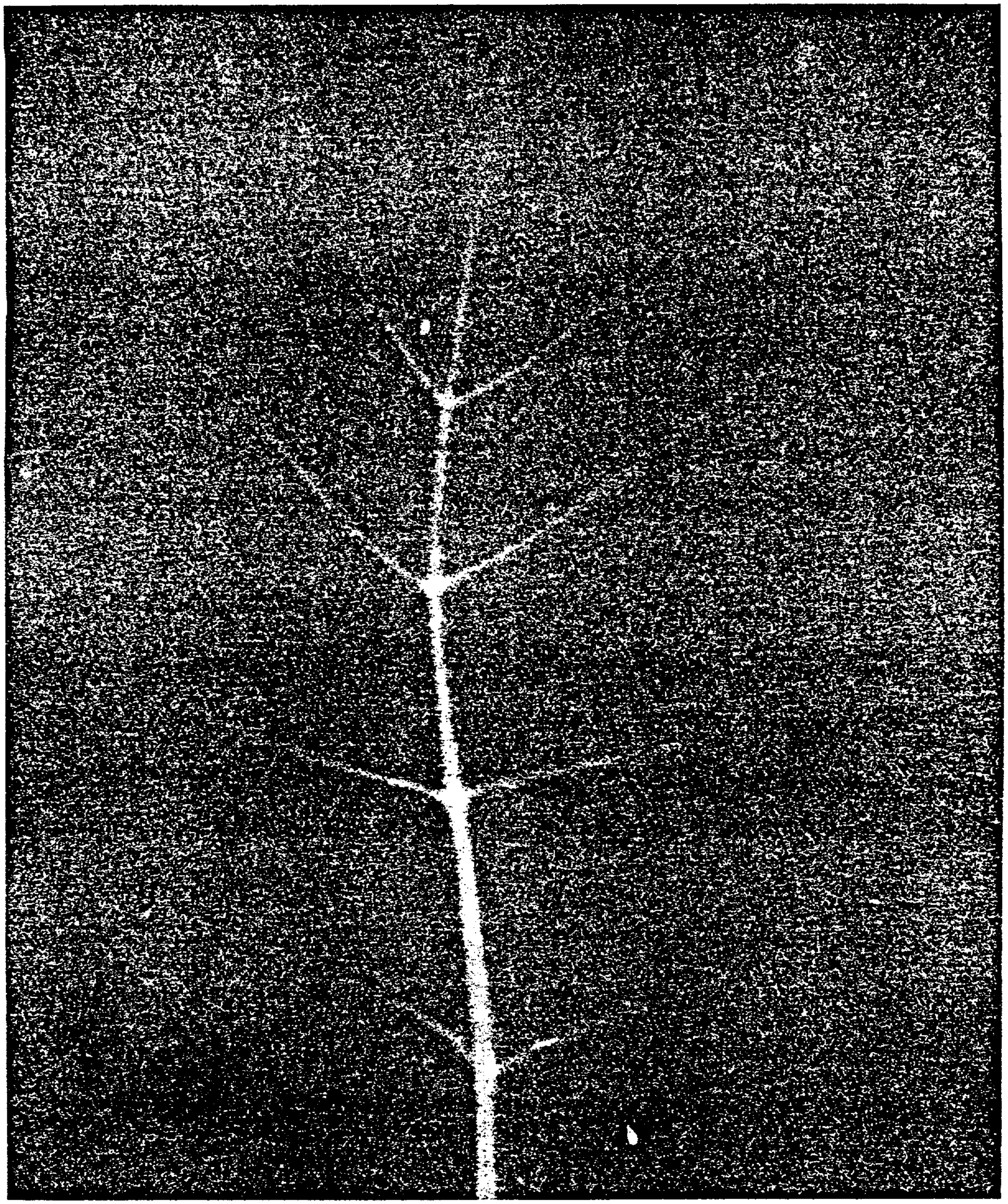


Figure 1. Autoradiogram following an exposure of 72 hours of the leaves of the fog-fruit (<u>Lippia lanceolata</u>).

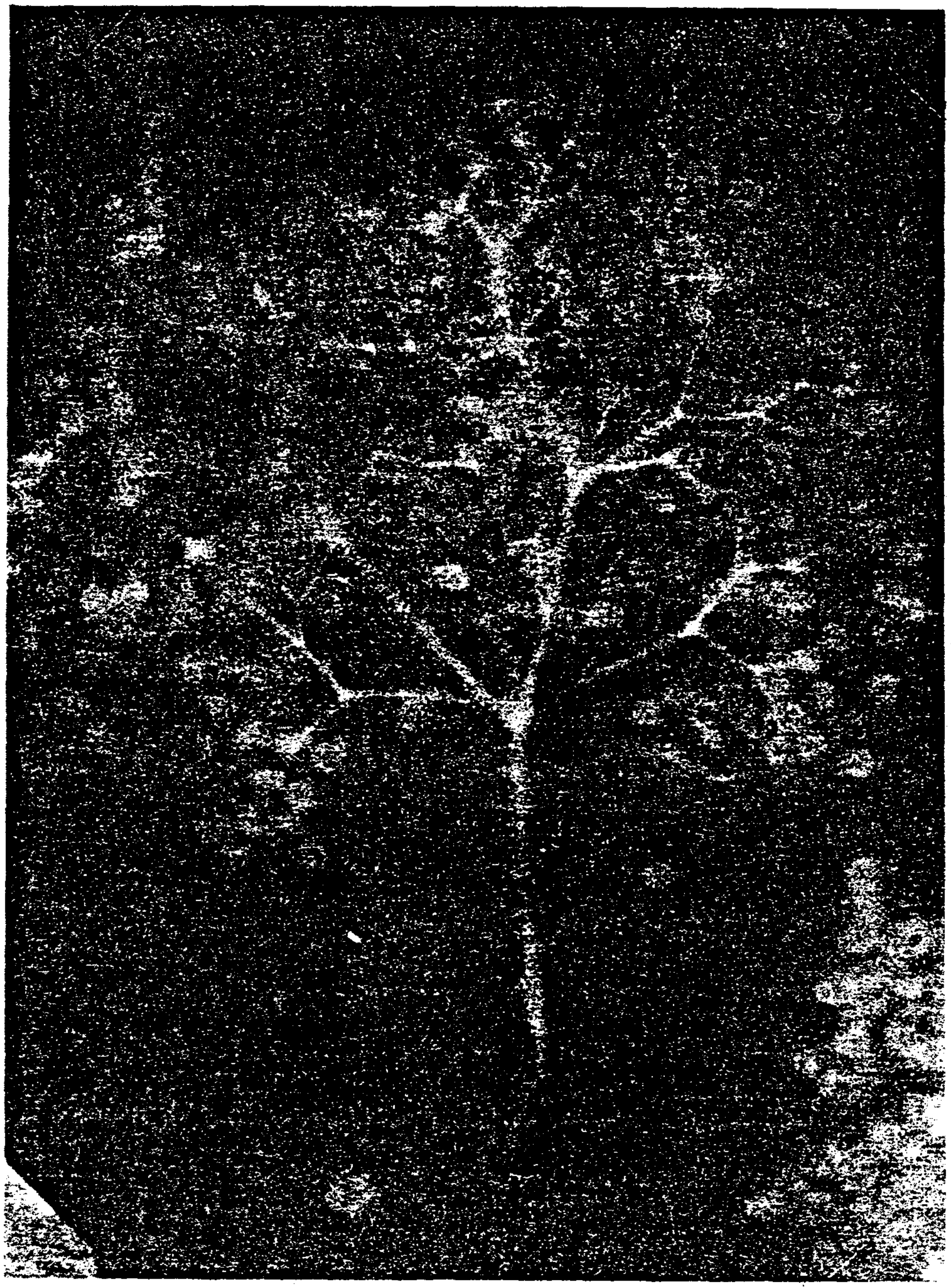


Figure 2. Autoradiogram following an exposure of 24 hours of the leaves of the elderberry (Sambucus canadensis).

Figure 3. Autoradiogram following a 24-hour exposure of the mature fruit of the elderberry (Sambucus canadensis).

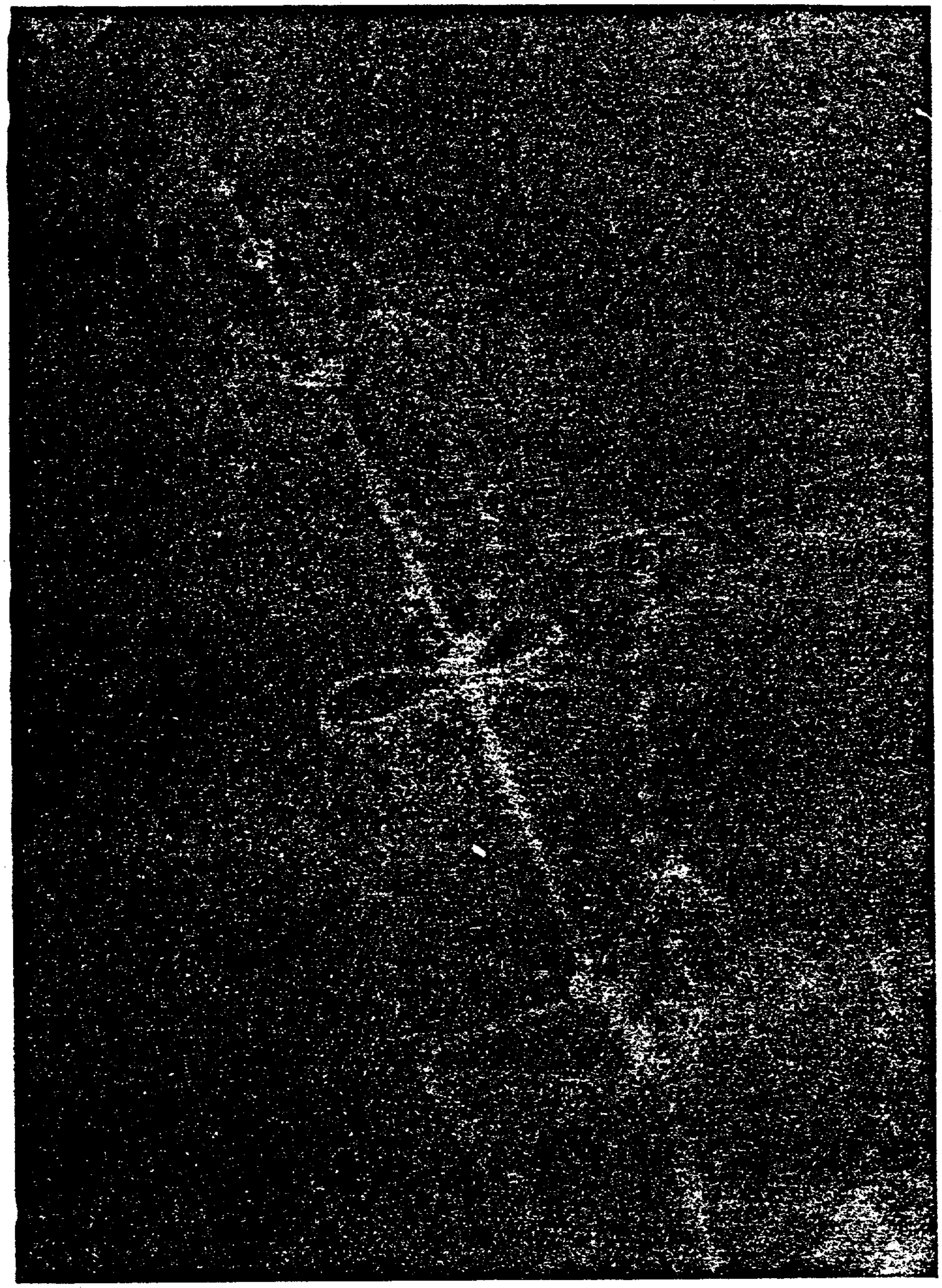


Figure 4. Autoradiogram following an exposure of 24 hours of the aerial parts of the sedge plant (Cyperus strigosus).

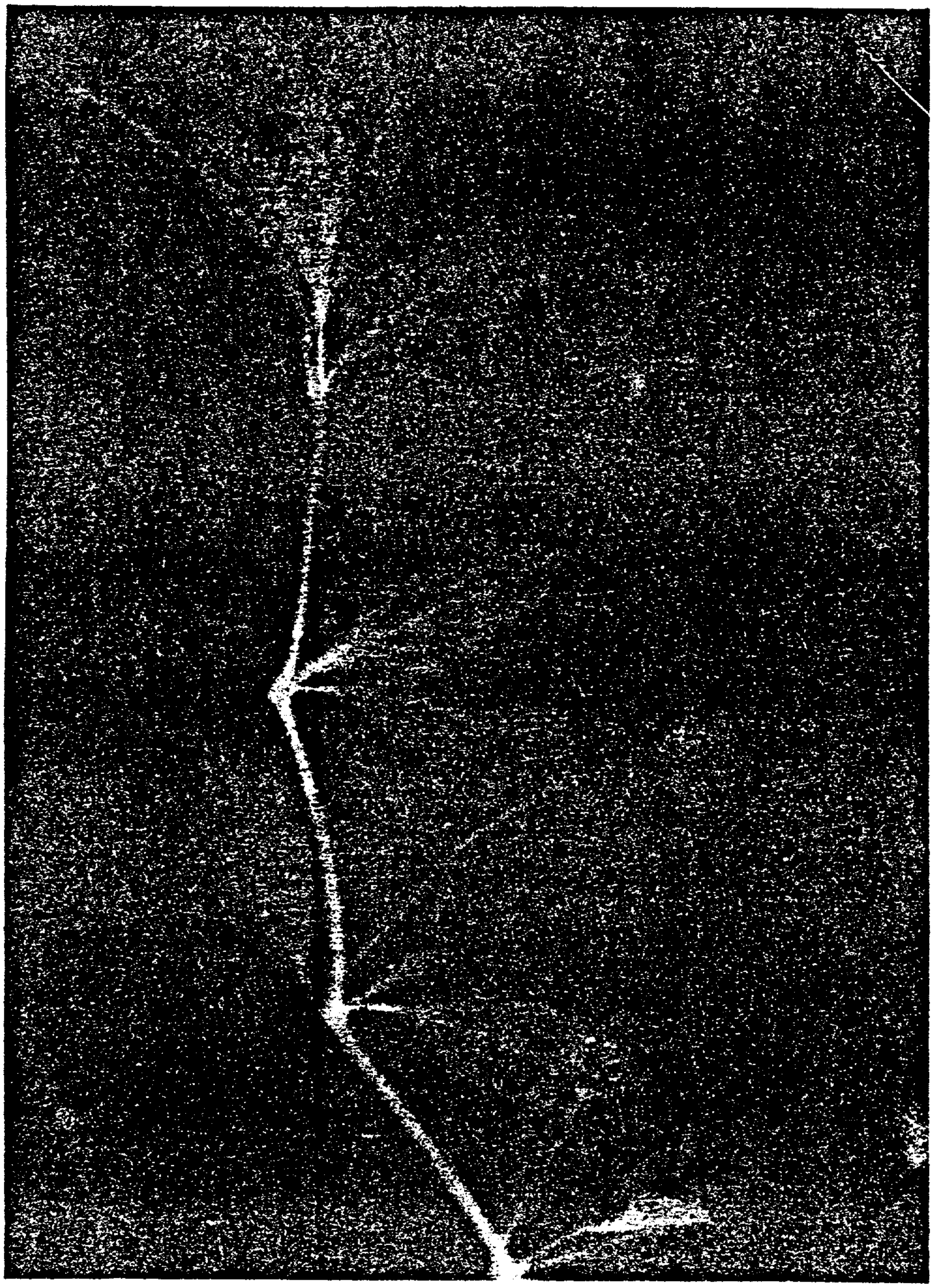


Figure 5. Autoradiogram following an exposure of 72 hours showing the flower clusters of various ages of the false nettle (Boehmeria cylindrica).

Autoradiograms were prepared from some plants having the greater part of the root system attached. There was no apparent longitudinal gradient in either direction in the concentration of radiomaterials. This information does not corroborate the findings of Kramer and Wiebe (1951) in their study of the absorption of radiophosphorus by barley roots.

Radioassay. This phase of the investigation, begun in the spring of 1951, introduced problems of sampling, sample size, and the preparation of samples for assay and radiochemical analysis. The sample size was standardized at five grams of fresh weight material. The samples were prepared for assay by digestion in concentrated nitric acid and oxidation with 30 percent hydrogen peroxide as outlined by Krumholz and Emmons (1953). The only deviation from the method as outlined was that the samples were diluted to 20 milliliters with distilled water instead of to 10. The counting time was standardized at five minutes for each sample. From these data the gross beta radioactivity was calculated in counts per minute per gram of fresh weight material.

As a protection against the inclusion of erratic data resulting from pipetting or counting, all duplicate samples which differed from each other by more than 10 counts per minute were rechecked. If the differences recurred, a new pair of samples was prepared from the original material and new counts made. In rare cases where the sample contained enough suspended material to render pipetting difficult, a third set of samples was required. The use of nitric acid in the digestion process allowed the preparation of additional samples as reliable as the original ones. The variation between duplicate samples did not occur frequently and fewer than 10 percent of the samples had to be rechecked.

During the summer of 1951, much of the time was spent in collecting field data and samples for radioassay. The greater part of the samples were collected, weighed, placed in bottles, and labelled. They were then stored in the laboratory and prepared for assay during the fall and winter.

Because of the wide variation in the types of plant material collected, and the lapse of time between the collection and assay, and, because of the fact that the greater part of the radioactivity encountered was known to be emitted by radioisotopes with relatively long half-lives, self-absorption and radioactive decay were not considered.

A number of scattered individual samples were collected and prepared for radioassay. From these data it was learned that the concentration of radiomaterials in the vegetation was extremely variable, not only among the types of vegetation such as grasses, forbs, and trees, but also among the different parts of a single plant, as the fruit, seeds, stem, leaves, wood, and bark. A survey of several woody species occurring along White Oak Creek showed that the majority of the radioactivity was concentrated in the bark as indicated in Table 1.

Subsequent individual samples failed to show any obvious relationship between the accumulation of fission products among different individuals of a particular species or between the various species growing on a particular site. This indicated that the concentration of radiomaterials by the flora did not reflect the levels of contamination in the disposal area. However, an analysis of the data from the individual samples indicated that for non-woody species, the highest concentration of radioactivity was generally in the leaves, as shown by the data in Table 2.

Table 1. Amounts of radioactivity, in counts per minute per gram, in the leaves, twigs, and bark of nine species of woody plants collected near White Oak Creek, Roane County, Tennessee

Species of plant	Radioactivity in counts per minute per gram		
	Leaves	Twigs	Bark
Poplar (*L. tulipifera*)	8	4	12
Sycamore (*P. occidentalis*)	12	8	20
Buckeye (*A. glabra*)	8	8	12
Hackberry (*C. occidentalis*)	Lost	60	32
Sweetgum (*L. styraciflua*)	4	0	32
Ash (*F. pennsylvanica*)	8	16	28
Boxelder (*A. negundo*)	52	68	44
Red maple (*A. rubra*)	4	0	8
American elm (*U. americana*)	40	60	32

Table 2. Amounts of radioactivity, in counts per minute per gram, in the leaves, vine, and stems, of several non-woody species of plants collected near White Oak Creek, Roane County, Tennessee

Species of plant	Radioactivity in counts per minute per gram		
	Leaves	Vine	Stem
Honeysuckle (*L. japonica*)	68	76	
Panic grass (*P. agrostoides*)	12		
Rose (*R. acicularis*)	180	92	
Goldenrod (*Solidago* sp.)	36		16
Dock (*R. crispus*)	46		17
Wild onion (*A. canadense*)	20		
Panicum (*P. clandestinum*)	56		44
Ironweed (*V. altissima*)	64		51
Sweet clover (*M. alba*)	42		13
Wild rye (*E. virginiana*)	52		16
Cat-tail (*T. latifolia*)	53		13
Big ragweed (*A. trifida*)	204		118
Little ragweed (*A. psilostachya*)	212		116
Beggar ticks (*B. bipinnata*)	112		82
Trumpet vine (*C. radicans*)	44	12	
Grape vine (*Vitis* sp.)	40	5	
Blackberry (*Rubus* sp.)	92		68

Individual samples were collected throughout the survey period in an attempt to check at least a few individuals of each species growing in the contaminated area. Approximately 2,000 individual samples were assayed for gross beta radioactivity. The results of those assays showed that there was a wide range in the amounts of radioactive fission products accumulated by the different plants. The results of those individual assays are listed by species in Appendix II.

As already indicated, there was a wide variation in the accumulation of radiomaterials by the different plants. To minimize the effects of that variation and to obtain a better average picture, samples were collected from each of 10 individuals of a selected species from a limited area. The first collection of this type was made from black willow trees growing along the edge of White Oak Creek in Haw Gap. From these data, the wide variation in the amounts of radiomaterials accumulated by individuals of the same species is obvious (Table 3). This wide range of levels of radioactivity suggests that factors other than the site must affect the accumulation of radiomaterials.

A similar picture of differences in the ability of individual plants to concentrate radiomaterials was obtained from samples of 10 plants of the little ragweed collected near White Oak Creek a short distance below the site of the collections of black willows. Here, however, and in some other mass collections, a soil sample was taken from near the base of each plant. An analysis of the data in Table 4 indicates that the total amounts of radioactivity present in the soil has little bearing on the amounts accumulated by the plants.

Table 3. Amounts of radioactivity, in counts per minute per gram, accumulated in samples of leaves, twigs, wood, and bark from 10 black willow trees collected near White Oak Creek, Roane County, Tennessee

Tree number	Radioactivity in counts per minute per gram				
	Leaves	1950 twigs	1951 twigs	Wood	Bark
1	27	178	12	15	105
2	33	63	45	19	96
3	44	69	63	19	126
4	82	129	113	25	221
5	40	63	70	16	122
6	54	58	67	6	57
7	14	31	23	12	52
8	51	72	71	100	132
9	16	100	21	32	62
10	132	212	172	52	260

Table 4. Amounts of radioactivity, in counts per minute per gram, accumulated in samples of leaves and stems of plants of little ragweed, together with samples of soil taken near the base of each plant, collected near White Oak Creek, Roane County, Tennessee

Plant number	Radioactivity in counts per minute per gram			
	Leaves	Upper stem	Lower stem	Soil
1	212	116	Lost	3,150
2	76	60	20	1,945
3	100	52	76	930
4	100	72	44	170
5	16	16	8	1,925
6	36	60	20	2,955
7	120	24	100	2,885
8	220	88	104	3,210
9	128	64	72	925
10	152	76	68	4,700

During this investigation, 18 group or mass collections were made from the contaminated area. The data for each of these collections are listed in Appendix II in relation to their distance from the Settling Basin (Figure 6).

The first collections of material for gross beta radioassay indicated that the leaves from herbaceous plants and the bark from trees usually contained the largest amounts of radioactive materials. Later collections, which included other parts of the plants as well, showed that there was little variation in the amounts of radioactivity among the parts of some herbaceous plants, whereas in others the leaves contained the most. An analysis of the data obtained from several of the mass collections showed that the most significant concentration of radioactive fission products is in the bark of trees. While the amounts of radiomaterials in the leaves of the herbaceious plants may not be significantly higher in some species, they do not differ significantly from other parts.

In general, the results of this investigation indicate that the bark and leaves are the best survey material if the area in question has been contaminated for any length of time. In cases where the contamination has existed for only a short time, it is believed that leaves would provide the best survey material for all types of vegetation.

Absorption and Decay Curves. In conjunction with the information on the radioactivity accumulated by the assimilation of radiomaterials, it was desirable to know which radionuclides were being concentrated by the vegetation. When as few as two or three nuclides were present in the sample, some idea of their identity was obtained from absorption curves. Absorption curves are usually prepared from samples having a fairly high

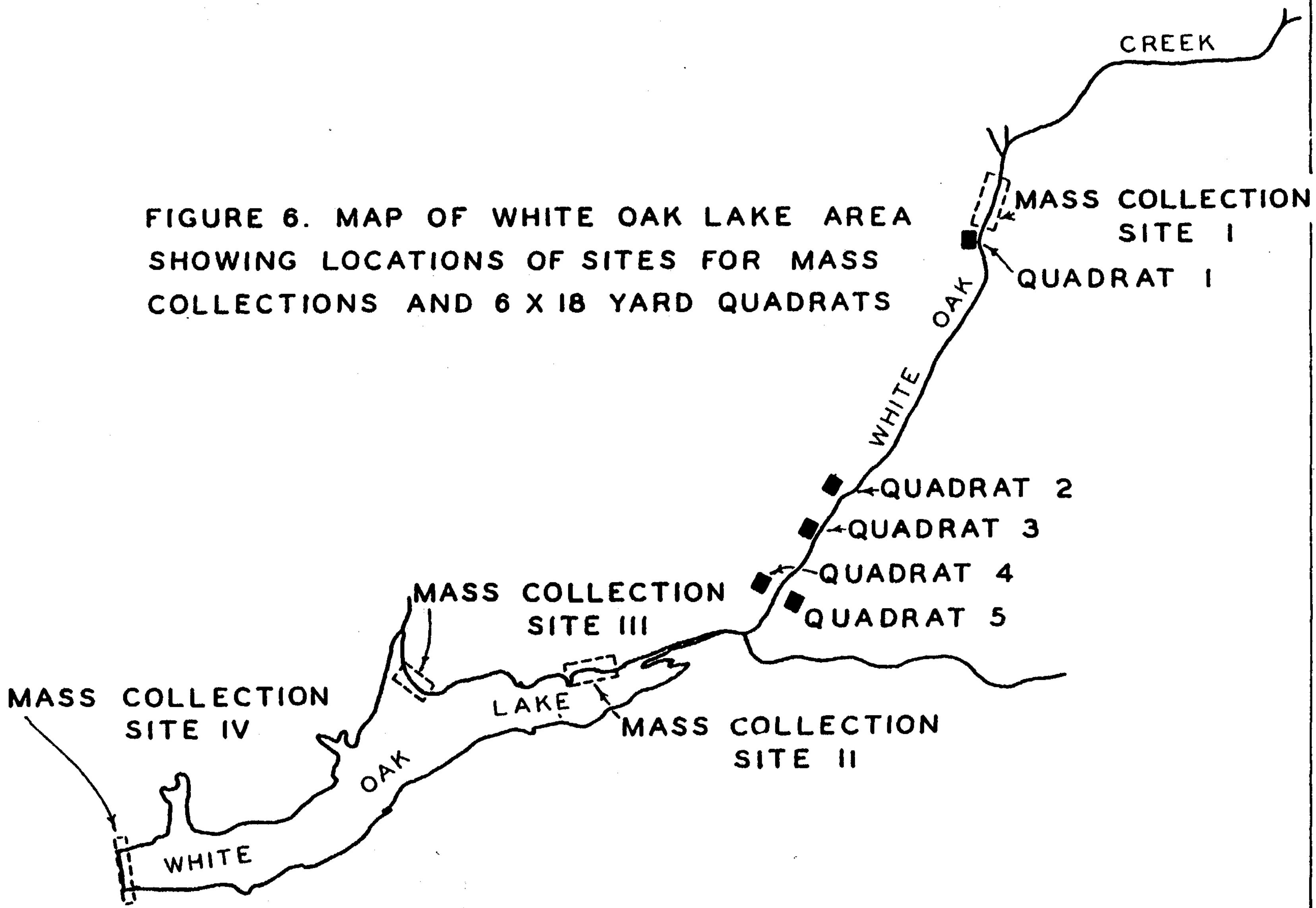


FIGURE 6. MAP OF WHITE OAK LAKE AREA SHOWING LOCATIONS OF SITES FOR MASS COLLECTIONS AND 6 X 18 YARD QUADRATS

specific activity. Such curves are relatively easy to prepare and are much less expensive than spectrographic or radiochemical analyses. They also offer a means of comparing the differences among the isotopes present in samples of several species, or from different tissues of the same species.

Although the range of gross beta radioactivity accumulated in woody species was about as wide as in the herbaceous plants, the absorption curves prepared from herbaceous material indicated that more different kinds of nuclides were present in the herbs. During the collections of the group samples, absorption curves were prepared from the plant and soil samples. Those curves showed a difference between the radioactivity in the soil and plant, indicating that not all of the available radiomaterials were being utilized by the plants.

The variation in the radioactivity in the soil was so great that no real comparison can be made between the nuclides present in the soil and those accumulated by the plants. Although there were exceptions, the general picture of radioactivity in all of the vegetation identified by absorption curves was remarkably similar. It was believed that any wide variation would be detected by comparing samples from a tree which had been growing throughout the period of contamination with the young growth of some herbaceous plant. The comparison of the curves from two such samples indicated that similar nuclides were absorbed in both cases.

The sap from a grape vine and some trees was assayed to obtain information on the concentration of radiomaterials in the plant juices. The counts on all samples were very low; never exceeding 1,000 counts per liter. In the spring of 1952, several boxelder and black walnut trees were tapped, and an attempt was made to obtain absorption curves for the sap. Despite the fact that several liters of sap were collected and concentrated, the amount of radioactivity was too low to allow for the preparation of absorption curves.

Decay curves were prepared from selected samples, so that by a comparison of the half-life of the sample with the absorption curves and data from radiochemical analysis the nuclides could be properly identified. Since the half-lives of most of the nuclides identified from the plant material were relatively long, there was little loss through decay. The decay curves for some of the samples collected from the growth in the spring of 1951 indicated that there was no appreciable decay in 30 days. This was also true for decay curves prepared from samples of elm and honeysuckle leaves collected below the lagoons. These curves showed the same rates of decay, indicating that they contained isotopes of similar half-life.

Radiochemical and Spectrographic Analyses. Before a sample was analyzed radiochemically, an indication of the kinds of elements present was determined from absorption curves, or, in some instances by spectrographic analysis. By following this procedure, much time was saved in analyses for elements known to be absent. Spectrographic analyses were made for the mass samples of black willow and ash collected near White Oak Creek, and were followed by radiochemical analyses.

In the preparation of samples for radiochemical analysis, the rate at which the samples was digested by the nitric acid depended on the kind of plant material in the sample. Young herbaceous samples were rapidly digested, whereas samples of woody material frequently required many hours.

After digestion was as complete as possible, any undigested solids were removed by centrifugation. The cleared sample usually contained so little radioactivity that concentration by evaporation was necessary. In some instances, that concentration caused supersaturation and crystallization of the salts present. However, in nearly all cases, some indication of the radioisotopes present was found. The primary isotopes accumulated by the plants living in the White Oak Lake area sampled during the study were strontium, cesium, the rare earths, ruthenium, and zirconium as indicated in Tables 5 and 6. From the data in those two tables, it is apparent that about half of the radioactivity in the samples is emitted by strontium, and its yttrium daughter, and the total rare earths. In the samples, however, approximately 40 percent of the radioactivity was emitted by radioactive isotopes of cesium and ruthenium. Although radiozirconium was frequently found, it never comprised a large percentage of the whole.

Physiological and Genetic Responses. The absorption of radioactive fission products by vegetation should not differ significantly from that of the stable chemical elements. Mineral absorption by plants is affected by a number of conditions, including soil moisture, temperature, oxygen level, and solute concentration (Hoagland, 1944).

An unusual feature of the concentration of radiomaterials in plants appears to be related to the formation of crystalline inclusions. Crystals commonly occur in plant cells, but they may be more abundant in some parts as the pith, cortex, or phloem than in others (Eames and MacDaniels, 1947). Most crystal formation results from the precipitation of calcium, usually as the oxalate, when the amount of calcium exceeds the physiological demand of the plant (Iljin, 1938). When crystallized, the calcium becomes immobile

Table 5. Radioelements isolated through radiochemical analysis from a sample of young sweet clover

Radioactivity emitted by	Counts per minute per milliliter	Percentage composition
Gross beta radioactivity	330	
Strontium and yttrium - beta	59	17
Total rare earths - beta	116	36
Unidentified radioactivity	155	47

Table 6. Radioelements isolated through radiochemical analyses of the majority of the samples prepared for gross beta radio-assay

Radioactivity emitted by	Counts per minute per milliliter	Percentage composition
Gross beta radioactivity	390	
Strontium - beta	67	17
Total rare earths - beta	116	30
Cesium - beta	95	24
Ruthenium - beta	73	18
Zirconium - beta	6	2
Unidentified radioactivity	35	9

and cannot be transported or enter into the physiological processes. Similarly, any absorption by the plants of fission products which become bound into crystals, continues to increase the specific activity of the tissues. The higher concentration of crystals in the bark, compared to that in the wood, undoubtedly accounts for the wide difference in the concentration of radiomaterials between these tissues in trees and shrubs.

The calcium content of plants gradually increases throughout the vegetative period, and the concentration in any species may vary as much as 500 percent according to the site of deposition (Iljin, 1938). It has been shown by the use of radiostrontium as a tracer that it follows the physiological path of calcium. Since the calcium has been shown to be practically immobile in leaves (Mason and Phillis, 1937), it cannot be expected to be readily translocated. It is probably true that other elements may act in this same manner, especially if they cannot be translocated in organic combination. Ruthenium, which follows the physiological path of iron, probably does not enter into organic combination, and should be retained in the leaves. Cesium has been shown to be physiologically similar to sodium, which is apparently present in the sap of all living cells in the form of sodium chloride (Meyer and Anderson, 1952). This suggests the cesium, when available, like sodium, is present in all living plant tissues.

The presence of radiomaterials throughout the plants growing in the White Oak Creek Basin was shown by autoradiograms and radioassay. From this, it is evident that the plants in the contaminated area are subjected to continuous internal radiation as long as they live. In addition to the internal radiation, the root systems received a far greater external dose from the soil and mud than the aerial parts.

There is no doubt that the radiation does some damage, but the manner in which the plant is affected is unknown. If the effects are to be judged by field observations, considering normal plant size, leaf and flower development, seed production, and general appearance, it must be concluded that the radiation dose received by the plants is below the threshold of injury.

The work of Mackie et al. (1951) has shown that where injury to barley plants was produced by exposure to radiophosphorus, there was no apparent threshold for injury. This condition appears to be true in the only case of apparent radiation damage observed during this investigation. Late in the summer of 1951, a high level of radioactivity (1,000 counts per minute per gram, fresh weight) was found in the leaves of an American elm tree growing below one of the waste lagoons. The following spring an autoradiogram was prepared from the expanding leaves which appeared normal in every respect, as indicated in Figure 7. Later in the summer, dead areas were observed along the margins of some of the leaves. The earliest signs of damage appeared in the tips of the serrations from where it gradually progressed into the leaf blade. By July, the greater part of the margins of some leaves had been affected (Figure 8).

Sections prepared from those damaged leaves showed, when examined under a microscope, that there was a sharp line of demarcation between the normal and injured tissue. This line was marked by a reduction in leaf thickness in the damaged tissue, which apparently resulted from the shrinkage of the palisade and mesophyll cells. No apparent indication of injury could be found in the normal cells. These observations support the results

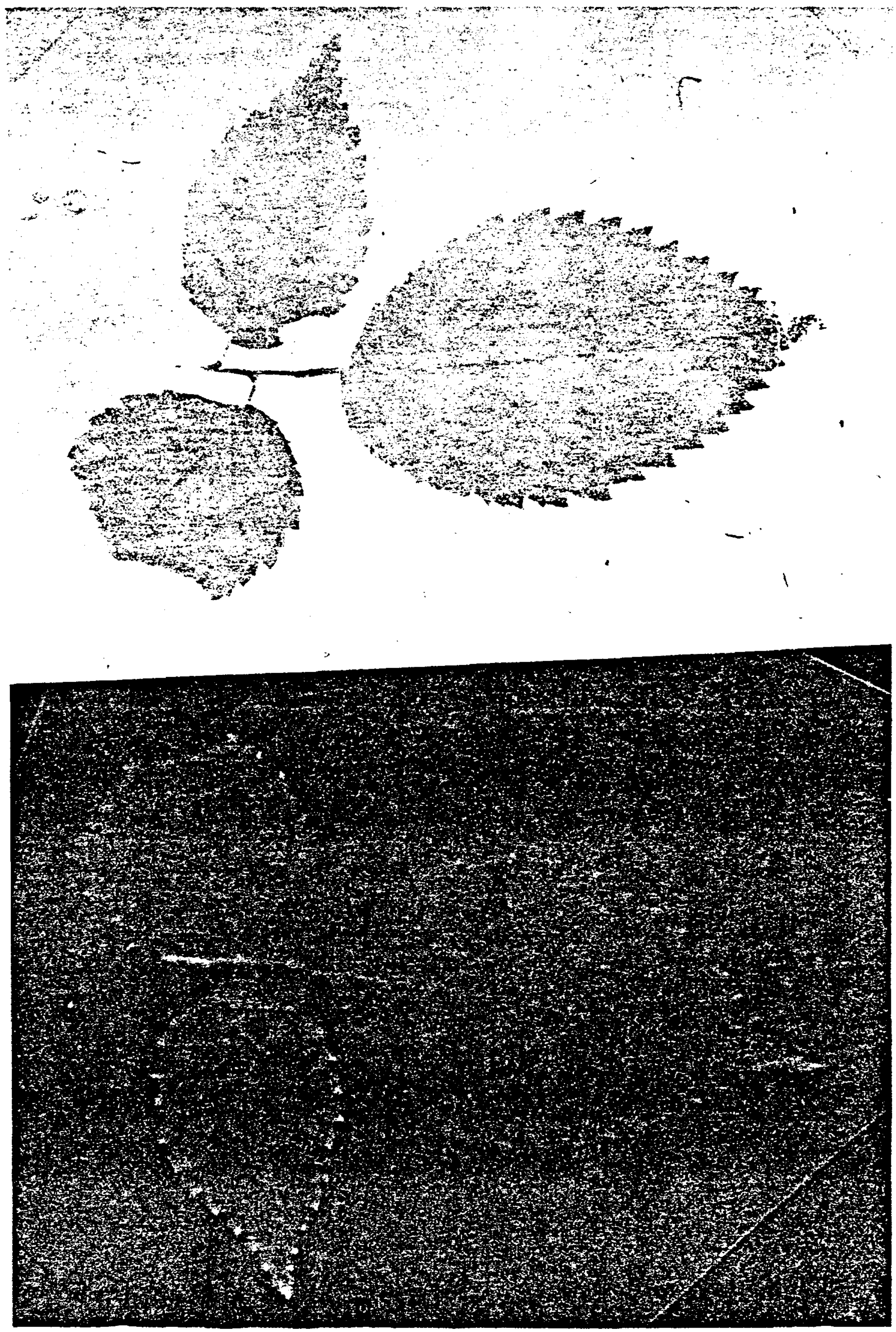


Figure 7. Photograph of leaves from American elm tree, together with an autoradiogram from the same leaves.

Figure 8. Photograph of leaves from an American elm tree showing damage to margins of leaves caused by radiation.

of the investigation of Mackie <u>et al.</u> (op. cit.) on the absence of an observable threshold of radiation injury.

The failure of the vegetation to show any visible response to the radiation is probably due to the low exposure. Plants growing in the area received both gamma and internal beta radiations throughout much, if not all of their lives. The gamma background around White Oak Lake amounts to about 25 roentgens per year. When this amount of radiation is compared with that of the cobalt field used at the Brookhaven National Laboratory, where corn produced normal plants under an exposure of 250 roentgens per day (Eleventh Semi-annual Report, AEC) the combined beta and gamma dosage received by the elm tree was probably far below the level necessary to affect growth.

Since the radiation level apparently does not influence growth, the information on the concentration of radiomaterials by the species in a limited area should indicate something of their physiological differences. It might also offer an excellent method of estimating certain physiological differences among individuals of the same species growing in a particular habitat. Most field methods of studying vegetation employ either quadrats or transects (Weaver and Clements, 1938). These same methods may be used in the studies of plant communities (Oosting, 1948). In either case, the results from the sample must express the physiological response of the individual or total species to the conditions existing at each particular site. The results may be expressed as basal area, diameter breast height, total dry weight, or numbers of individuals. In each instance, the results are based on gross measurement, and cannot reflect the physiology of the individual. It is believed that the results obtained in the mass collections show the differences between individuals as well as among species.

The estimation of the number of individuals necessary to give an adequate sample confronts every ecological investigator. This problem is an attempt to include enough individuals to express the relative importance of the species in the habitat or community. This can be further resolved to obtain a value which will express the degree of physiological responses by the species under the conditions being considered. In every instance, the number will depend largely on a level which will express individual differences. Since radioassay can detect much more minute differences than radiochemical or spectrographic analysis, it is effective at a much lower level of radioactivity. Consequently, the results are indicative of real differences in the individuals sampled.

The question of how much and what kind of injury results from the constant low level radiation from absorbed radiomaterials should be partly answered in the reaction of the plants near White Oak Creek to this condition. Radioactive materials were found throughout the plants studied. The emission of radiations from internal sources must be accompanied by the formation of ion pairs and the organism damaged in some manner.

The effect of high energy radiation on genetic material has no threshold regardless of dose (Muller, 1950). Mutations, either natural or induced, generally affect physiological processes rather than morphological characteristics. These mutations could hardly be observed in the field and consequently should not be expected to be found in a survey.

During the present survey, approximately 2,000 sheets of material representing about 400 species of plants were collected. The only plants which appeared unusual from a genetic standpoint was a clone of cat-tails which showed a variegated leaf pattern. Similar plants were produced by this clone in 1951 and again in 1952, a suggestion that the variation is permanent. A study of the plants collected did not show any differences from similar specimens in the herbarium at the University of Tennessee.

The absence of morphological changes which might indicate genetic damage probably should not be considered as evidence of the absence of radiation injury. A study of the seed viability and seedling development might show effects which were not apparent in mature plants. The lack of information on this phase of plant development suggests the desirability of such an investigation.

Adsorption of Fission Products by Soils

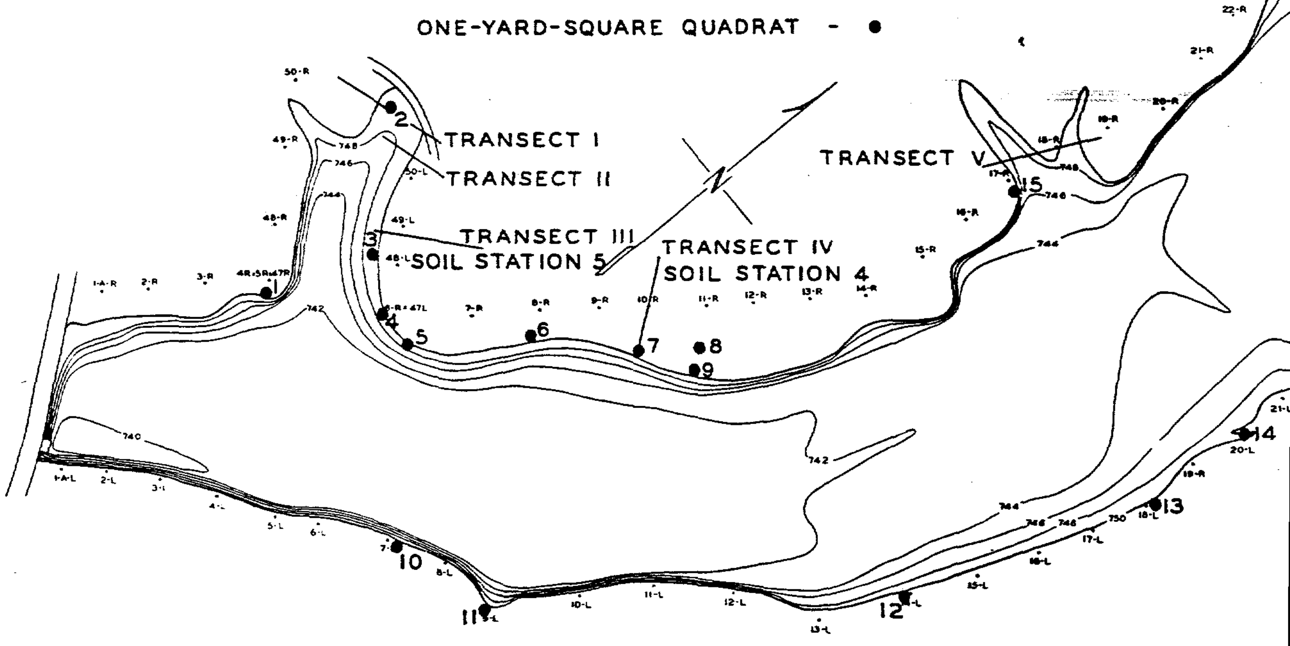
The radioactive wastes released from the Oak Ridge National Laboratory through the Settling Basin enter White Oak Creek about 0.3 mile above Haw Gap. From that point of entry, the creek flows in a narrow channel to an intermediate marshy area about 0.3 mile below Haw Gap. That marshy area is the remains of an intermediate settling pond whose dam was washed out in September 1944. The area is heavily silted and has retained very little water since the dam failed. The old pond site is now ringed with willows and cat-tails, showing a typical hydrarch succession. From the intermediate pond area the creek flows through a wider floodplain for a distance of about 0.5 mile to the upper end of White Oak Lake. The entire floodplain is inundated by occasional floods and is contaminated with radioactive waste materials.

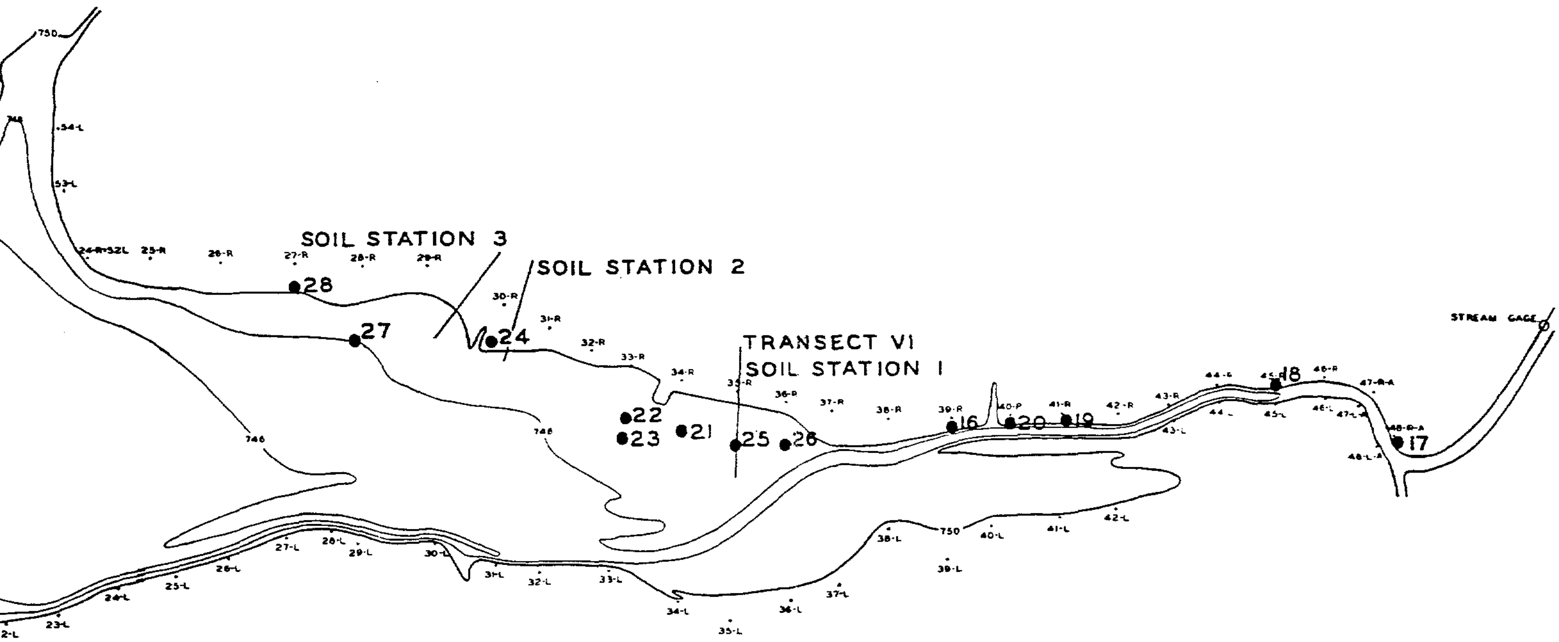
The bottom muds and shoreline of White Oak Lake are more heavily contaminated than the creek floodplain. A survey of the radioactivity in the bottom mud of White Oak Lake has been conducted by personnel of the Health Physics Division during the past several years (Abee, 1953). The results of that survey indicated that approximately 85 percent of the radioactivity present is confined to the upper three inches of mud. Since that survey was interested only in the lake bottom, no information was available on the extent of contamination of the soil within the zone of fluctuation of the water level of the lake.

To determine the distribution of radioactivity in the soil above normal pool level, five stations were established on the north bank of White Oak Lake (Figure 9). At each station, collections were made at every six-inch contour to an elevation of six feet above normal pool level. Each collection consisted of a sample of the top three inches of soil, which were prepared for radioassay by thoroughly mixing in a mortar and screening through a 200-mesh sieve. Duplicate samples of the assay mixture were placed in aluminum counting dishes, dried under heat lamps, and counted. The data from these collections showed that there was a progressive reduction in the amount of radioactivity in the soil with increased elevation above normal pool level, particularly above the 1.5 foot contour (Table 7). It is to be noted that no contamination was detected above the five-foot contour.

A study of root growth in the contaminated area indicated that there was considerable root development below the top three inches of soil. In an attempt to correlate the amount of radioactivity with depth of soil near the lake, with that of the White Oak Creek bank, core samples were taken at normal pool level at Stations 1, 3, 4, 5, and the creek bank. In this series, the concentration of the radioactivity in the upper three inches of

FIGURE 9. MAP OF WHITE OAK LAKE SHOWING LOCATIONS OF TRANSECTS, ONE-YARD-SQUARE QUADRATS, AND STATIONS FOR SOIL SAMPLING





TENNESSEE VALLEY AUTHORITY
FISH AND GAME BRANCH
ECOLOGICAL SURVEY OF WHITEOAK CREEK

MAP OF WHITEOAK LAKE

SHOWING CONTOUR INTERVALS
FULL POOL AT ELEVATION 750

0 100 200 300 400 500
SCALE IN FEET

JUNE 1953 LAK

soil was again demonstrated. The only lo
activity was very high below a depth of s
silted area in upper White Oak Lake (Tabl

The increase in radioactivity belo
bottom and creek bank shown by the two co
a more detailed study. Accordingly, core
2, and 3, near the previous sites. These
prepared from each layer one centimeter t
The data from these samples (Table 9) ind
decrease in radioactivity according to th
exception of the core taken at Station
radioactivity was found at a depth o

To supplement the informat
of radioactivity and the depth
the size of the soil particles
was undertaken. Cores, similar
at Stations 1, 3, and 4, and a ver
each core. This material was washed th
All material which remained on each of t
that fraction which floated to the top, t
off and assayed separately from the miner
bottom of the container. Following each
were removed, placed in aluminum counting
and counted. The data from this series o
the dead plant material and humus played
centration of radioactive fission product

Table 9. Amounts of radioactivity, in counts per minute per gram, dry weight, in relation to soil depth as shown by sampling continuous layers of soil one centimeter thick, White Oak Lake, Roane County, Tennessee

Depth in centimeters	Station		
	1	2	3
0-1	3,700	5,700	4,700
1-2	6,300	3,600	4,600
2-3	16,000	300	450
3-4	4,900	115	435
4-5	900	80	150
5-6	350	45	120
6-7	150	45	40
7-8	40	300	35
8-9	20	50	16
9-10	20	50	35
10-11	10	25	260
11-12	10	25	20

Table 10. Comparison of the amounts of radioactivity, in counts per minute per gram, dry weight, adsorbed by the organic and mineral fractions of soil particles of different sizes, as determined by the size of the apertures in different soil sieves

Station number	Size of apertures in square millimeters						
	2.00	0.84	0.42	0.177	0.074	0.044	0.044
	Radioactivity present						
1							
Organic	11,000	16,000	19,000	20,000	22,000	26,000	
Mineral		7,800	14,000	8,300	2,600	870	12,000
3							
Organic				720	11,000	630	
Mineral	12	700	720	420	90	60	250
4							
Organic			540	540	330		
Mineral	4	22	15	7	5	8	35

addition, there is a much more apparent inverse relationship between the size of the particles in the organic fraction and the amount of radioactivity present than in similar data for the mineral fraction. Under none of the conditions found in the entire waste disposal system did any living plants concentrate amounts of radioactivity as great as that found in the organic fraction of the mud taken from the upper end of White Oak Lake.

The adsorption of mixed radioactive fission products and other specific radioisotopes by Conasauga shale has been investigated in the laboratories of the Health Physics Division by the U. S. Corps of Engineers Research Project under the direction of W. J. Lacy. The results of that investigation indicated that Conasauga shale particles are capable of adsorbing about five million counts per gram of shale, dry weight. From this it can be assumed that the silt in White Oak Lake is far from being saturated with radiomaterials. The very low counts obtained from the well washed fine and very fine sand show that little radioactivity is adsorbed on those materials.

The amount of organic material determined to be present is indicated by the loss of radioactivity on combustion, when compared to the amount of radioactivity present in the soil sample, did not show any consistent relationship (Table 11).

The high concentration of radioactive materials found in the organic fraction removed from the core samples indicated that the emergent and shoreline vegetation might possibly affect the accumulation of fission products in the associated muds. A series of samples was taken at the shoreline near Stations 1, 2, 3, and 4 in an attempt to establish any relationship between the amount of vegetational cover and the radioactivity in the

Table 11. Comparison of radioactivity in soil samples, in counts per minute per gram, and organic matter, as indicated by loss on combustion, dry weight

Sample number	Station number	Radioactivity in soil	Percentage loss on combustion
Smartweed			
1		0	12
2	1	160	16
3		1,670	18
4		3,550	18
5		2,950	21
Swamp hemlock			
1		720	8
2	2	1,130	11
3		2,340	28
4		1,010	8
6		1,080	32
Button ball			
2		3,675	9
3	2	7,360	23
4		5,340	8
5		5,370	9
6		5,400	9

mud. Representative counts of soil samples taken from the surface under various percentages of vegetational cover indicated that there was no marked correlation (Table 12).

Adsorption of Strontium 90 and Cesium 137 by Dead Leaves and Conasauga Shale

The high content of radiomaterials in the organic fraction of the soil from the core samples suggested that the large amount of leaves and other dead vegetation which fell and washed into White Oak Creek and Lake each year might be a significant factor in the accumulation of radioactive fission products in the waste disposal system. In order to obtain some pertinent information on the adsorptive qualities of these materials, it was decided to filter known amounts of radioisotopes through a filterbed of leaves and shale. Accordingly, the bottom was removed from a five-gallon glass carboy and the vessel inverted to serve as a funnel. Alternate layers of Conasauga shale and mixed deciduous tree leaves, each about an inch thick, were then placed in the carboy. A mixture of 47 percent cesium 137 and 53 percent strontium 90, which contained a total of 6,680 counts per minute per milliliter of gross beta radioactivity, was allowed to pass through the filter until the amount of radioactivity was reduced to 175 counts per minute per milliliter. Following the filtration procedure, samples of the leaves and the shale were removed, dried, counted, and analyzed radiochemically. The amount of radioactivity in the shale was determined to be approximately 50,000 counts per minute per gram, dry weight. Upon radiochemical analysis, it was found that 72 percent of the radioactivity was emitted by strontium 90 and the remaining 28 percent by

Table 12. Amounts or radioactivity, in counts per minute per gram, dry weight, in soil samples collected under various percentages of cover

Contour elevation, inches	Station 1		Station 2		Station 3		Station 4	
	Cover	Counts	Cover	Counts	Cover	Counts	Cover	Counts
Open water	0	9,280	0	17,830				
- 18	0	9,500			0	11,230	0	6,580
- 12	0	17,200	0	13,480			0	5,360
			90	19,300				
- 6	0	31,810						
			10	10,360	40	12,640		
Normal pool					0	10,890		
level	40	10,650	40	6,880	10	9,210	10	3,380
+ 6	0	13,810						
	20	18,490	90	7,900	80	1,500		
+ 12	0	9,280			90	2,430		
+ 18	80	5,100						

the cesium 137. The radioactivity in the leaves amounted to approximately 10,000 counts per minute per gram, dry weight, which, when analyzed radiochemically, revealed that 91 percent was emitted by the radiostrontium and the remaining 9 percent by the radiocesium. These data indicated that the dead leaves selectively adsorbed about 20 percent more radiostrontium than the shale. Thus, there appears to be a possibility that such selective adsorption may assist in the introduction of that radioelement into the food chain of animals in the area.

During the study, a heavy film of bacteria (Bacillus mycoides) developed in the receptacle used to catch the effluent from the filter. Some of that material, collected and assayed for radioactivity, yielded a surprisingly high count of 102,000 counts per minute per gram, dry weight. An analysis, made to determine the relative concentration of the two isotopes, showed that 99 percent of the radioactivity was emitted by the radiocesium. The accumulation of the cesium 137 by the bacterial culture is an outstanding example of selective absorption. Since most bacteria enter into the food chain, and since cesium 137 is an important constituent of the waste material released into White Oak Creek, its appearance in some of the higher animals in White Oak Lake may be directly related to the selective absorption of that element by the micro-flora.

Plant Succession in the Contaminated Area

The contaminated section of the White Oak Creek drainage area supports a large number of cover types. From the Laboratory site to the area of the intermediate marsh, the floodplain has been disturbed by grading, clearing, mowing, siltation, and flooding. These disturbances have resulted in the formation of virtually all kinds of environment from denuded areas to a cat-tail swamp. Fortunately, there has been little recent disturbance between the intermediate marsh area and White Oak Lake. That section is typically cutover mixed hardwoods and old fields in several stages of succession. The presence of large numbers of intermediately tolerant and intolerant species of plants in this area is a good indication that some of the fields were abandoned prior to 1942.

Any of a number of methods might have been used in describing the plant succession along White Oak Creek. Of these, an adequate sample of the area taken by large quadrats would undoubtedly have yielded the best results. However, inasmuch as only five such quadrats were used, the data can serve only as a permanent record of the species present in each plot and as a support to field observations.

Under such circumstances, it appears that a comparison of the tolerance values of the various species observed would give the best indication of the present status of the forest cover in the contaminated area. The Society of American Foresters defined tolerance as "the capacity of a tree to develop and grow in the shade and in competition with other trees." (Toumey and Korstian, 1947). The principal species forming the hardwood forest along White Oak Creek, arranged according to the modification of Zon and Graves' tolerance scale by Toumey and Korstian (1947) are:

VERY TOLERANT

Beech (F. grandifolia)

TOLERANT

Red maple (_A. rubrum_)

Black gum (_N. sylvatica_)

Sourwood (_O. aboreum_)

INTERMEDIATE

Sweet gum (_L. styraciflua_)

White oak (_Q. alba_)

Southern red oak (_Q. rubra_)

American elm (_U. americana_)

Sycamore (_P. occidentalis_)

INTOLERANT

Black walnut (_J. nigra_)

In addition to these plants, the forest floor supports the following vegetation:

Mosses (_Musci_ spp.)

Sedges (_Carex_ spp.)

Nut sedge (_Scleria_)

Ferns

Grasses (_Melica mutica_ and others)

Wakerobin (_Trillium_)

May apple (_P. peltatum_)

Poison ivy (_R. toxicodendron_)

Violets (_Viola_ spp.)

Grapes (_Vitis_ spp.)

In the old fields the cover ranged from saplings to young trees. Since a number of age classes were represented here, the ground cover varied according to the development of the overstory. The principal species found are listed below according to their tolerance value:

TOLERANT

Black gum (*N. sylvatica*)

Red maple (*A. rubrum*)

INTERMEDIATE

Sweet gum (*L. styraciflua*)

Sycamore (*P. occidentalis*)

American elm (*U. americana*)

INTOLERANT

Yellow poplar (*L. tulipifera*)

Black walnut (*J. nigra*)

Ash (*F. pennsylvanica*)

Boxelder (*A. negrundo*)

Pine (*P. virginiana*)

VERY INTOLERANT

Black willow (*S. nigra*)

Sumac (*R. glabra*)

River locust (*A. fruticosa*)

Juniper (*J. virginiana*)

The ground cover is more extensive and includes more species than in the area of mature forest. These species are listed below in order of their relative cover importance:

GRASSES

Wood reedgrass (*C. latifolia*)

Wild rye (*E. canadensis*)

Manna-grass (*G. stricta*)

Rice cutgrass (*L. oryzoides*)

Bottle-brush grass (*H. patua*)

Panic grasses (*Panicum* spp.)

FORBS

Goldenrods (*Solidago* spp.)

Asters (Aster spp.)

Lespedeza (*L. striata*)

Tick-clover (*Desmodium* spp.)

Buttercups (*Ranunculus* spp.)

Pokeweed (*P. americana*)

Ironweed (*V. altissima*)

VINES

Poison ivy (*R. toxicodendron*)

Trumpet vine (*C. radicans*)

Virginia creeper (*P. quinquefolia*)

Grapes (*Vitis* spp.)

Greenbriar (*Smilax* spp.)

In order to obtain some permanent record of the bottomland forest and the successional stages present in the old fields, five quadrats, each six yards wide and 18 yards long, were established in the contaminated section of White Oak Creek bottom (Figure 6). In each quadrat a nest of two smaller quadrats were placed in a selected corner. Those two smaller areas were three yards by six yards for checking saplings and transgressive species, and one yard by three yards for checking the seedlings and ground cover.

In each of these quadrats every individual plant in the overstory and understory was charted as to its position, and the diameter breast height of the trees recorded. Similar records were made for the species in the smaller nested quadrats, and, whenever possible, the relative cover values of the plants in the one-yard by three-yard quadrats were noted as percentage of the total cover. A study of the plants growing in these five quadrats indicates that the conditions present in this area reflect a highly unstable situation in the bottomland forest. The presence of 50 percent or more of plants classified as intolerant or very intolerant in all of the quadrats except Quadrat Number 2, indicates that a great deal of change is to be expected in the makeup of these quadrats during the next 20 years. Although the trees are growing on contaminated soil, the successional stages observed during the two years of study have not shown any unusual pattern.

The area around White Oak Lake presents the largest area of contamination, the greatest number of species, and the widest range of cover types. The alteration of habitats following the impoundment of the lake is still evident from the large number of dead and dying trees present. Although these changes are still occurring, there has been sufficient time since impoundment to allow the establishment of definite vegetational zones around the lake which correspond to similar zones in the nearby larger impoundments. In these larger reservoirs, the ecological top pool level is considered to be the invading edge of the broomsedge (Andropogon) zone. Around White Oak Lake this appears immediately above the sedge (Carex) zone.

The width of the various succession zones around White Oak Lake depends upon the slope of the bank. On the steeper slopes, the mixture of species present is sometimes confusing, whereas on the gentler slopes, the zones exhibit a regular sequence.

The results of the studies of the transects located in the contaminated area (Figure 9) failed to show any differences in the successional patterns between the upper end of the lake where the amount of contamination was relatively high and the lower end of the lake where the amount of contamination was relatively low.

In order to supplement the successional record obtained from the transects, and to accurately check the vegetation for the concentration of radiomaterials, 28 quadrats, each one-yard square, were established around White Oak Lake (Figure 9). In each quadrat the vegetation was charted and the percentage of total cover for each species was estimated. Standard five-gram samples were taken from each species for radioassay. In cases where a species made up a considerable portion of the total cover, samples were taken from different parts of the quadrat. In addition, five soil samples were collected, one from each corner, and one from the center of each quadrat in order to evaluate the amount of radioactivity present in the soil underlying each quadrat.

The radioassay of the samples of vegetation was completed for 14 of the quadrats along with the soil samples from nine quadrats. From these data it was impossible to obtain any satisfactory correlation between the amount of radioactivity in the soil and the plants growing therein. Also, no satisfactory scale of accumulation of radiomaterials between the species of plants checked could be formulated.

A one-yard-square plot represents the minimum size of sample plot for the vegetation growing around White Oak Lake. If, in this small an area, wide differences were found in the concentration of radioactive fission products among the major species, it must be concluded that the level of soil contamination had little influence on the absorption of radiomaterials by the vegetation. These findings substantiate the conclusions drawn from the general survey of the flora by both individual and mass collections and radioassay.

Relation of Emergent Vegetation to Radioactive Waste Disposal

The presence of emergent vegetation in natural or impounded waters used for the disposal of radioactive wastes presents two problems: (1) the absorption and concentration of radioactive materials by the vegetation, and (2) the growth of attached algae on the rooted plants.

In White Oak Lake the most extensive growth of any plant is that of the soft rush (*J. effusus*) which grows in the water to a depth of about 18 inches. The woody plants, black willow (*S. nigra*), ash (*F. pennsylvanica*), and buttonbush (*C. occidentalis*) are found growing in water up to three feet deep. All of these plants support some growth of attached algae, but the formation of the large algal mats is generally restricted to the herbaceous plants. Mats of attached algae may grow in White Oak Lake for several weeks under favorable conditions.

Observations during the two-year study period indicate that the development of algal mats is not directly dependent on the amount of surface area of the host plant, but rather on the area of the plant which remains at the surface during fluctuations in the water level. As a result, there is a development of large mats of attached algae in the rush zone where a great many flexuous stems remain on the surface irrespective of the water level. In addition, the mats growing on such stems is not affected by wave action as much as that attached to more rigid plants. Although trees offer a sizeable area for attachment of algae, the growth seldom exceeds a ring that extends more than a few inches into the water. In vegetative cover where bulrush is growing, it was estimated that less than 10 percent of the cover was provided by the rush plants while about 75 percent of the cover was provided by the algal mats. Among black willows and ash, there was an intersectional cover value of less than 10 percent, whereas that of the algal growth was also less than 10 percent.

Samples of both woody and herbaceous plants, along with samples of an attached alga (Spirogyra), were assayed for gross beta radioactivity. The results obtained indicate that the concentration of radiomaterials by the rooted vegetation was extremely low when compared to that of the attached algae (Table 13).

During the growing periods of these algal mats, high concentrations of radioactive materials are available to aquatic animals, especially those which feed directly on algae. Furthermore, it has been pointed out in the report of the Limnology Section of the survey that large concentrations of algae result in the accumulation of relatively large amounts of radioactivity. The methods of shoreline management employed by the Tennessee Valley Authority

Table 13. Concentrations of radioactivity, in counts per minute per gram, wet weight, and in lake water, in counts per minute per milliliter, upper White Oak Lake, Roane County, Tennessee

Sample	Radioactivity
Water	6
Black willow leaves	130
Ash leaves	90
Buttonbush leaves	20
Rush (*J. effusus*) stem	30
Rush (*J. acuminatus*) whole plant	20
Rush (*J. tenuis*) whole plant	30
Bulrush (*S. lineatus*) whole plant	30
Sedge (*C. vulpinoidea*) whole plant	105
Algae (*Spirogyra*)	15,000

in the control of emergent vegetation in the mainstream reservoirs, provide sufficient information to minimize these problems in impoundments such as White Oak Lake.

Accumulation of Radioactivity in Hardwood Trees

The general survey of the contaminated area by scattered individual samples and mass collections presented the problem of seasonal variation in the accumulation of radioactivity in the trees growing along White Oak Creek.

Early in September 1951, most of the trees growing in the Haw Gap Area were cut down. This clearing procedure provided an excellent opportunity to collect simultaneous samples from all parts of the trees. Samples had been taken from a large number of trees for radioassay, but only a very few had been sampled from base to tip. Accordingly, samples of wood and bark were taken at intervals of four feet from each tree from the ground upwards. Other samples were collected from the lowest limb, a middle limb, and the terminal branch. Enough trees of several species were sampled to furnish a representative picture of the vertical distribution of radiomaterials throughout the different parts. Data from the following trees are included in Table 14: sycamore (*P. occidentalis*), black willow (*S. nigra*), ash (*F. pennsylvanica*), American elm (*U. americanus*), and smooth sumac (*R. glabra*).

These data indicate that there is very little variation in the amount of radioactivity in the wood throughout the individual trees. In most instances in the samples of bark, it is apparent that the basal bark was probably contaminated with silt, and higher counts were recorded there

Table 14. Vertical distribution of radioactivity, in counts per minute per gram, fresh weight, in trees growing near White Oak Creek in the Haw Gap area, Roane County, Tennessee

Tissue sampled	Radioactivity in kind and number of tree								
	Sycamore		Black willow		Ash		American elm		Sumac
	4	5	1	2	1	2	1	2	1
Wood									
at base	12	28		16	8	4	12	24	24
at 4 feet	32	24		4	4	20	12	12	20
at 8 feet	40		12	4	4	4	12	12	8
at 12 feet			16	0		4	16	20	20
at 16 feet			12	8		4		8	
at 20 feet			28	4					
at 24 feet			4						
Bark									
at base	250	250		50	35	55	150	270	125
at 4 feet	60	190		12	12	30	165	170	30
at 8 feet	50	130	200	45	25	25	90	135	25
at 12 feet			130	20		8	110	85	20
at 16 feet			140	12		25		100	
at 20 feet			75	20					
at 24 feet			55						
Lowest limb									
1951 twigs		70		16			130		
1950 twigs		60		4			150	95	
Leaves		16		25		30	135	100	
Middle limb									
1951 twigs		75				20	100	100	
1950 twigs	45	50					80	90	
Leaves		85				30	90	80	
Terminal limb									
1951 twigs	130	50	30	16		12	16	35	16
1950 twigs	20	30	30	20		30	30	30	12
Leaves	160	60	50	25		70	50	25	40

than among the other samples. The general trend in all samples other than the wood, was a decrease in radioactivity from the lower parts of the tree toward the top. Such a decrease is to be expected if the greater part of the radioactivity is confined to crystals because it is known that the older plant tissues contain more crystalline materials than the younger ones.

Concentration of Waste Storage Effluent by Plants

In October 1951, following the filling of a waste storage pit (lagoon), some of the plants growing near an intermittent stream below that installation became contaminated. A survey of the area indicated that a number of species had concentrated various amounts of gross beta radioactivity. The plants sampled were honeysuckle, trumpet vine, American elm, maple, ironweed, and sycamore (Table 15).

In each species, regardless of its growth form, the greatest amount of radioactivity was in the leaves. Absorption curves prepared from the samples of leaves of the elm and honeysuckle indicated that the radioactivity in both species was emitted by a similar combination of radioisotopes. Radiochemical analyses of those samples revealed that more than 75 percent of the radioactivity in each one was emitted by radioruthenium, about the same concentration as that found in the effluent. That elm tree was the largest plant observed to date that was heavily contaminated with radioruthenium. Since the biochemistry of this element is poorly understood, it is of interest to note that the concentration of radiomaterials was primarily in the leaves. However, the concentration in the leaves should not necessarily be considered unusual, inasmuch as there was a

Table 15. Accumulation of radioactivity, in counts per minute per gram, fresh weight, by plants growing near a waste storage pit, White Oak Lake, Roane County, Tennessee

Tissue sampled	Kind of plant					
	Honeysuckle	Trumpet vine	American elm	Maple	Ironweed	Sycamore
Leaves	3,700	120	1,180	20	205	135
Vine	200	16				
Twigs						0
Stem					0	
Wood			30	4		

Table 16. Accumulation of radioactivity, in counts per minute per gram, fresh weight, in the twigs of an American elm tree

Date of collection	Radioactivity
October 29, 1951	160
January 18, 1952	770
March 26, 1952	1,000
May 2, 1952	1,370

consistent increase in the amounts of ruthenium in the twigs of that tree during the period of observation as shown by the data in Table 16. This accumulation of radiomaterials throughout the winter months provides good evidence that solutes were continually absorbed by the tree. Perhaps this same sort of solute absorption occurs in all deciduous trees throughout the winter.

Summary and Conclusions

The two-year study conducted by the Botanical Section of the Ecological Survey of White Oak Creek did not detect any changes in the vegetation which could be related to contamination by radioactive fission products. A survey of the flora revealed no unusual morphological abnormalities which might suggest genetic changes with the single exception of one clone of cat-tails near the Settling Basin. That clone exhibited a variegated leaf pattern which was similar in the springs of 1951 and 1952, a suggestion that it had been permanently altered.

Autoradiography of individuals of several species of plants showed the presence of radiomaterials throughout the plants. Autoradiograms prepared from sections of wood older than the period of contamination showed no differences in the layers of various ages. Most of the radioactivity was accumulated in the bark.

Gross beta radioassay of individuals of any species of plant growing in the contaminated area showed that they all may absorb radioactive fission products. A wide range in the concentration of such materials was found in individuals of the same species as well as among the various species growing on the same site. There was no apparent correlation between the amount of radioactivity in the soil and the amounts absorbed by the vegetation growing in it. Absorption curves prepared from material collected from different species indicated that a similar combination of radiomaterials was concentrated by all species, and gave some indication of selective absorption. Similar combinations of radioisotopes was shown by decay curves. The following radioisotopes were identified from plant material by radiochemical analysis: strontium, cesium, ruthenium, rare earths, and zirconium.

No apparent genetic effects, with the single exception of the cattails already mentioned, were found. Even though no work was done on seed viability and survival of seedlings, it is believed that the lack of abnormal mature individuals should not be accepted as proof that no genetic injuries are occurring.

No physiological differences were revealed either by growth characteristics or by size between plants growing in the most heavily contaminated areas and those on normal sites. The accumulation of radioactive fission products in plant tissues showed a high correlation with the amount of crystalline inclusions expected in the particular tissues. Strontium and cesium, when used as isotopic tracers, apparently follow the paths of calcium and sodium respectively. Consequently, the amount of calcium oxalate crystals in a plant should have some relationship to the amount of strontium absorbed. The overall results of the survey indicated that the amount of radiomaterials concentrated by the vegetation is dependent to a certain extent upon the amount of calcium in the plant and also in the soil.

The plant succession in the contaminated area along White Oak Creek and around White Oak Lake appeared to be normal. Permanent quadrats, six yards by eighteen yards, were established in the bottomland forest area along White Oak Creek. Future alterations in the forest cover may be evaluated in these plots. Plant succession and changes in the amounts of radioactivity in the soil as well as the plants can readily be followed in the 28 one-square-yard plots established around White Oak Lake. Preliminary results from these small quadrats indicated a wide range of concentration of radiomaterials by the species present.

A limited survey of the radioactivity in trees growing along White Oak Creek showed little or no seasonal variation.

The results of radioassay of samples of wood from a few trees in the Haw Gap area indicated that there was little variation from the base to the top. The amounts of radioactivity in samples of leaves, twigs, and bark from the same trees appeared to decrease from the base towards the top.

Plants growing in an area contaminated largely by radioruthenium showed the greatest concentration of radioactivity in the leaves. Samples of twigs from an American elm tree showed a gradual increase in accumulation from October 1951 to the following May.

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APPENDIX I

LIST OF PLANTS COLLECTED AND IDENTIFIED

The following plants are listed according to the system of Engler and Prantl, and the nomenclature of Gray's *Manual of Botany*, Eighth Edition. Small's *Flora of the Southeastern States*, and Britton and Brown's *Illustrated Flora* were used as supplementary references. In addition, the following special keys were very useful: Shanks - *Key to Juncus in Tennessee*, Underwood - *The Cyperaceae of Tennessee*, Hudson - *Asters of East Tennessee*, and Conrad - *How to Know the Mosses*.

Among the vascular plants, the notations on the right side of the paper indicate where collections of the plants have been placed: US - U. S. National Herbarium, UT - University of Tennessee, DU - Duke University. In all cases where there is no such indication, the plants were identified in the field but were not collected.

Bryophyta (Mosses and Liverworts)

Musci (Mosses)

Polytrichaceae

Atrichum undulatum (Hedw.) Beauv.

Atrichum sp.

Polytrichum ohioense R. & C.

Fissidentaceae

Fissidens sp.

Ditrichaceae

Ditrichum pallidum (Hedw.) Hampe

Dricanaceae

Dicranum scoparium Hedw.

Pottiaceae

Tortella humilis (Hedw.) Jenn.

Grimmiaceae

Grimmia apocarpa Hedw.

Funariaceae

Funaria sp.

Physcomitrium turbinatum (Mx.) Brid.

Aulacomniaceae

Aulacomnium heterostichum (Hedw.) Bry. Eur.

Bartramiaceae

Bartramia pomiformis Hedw.

Bryaceae

Bryum sp.

Mniaceae

Mnium affine Bland.

Mnium cuspidatum Hedw.

Hypnaceae

Amblystegium sp.

Barachythecium acuminatum (Hedw.) Kindb.

Campylium chrysophyllum (Brid.) Bryhn

Campylium hispidulum (Brid.) Mitt.

Cirriphyllum boscii (Schw.) Grout

Climacium americanum Brid.

Entodon seductrix (Hedw.) C. M.

Entodon sp.

Hypnum curvifolium Hedw.

Hypnum sp.

Plagiothecium sp.

Pylaisia sp.

Leskeaceae

Anomodon attenuatus (Hedw.) Hueben.

Anomodon rostratus (Hedw.) Schimp.

Leskea sp.

Thuidium virginianum (Brid.) Lindb.

Thuidium sp.

Fabroniaceae

Clasmatodon parvulus (Hampe) Sull.

Hepaticae (Liverworts)

Porellaceae

Porella pinnata L.

Frullaniaceae

Frullania sp.

Pelliaceae

Pellia epiphylla (L.) Corda

Marchantiaceae

Conocephalum conicum (L.) Dumort.

Anthocerotaceae

Anthoceros sp.

Pteridophyta (Vascular Cryptogams)

Selaginellaceae (Spikemoss)			
Selaginella apoda (L.) Fern.	US	UT	DU
Ophioglossaceae (Adder's-tongue)			
Botrychium dissectum (Spreng.) Clute			
Botrychium virginianum (L.) Sw.			
Polypodiaceae (Ferns)			
Onoclea sensibilis L.	US	UT	DU
Dryopteris hexagonoptera (Michx.) Christens	US	UT	DU
Polystichum acrostichoides (Michx.) Schott	US	UT	DU
Campostorus rhizohhyllus (L.) Link			
Asplenium cryptolepis Fern.	US	UT	DU
Asplenium resiliens Kunze.	US	UT	DU
Asplenium platyneurion (L.) Oakes.	US	UT	
Pellaea atropurpurea (L.) Link	US		
Adiantum pedatum L.	US	UT	DU
Polypodium virginianum L.	US	UT	DU

Spermatophyta (Seed plants, Flowering plants)

Gymnospermae (Gymnosperms)

Pinaceae (Pine)			
Pinus strobus L.	US	UT	DU
Pinus echinata Mill.	US	UT	DU
Pinus virginiana Mill.	US	UT	DU
Juniperus virginiana L.	US	UT	DU

Angiospermae (Angiosperms)			
Monocotyledoneae (Monocotyledons)			
Typhaceae (Cat-tail)			
Typha latifolia L.	US	UT	DU
Zosteraceae (Pondweed)			
Potamogeton crispus L.			
Alismataceae (Water plantain)			
Alisma subcordatum Raf.		UT	
Sagittaria australis (J. G. Sm.) Small	US	UT	DU
Gramineae (Grass)			
Arundinaria gigantea (Walt.) Chapmn.	US	UT	DU
Bromus tectorum L.	US	UT	
Glyceria striata (L.) Hitch.	US		DU
Poa autumnalis Muhl.	US	UT	DU
Melica mutica Walt.	US	UT	DU
Dactylis glomerata L.			
Triodia flava L. Smyth	US		
Elymus canadensis L.	US	UT	DU
Hystrix patula Moench	US	UT	DU
Danthonia spicata (L.) Beauv.	US	UT	DU
Agrostis perennans (Walt.) Tuckerm.	US	UT	DU
Cinna arundinacea L.	US	UT	DU
Phleum pratense L.	US	UT	DU
Aristida oligantha Michx.	US	UT	DU
Aristida dichotoma Michx.	US	UT	DU

Eleusine indica (L.) Gaertn.	US	UT	
Leersia virginica Willd.	US	UT	DU
Leersia oryzoides (L.) Sw.	US	UT	DU
Digitaria sanguinalis (L.) Scop.	US		
Paspalum laeve Michx.	US	UT	
Paspalum boscianum Flugge	US		DU
Paspalum dilatatum Poir.	US	UT	
Panicum dichotomiflorum Michx.	US	UT	
Panicum philadelphicum Bernh.	US	UT	DU
Panicum anceps Michx.	US		
Panicum stipitatum Nash	US	UT	DU
Panicum microcarpon Muhl.	US	UT	DU
Panicum lanuginosum Ell.	US		
Panicum polyanthes Schultes	US	UT	
Panicum commutatum Schultes	US	UT	DU
Panicum boscii Poir.	US	UT	DU
Echinochloa crusgalli (L.) Beauv.	US	UT	DU
Echinochloa walteri (Pursh) Nash			
Setaria geniculata (Lam.) Beauv.	US	UT	
Setaria lutescens (Weigle.) Beauv.	US	UT	DU
Andropogon scoparis Michx.			
Andropogon tenarius Michx.	US	UT	DU
Sorgum halepense (L.) Pers.	US		

Cyperaceae (Sedge)

Cyperus flavescens L.	US	UT	DU
Cyperus strigosus L.	US	UT	DU

Cyperus tenuifolius (Steud.) Dandy	US	UT	DU
Eleocharis obtusa (Willd.) Schultes	US	UT	DU
Fimbristylis autumnalis (L.) R. and S.	US	UT	DU
Scirpus atrovirens Willd.	US	UT	DU
Scirpus lineatus Michx.	US	UT	DU
Scirpus rubricosus Fern.	US	UT	
Scleria triglomerata Michx.	US	UT	DU
Carex texensis (Torr.) Bailey	US	UT	DU
Carex rosea Schkuhr	US	UT	DU
Carex cephalophoras Muhl.	US	UT	DU
Carex vulpinoides Michx.	US	UT	DU
Carex tribuloides Wahlenb.	US	UT	DU
Carex normalis Mackenz.	US	UT	DU
Carex festucacea Schkuhr			
Carex artitecta Mackenz.	US	UT	DU
Carex nigromarginata Schwein.	US	UT	
Carex hirsutella Mackenz.	US	UT	DU
Carex caroliniana Schwein.	US	UT	DU
Carex oxylepis Torr. & Hook.	US		
Carex granularis Muhl.	US	UT	DU
Carex oligocarpa Schkuhr	US	UT	DU
Carex digitalis Willd.	US	UT	DU
Carex blanda Dew.	US		
Carex frankii Kunth	US	UT	DU
Carex lurida Wahlenb.	US	UT	DU
Carex louisianica Bailey			

Araceae (Arum)

Arisaema triphyllum (L.) Schott	US	UT	DU
Arisaema dracontium (L.) Schott	US	UT	DU

Juncaceae (Rush)

Juncus tenuis Willd.	US	UT	DU
Juncus platyphyllus (Weig.) Fern.			
Juncus dudleyi Weig.			
Juncus coriaceus Mackenz.	US	UT	DU
Juncus effusus L.	US	UT	DU
Juncus marginatus Rostk.	US	UT	DU
Juncus acuminatus Michx.	US	UT	DU
Juncus debilis Gray	US	UT	
Luzula acuminata Raf.	US	UT	
Luzula echinata (Small) F. J. Herm.	US	UT	DU

Liliaceae (Lily)

Chamaelirium luteum (L.) Gray	US		
Uvularia perfoliata L.	US	UT	
Uvularia sessilifolia L.		UT	
Allium canadense L.	US	UT	
Hemerocallis fulva L.	US	UT	
Erythronium americanum Ker	US	UT	DU
Yucca smalliana Fern.			
Smilacina racemosa (L.) Desf.	US	UT	DU
Polygonatum biflorum (Walt.) Ell.	US	UT	DU
Trillium luteum (Muhl.) Harbison	US	UT	DU
Smilax ecirrhata (Engelm.) S. Wats.	US		
Smilax glauca Walt.	US	UT	

Dioscoreaceae (Yam)			
Dioscorea quaternata (Walt.) J. F. Gmel.	US	UT	DU
Amaryllidaceae (Amaryllis)			
Hypoxis hirsuta (L.) Coville	US		
Iridaceae (Iris)			
Sisyrinchium angustifolium Mill.	US	UT	DU
Iris verna L.	US	UT	DU
Orchidaceae (Orchid)			
Spiranthes praecox (Walt.) S. Wats.	US		
Corallorhiza wisteriana Conrad	US	UT	DU
Corallorhiza odontorhiza (Willd.) Nutt.	US		
Tipularia discolor (Pursh.) Nutt.	US		DU
Dicotyledeneae (Dicotyledons)			
Saururaceae (Lizard's tail)			
Saururus cernuus L.	US	UT	DU
Salicaceae (Willow)			
Salix nigra Marsh.	US	UT	DU
Salix babylonica L.			
Populus nigra L.			
Juglandaceae (Walnut)			
Juglans nigra L.	US		
Carya tomentosa Nutt.	US	UT	DU
Corylaceae (Hazel)			
Ostrya virginiana (Mill.) K. Koch			
Carpinus caroliniana Walt.	US	UT	DU
Alnus serrulata (Ait.) Willd.	US	UT	DU

Fagaceae (Beech)			
Fagus grandifolia Ehrh.	US		
Quercus alba L.	US		DU
Quercus muhlenbergii Engelm			
Quercus rubra L.			
Quercus falcata Michx.	US	UT	DU
Ulmaceae (Elm)			
Ulmus americana L.	US	UT	DU
Ulmus alata Michx.	US	UT	DU
Celtis occidentalis L.			
Moraceae (Mulberry)			
Morus rubra L.			
Maclura pomifera (Raf.) Schneid.			
Urtiaceae (Nettle)			
Urtica dioica L.			
Boehmeria cylindrica (L.) Sw.	US	UT	DU
Loranthaceae (Mistletoe)			
Phoradendron flavescens (Pursh) Nutt.			
Aristolochiaceae (Birthwort)			
Asarum ruthii Ashe	US	UT	DU
Polygonaceae (Buckwheat)			
Rumex orbiculatus Gray		UT	
Rumex crispus L.			
Rumex conglomeratus Murr.		UT	
Rumex obtusifolius L.	US	UT	DU
Rumex acetosella L.	US	UT	DU
Tovara virginiana (L.) Raf.	US	UT	DU

Polygonum pennsylvanicum L.	US	UT	
Polygonum lapathifolium L.	US	UT	DU
Polygonum punctatum Ell.		UT	
Polygonum hydropiperoides Michx.	US	UT	DU
Chenopodiaceae (Pigweed)			
Chenopodium ambrosioides L.	US	UT	
Amaranthaceae (Amaranth)			
Amaranthus hybridus L.	US		
Phytolaccaceae (Pokeweed)			
Phytolacca americana L.	US	UT	DU
Portulacaceae (Purslane)			
Claytonia virginica L.	US	UT	DU
Caryophyllaceae (Pink)			
Stellaria pubera Michx.	US	UT	DU
Agrostemma githago L.			
Silene virginica L.	US	UT	
Dianthus armeria L.	US	UT	
Ranunculaceae (Crowfoot)			
Ranunculus abortivus L.	US	UT	DU
Ranunculus recurvatus Poir.	US	UT	
Thalictrum polygamum Muhl.	US	UT	DU
Anemonella thalictroides (L.) Spach	US	UT	DU
Hepatica americana (DC.) Ker	US		
Anemone virginiana L.	US	UT	DU
Anemone lancifolia Pursh	US	UT	DU

Berberidaceae (Barberry)			
Podophyllum peltatum L.	US	UT	DU
Magnoliaceae (Magnolia)			
Magnolia acuminata L.			
Magnolia tripetala L.	US	UT	
Liriodendron tulipifera L.	US	UT	
Calycanthaceae (Calycanthus)			
Calycanthus floridus L.			
Annonaceae (Custard-apple)			
Asimina triloba (L.) Dunal	US	UT	
Lauraceae (Laurel)			
Sassafras albidum (Nutt.) Nees	US	UT	DU
Lindera benzoin (L.) Blume	US	UT	DU
Papaveraceae (Poppy)			
Sanguinaria canadensis L.	US	UT	DU
Cruciferae (Mustard)			
Draba verna L.	US	UT	
Lepidium sp.			
Capsella bursa-pastoris (L.) Medic.			
Arabidopsis thaliana (L.) Heynh.	US	UT	DU
Rorippa sessiliflora (Nutt.) Hitchc.	US	UT	
Nasturtium officinale R. Br.	US	UT	
Barbarea verna (Mill.) Aschers.	US	UT	DU
Dentaria laciniata Muhl.	US	UT	DU
Cardamine bulbosa (Schreb.) BSP.	US	UT	DU
Arabis canadensis L.	US		

Arabis virginica (L.) Trealease	US	UT	DU
Crassulaceae (Orpine)			
Sedum ternatum Michx.	US	UT	DU
Saxifragaceae (Saxifrage)			
Penthorum sedoides L.	US	UT	DU
Saxifraga caroliniana Gray			
Tiarella cordifolia L.	US	UT	DU
Heuchera americana L.			
Mitella diphylla L.			
Hydrangea aborescens L.	US	UT	DU
Hamamelidaceae (Witch-hazel)			
Hamamelis virginiana L.	US	UT	DU
Liquidambar styraciflua L.	US	UT	DU
Platanaceae (Plane-tree)			
Platanus occidentalis L.	US	UT	DU
Rosaceae (Rose)			
Gillenia trifoliata (L.) Moench			
Pyrus communis L.			
Pyrus malus L.	US	UT	DU
Amelanchier laevis Wieg.	US	UT	DU
Crataegus crus-galli L.	US	UT	DU
Fragaria virginiana Duchesne	US	UT	DU
Potentilla canadensis L.	US	UT	DU
Geum canadense Jacq.	US		
Rubus laciniatus Willd.			
Rubus trivialis Michx.			

Rosa setigera Michx.			
Prunus americana Marsh.	US	UT	DU
Prunus persica (L.) Batsch	US	UT	DU
Leguminosae (Pulse)			
Gleditsia triacanthos L.			
Cassia fasciculata Michx.	US	UT	
Cassia nictitans L.	US	UT	DU
Cercis canadensis L.	US		DU
Trifolium pratense L.	US	UT	
Trifolium procumbens L.	US	UT	
Melilotus officinalis (L.) Lam.	US		
Melilotus alba Desr.	US		
Amorpha fruticosa L.	US	UT	DU
Robinia pseudo-acacia L.			
Desmodium nudiflorum (L.) DC.	US		
Desmodium rigidum (Ell.) DC.	US	UT	
Desmodium ciliare (Muhl.) DC.	US	UT	
Lespedeza procumbens Michx.	US		
Lespedeza violacea (L.) Pers.	US	UT	
Lespedeza intermedia (S. Wats.) Britt.	US		
Lespedeza cuneata (Dumont) G. Don	US	UT	DU
Vicia caroliniana Walt.	US		
Amphicarpa bracteata (L.) Fern.	US		
Linaceae (Flax)			
Linum striatum (Walt.)	US	UT	DU

Oxalidaceae (Wood-sorrel)			
<u>Oxalis</u> <u>violacea</u> L.	US	UT	
<u>Oxalis</u> <u>stricta</u> L.	US	UT	DU
Geraniaceae (Geranium)			
<u>Geranium</u> <u>maculatum</u> L.	US	UT	DU
<u>Geranium</u> <u>carolinianum</u> L.	US	UT	DU
Euphorbiaceae (Spurge)			
<u>Acalypha</u> <u>virginica</u> L.	US	UT	DU
<u>Acalypha</u> <u>gracilens</u> Gray	US	UT	DU
<u>Phyllanthus</u> <u>carolinensis</u> Walt.	US	UT	
<u>Euphorbia</u> <u>corollata</u> L.	US	UT	DU
Anacardiaceae (Cashew)			
<u>Rhus</u> <u>glabra</u> L.	US	UT	
<u>Rhus</u> <u>copallina</u> L.			
<u>Rhus</u> <u>radicans</u> L.			
Aquifoliaceae (Holly)			
<u>Ilex</u> <u>opaca</u> Ait.			
Celastraceae (Staff-tree)			
<u>Euonymus</u> <u>americanus</u> L.	US	UT	DU
Aceraceae (Maple)			
<u>Acer</u> <u>rubrum</u> L.	US	UT	DU
<u>Acer</u> <u>negundo</u> L.	US	UT	DU
Hippocastanaceae (Buckeye)			
<u>Aesculus</u> <u>octandra</u> Marsh	US	UT	DU
Balsaminaceae (Touch-me-not)			
<u>Impatiens</u> <u>capensis</u> Meerb.	US	UT	DU

Vitaceae (Vine)			
Ampelopsis cordata Michx.	US	UT	DU
Parthenocissus quinquefolia (L.) Planch.			
Vitis cinerea Engelm.	US	UT	DU
Tiliaceae (Linden)			
Tilia americana L.	US	UT	DU
Malvaceae (Mallow)			
Hibiscus militaris Cav.	US	UT	
Guttiferae (St. John's-wort)			
Hypericum punctatum Lam.	US	UT	DU
Hypericum densiflorum Pursh	US	UT	DU
Violaceae (Violet)			
Viola papilionacea Pursh	US	UT	DU
Viola triloba Schwein.	US	UT	DU
Viola tripartita Ell.	US	UT	
Viola kitaibeliana rafinesquii (Greene) Fern.	US	UT	DU
Cactaceae (Cactus)			
Opuntia humifusa Raf.			
Lythraceae (Loose strife)			
Cuphea petiolata (L.) Koehne	US		
Nyssaceae (Sour gum)			
Nyssa sylvatica Marsh.	US	UT	DU
Onagraceae (Evening-primrose)			
Jussiaea decurrens (Walt.) DC.	US	UT	DU
Ludwigia alternifolia L.	US	UT	DU

Epilobium coloratum Biehler	US	UT	DU
Oenotheru biennis L.	US	UT	DU
Gaura biennis L.	US	UT	
Umbelliferae (Parsley)			
Sanicula canadensis L.	US	UT	DU
Zizia aptera (Gray) Fern.	US		
Cicuta maculata L.	US	UT	DU
Daucus carota L.			
Cornaceae (Dogwood)			
Cornus florida L.	US	UT	DU
Cornus foemina Mill.	US	UT	DU
Pyrolaceae (Wintergreen)			
Chimaphila maculata (L.) Pursh	US	UT	DU
Monotropa uniflora L.	US	UT	
Ericaceae (Heath)			
Rhododendron nudiflorum (L.) Torr.	US	UT	DU
Kalmia latifolia L.			
Oxydendrum arboreum (L.) DC.	US	UT	DU
Vaccinium stamineum L.	US	UT	DU
Vaccinium angustifolium pallidum Ait.	US	UT	
Primulaceae (Primrose)			
Samolus parviflora Raf.	US		
Sapotaceae (Sapodilla)			
Bumelia lycioides (L.) Gaertn.			
Ebenaceae (Ebony)			
Diospyros virginiana L.	US	UT	

Oleaceae (Olive)			
Fraxinus pennsylvanica Marsh.	US	UT	DU
Ligustrum sp.			
Gentianaceae (Gentian)			
Sabatia angularis (L.) Pursh	US	UT	DU
Gentiana villosa L.	US		
Obolaria virginica L.	US	UT	DU
Apocynaceae (Dogbane)			
Amsonia tabernaemontana Walt.	US	UT	DU
Asclepiadaceae (Milkweed)			
Asclepias tuberosa L.	US	UT	DU
Asclepias syriaca L.	US	UT	
Convolvulaceae (Convolvulus)			
Ipomoea coccinea L.	US	UT	DU
Ipomoea pandurata (L.) G. F. W. Mey.	US	UT	DU
Cuscuta glomerata Choisy	US	UT	
Polemoniaceae (Polemonium)			
Phlox divaricata L.	US	UT	DU
Phlox amoena Sims	US	UT	DU
Phlox maculata L.	US	UT	DU
Boraginaceae (Borage)			
Lithospermum canescens (Michx.) Lehm.	US	UT	DU
Verbenaceae (Vervain)			
Verbena urticifolia L.	US	UT	DU
Verbena simplex Lehm.	US		
Lippia lanceolata Michx.	US	UT	DU

Labiatae (Mint)			
Teucrium canadense L.	US	UT	DU
Prunella vulgaris L.	US	UT	DU
Monarda fistulosa L.	US	UT	DU
Hedeoma pulegioides (L.) Pers.	US	UT	
Pycnanthemum flexuosum (Walt.) BSP.	US	UT	DU
Pycnanthemum incanum (L.) Michx.	US	UT	DU
Lycopus virginicus L.	US	UT	DU
Lycopus uniflorus Michx.	US	UT	DU
Solanaceae (Nightshade)			
Solanum carolinense L.	US	UT	
Datura stramonium L.			
Scrophulariaceae (Figwort)			
Verbascum thapsus L.			
Verbascum blattaria L.	US	UT	
Chelone glabra L.	US		
Penstemon laevigatus Ait.	US	UT	DU
Mimulus alatus Ait.	US	UT	DU
Bacopa acuminata (Walt.) Robins.	US	UT	DU
Lindernia dubia (L.) Pennell	US	UT	DU
Gerardia setacea (Walt.) J. F. Gmel.	US	UT	DU
Gerardia flava L.	US	UT	DU
Bignoniaceae (Bignonia)			
Campsis radicans (L.) Seem.	US	UT	DU
Orobanchaceae (Broom-rape)			
Conopholis americana (L.) Wallr.	US	UT	

Phrymaceae (Lopseed)

Phryma leptostachya L.	US	UT	DU

Plantaginaceae (Plantain)

Plantago media L.	US	UT	
Plantago lanceolata L.	US	UT	DU
Plantago aristata Michx.	US		

Rubiaceae (Madder)

Galium aparine L.	US	UT	
Galium pilosum Ait.	US		
Galium circaezans Michx.	US	UT	
Galium palustre L.	US	UT	
Diodia virginiana L.	US		
Diodia teres Walt.	US	UT	DU
Cephalanthus occidentalis L.	US	UT	DU
Houstonia patens Ell.	US	UT	DU
Houstonia purpurea L.	US	UT	DU
Houstonia lanceolata (Poir.) Britt.	US	UT	DU
Houstonia ciliolata Torr.	US		

Caprifoliaceae (Honeysuckle)

Lonicera japonica Thunb.			
Sambucus canadensis L.	US	UT	DU

Campanulaceae (Bluebell)

Specularia perfoliata (L.) A. DC.			
Campanula sp.			
Lobelia cardinalis L.	US	UT	DU
Lobelia siphilitica L.	US	UT	DU

Lobelia spicata Lam.	US	UT	DU
Lobelia inflata L.	US	UT	DU
Compositae (Composite)			
Vernonia altissima Nutt.	US	UT	DU
Elephantopus carolinianus Willd.	US		
Elephantopus tomentosus L.	US	UT	DU
Eupatorium serotinum Michx.	US	UT	DU
Eupatorium coelestinum L.	US	UT	DU
Solidago nemoralis Ait.	US	UT	DU
Solidago fistulosa Mill.	US	UT	DU
Solidago gigantea Ait.	US		
Aster cordifolius L.	US	UT	DU
Aster patens Ait.	US	UT	
Aster pilosus Willd.	US	UT	
Aster dumosus L.	US	UT	DU
Aster lateriflorus (L.) Britt.	US	UT	DU
Erigeron pulchellus Michx.	US	UT	DU
Erigeron annuus (L.) Pers.	US	UT	DU
Antennaria plantaginifolia (L.) Hook.	US	UT	DU
Gnaphalium obtusifolium L.	US	UT	DU
Ambrosia trifida L.	US	UT	DU
Ambrosia artemisiifolia L.	US		
Ambrosia psilostachya DC.	US	UT	
Xanthium strumarium L.	US		
Xanthium americanum Walt.	US		
Silphium brachiatum Gattinger	US	UT	DU

Eclipta alba (L.) Hassk.	US	UT	DU
Rudbeckia hirta L.	US	UT	DU
Helianthus hirsutus Raf.	US	UT	DU
Helianthus microcephalus T. & G.	US	UT	DU
Helianthus eggertii Small	US	UT	DU
Actinomeris alternifolia (L.) DC.	US	UT	DU
Verbesina occidentalis (L.) Walt.	US	UT	DU
Coreopsis tinctoria Nutt.	US	UT	DU
Coreopsis auriculata L.	US	UT	DU
Coreopsis major Walt.	US	UT	DU
Bidens cernua L.	US	UT	DU
Bidens frondosa L.	US	UT	DU
Bidens bipinnata L.	US		
Helenium autumnale L.	US	UT	DU
Achillea millefolium L.	US	UT	DU
Chrysanthemum leucanthemum L.	US	UT	
Cacalia atriplicifolia L.			
Senecio smallii Britt.	US	UT	DU
Senecio obovatus Muhl.	US	UT	
Krigia virginica (L.) Willd.	US		
Taraxacum officinale Weber	US		
Lactuca biennis (Moench) Fern.	US	UT	DU
Lactuca sagittifolia Ell.	US		
Hieracium venosum L.	US		
Hieracium gronovii L.	US	UT	DU

APPENDIX II

This appendix contains the results of the radioassays of approximately 2,000 samples of vegetation, collected from a large variety of plants throughout the contaminated area surrounding White Oak Creek and Lake. For sake of convenience it has been divided into four parts: (1) which includes all the data from the assays of the scattered individual samples taken throughout the duration of the survey from as many individual species as possible, (2) which includes the individual counts of the samples of the different parts of the same plant from the mass collections, together with a limited amount of data on radioactivity in soils, (3) which contains a listing of the data from the study of seasonal variation in accumulation of radioactivity in trees, and (4) which includes the data on the concentration of radioactive materials by plants below the waste lagoon.

All species are listed according to the taxonomic order as set forth in the Eighth Edition of Gray's Manual of Botany (Fernald, 1950). All samples, with a very few exceptions, were prepared from five grams of fresh material. The radioactivity of the vegetation, in all instances, is recorded as counts per minute per gram, fresh weight. In the case of the soil samples, the radioactivity is recorded as counts per minute per gram, oven dry weight. All counts were made with an end-window G-M counter at approximately 10 percent geometry.

Section 1

Data for Individual Samples

Vegetation sampled	Radioactivity			Collection site
Pinus echinatus				
Old needles #1	0			Haw Gap
Old needles #2	8			
1951 needles #1	0			
1951 needles #2	8			
Old twigs	8			
1951 twigs	12			
1950 twigs	12			
Active bark	12			
Dead bark	12			
Wood	12			
Juniperus virginiana				
Bark	16			White Oak Creek
Twigs	0			White Oak Lake
Leaves	0			
Wood	0			
Bark	0			
Berries	0			
Typha latifolia				
Leaves (normal)	760			Settling Basin
Leaves (variegated)	545			
Leaf bases	310			
Leaves	56, 44			Haw Gap
Leaf bases	22			
Leaves	72, 152, 176, 104, 256			
Rhizome	12			Intermediate pond
Stem	30			
Roots	39			
	Head	Stem	Leaf	White Oak Lake
	18	13	53	Silt Range 10
	5	6	26	
	14	6	20	
	0	0	40	
	0	0	15	Silt Range 6
	0	0	0	
	13	0	20	
	0	0	0	
	0	0	30	
	8	4	36	Quadrat 6
	4	8	36	

Vegetation sampled	Radioactivity			Collection site
Arundinaria tecta	Stem	Leaf		
	0	32		Lower W. O. Creek
Poa spp.				
Leaf	28			Lower W. O. Creek
Glyceria striata				
Stem	44			Lower W. O. Creek
Leaf	56			
Seed	46			
Whole plant	28			
Elymus canadensis	Head	Stem	Leaf	
			44	Haw Gap
	8		52	
	16	16	56	
			32	
Leersia sp.				
Whole plant	32			Quadrat 18
Panicum sp.	Leaf	Stem	Seed	
	0			Upper W. O. Lake
	48	4		Quadrat 8
P. agrostoides	12			Upper W. O. Lake
	36	8	12	
	44			
	0			Quadrat 16
	0			
Andropogon sp.				
Dead plant	44			Upper W. O. Lake
Leaf	36			Quadrat 8
Leaf	8, 4			Quadrat 1
Cyperus sp.				
Eleocharis obtusa				
Whole plant	108			Haw Gap
Scirpus lineatus				
Whole plant	32, 36			Quadrat 25

Vegetation sampled	Radioactivity			Collection site
S. atrovirens	Spikelet	Stem	Leaf	
	24	0	24	Quadrat 7
		8		
S. pedicellatus	12	16		Upper W. O. Lake
	4	60		
	8	8	36	Quadrat 3
	8	12	20	
Carex vulpinoidea				
Whole plant		16		Quadrat 26
Spike		12		Quadrat 8
Stem		8		
Carex festucaceae				
Leaf		108		Quadrat 26
Whole plant		40, 140		Silt Range 9
Carex frankii	Spike	Stem	Leaf	
	108	44	156	Quadrat 26
	0	0		Quadrat 6
	16		8	Quadrat 8
	8	8	0	Quadrat 4
	8		0	
Whole plant		36, 36		Silt Range 9
Carex louisianica	Spike	Stem	Leaf	
	16	20	32	Upper W. O. Lake
	16			
	24	8	16	Quadrat 7
	16			
	0	0	8	Quadrat 4
	4	0		
Carex sp.				
Leaf		388		Settling Basin
Whole plant		24		Upper W. O. Lake
Arisaema triphyllum				
Whole plant		4		White Oak Creek

Vegetation sampled	Radioactivity					Collection site
Juncus effusus	Flowers	Stem				
	24	54				Upper W. O. Lake
	32	20				
		20				
		42				Quadrat 23
		84				
		28				Quadrat 26
		8				Quadrat 7
		22				Quadrat 8
		56				Quadrat 3
		58				
		30				Silt Range 10
		14				
		6				
Whole plant	32, 36					Silt Range 9
Juncus acuminatus						
Whole plant	28, 48					Silt Range 9
Juncus tenuis						
Whole plant	28, 48					Silt Range 9
Allium canadense	Stem	Bulb	Bulblet			
	8	16	0			White Oak Creek
	28	8	0			Upper W. O. Lake
	16	4	8			
	16	0	12			
	16	8	4			
	20	12	12			
Trillium sp.						
Whole plant	0, 20, 36					White Oak Creek
Smilax sp.						
Vine	12, 16					White Oak Creek
Salix nigra	Aments	Leaf	Twigs	Bark	Wood	
			272		54	Haw Gap
			178			
	40	36		92	8	
	48	76	68			
	40	64	72			
	8		72	52	12	Upper W. O. Lake
	4			100	4	
		44	36			Quadrat 3
		44	56			

Vegetation sampled	Radioactivity					Collection site
Juglans nigra		Twigs	Bark	Buds		
		20	8	0		White Oak Creek
Carya sp.						
Nuts			7			White Oak Creek
Alnus serrulata	Aments	Leaf	Twigs	Bark	Wood	
	120	20	48	152	4	W. O. Lake Dam
	45	20	48	120	16	
	38					
	24					
	16					
		28				White Oak Creek
	11					Upper W. O. Lake
	10					
	19					Intermediate pond
Fagus grandifolia	Twigs	Wood	Bark	Buds		
	0	0	1	0		White Oak Lake
Quercus falcata	Acorns	Leaf	Wood	Bark	Buds	
	2	1	0	2	0	White Oak Lake
Quercus alba	1950 acorns		1951 acorns			
	4		28			W. O. Lake Dock
Wood			4			Haw Gap
Bark			32			
Ulmus americana	1950 seed	1951 seed	Wood	Bark	Leaf	
	74	8	5	39		White Oak Creek
	60			32	40	
	8	6	3	2		W. O. Lake Dock
					0	
					36	Upper W. O. Lake
		116			100	Quadrat 18
Ulmus alata	Wood	Leaf	Bark	Twigs		
	8		60			Haw Gap
	4	8	16	0		Quadrat 1
		4				
Celtis occidentalis						
Bark			32			White Oak Creek
1950 twigs			60			

Vegetation sampled	Radioactivity				Collection site
Rumex sp.	Leaf	Stem	Seed	Root	
	16				Haw Gap
	46	17	24	82	
	292	84	215	292	
	308	96	316	308	
	104				Settling Basin
	691				
		24	56	36	Upper W. O. Lake
		36	35	40	
	Upper leaves		Lower leaves		
	196		116		Haw Gap
	188		56		
Podophyllum sp.					
Whole plant		24			White Oak Creek
Magnolia acuminata					
Twigs		4			White Oak Creek
Liriodendron tulipifera	Twigs	Bark	Wood		
	8	0	0		White Oak Creek
	8	4	12		
Lindera benzoin	Bark	Wood	Flowers		
	32	16	16		White Oak Lake
Sedum ternatum					
Whole plant		3			White Oak Lake
Hamamelis virginiana					
Twigs		4			White Oak Lake
Bark		16			
Wood		0			
Liquidambar styraciflua	Twigs	Bark	Leaf		
	0	32	4		White Oak Creek
		4			
	7	31			
Platanus occidentalis	Twigs	Wood	Bark	Leaf	
	130	10	27		Haw Gap
	32	14	82		
	120	0	0		Upper W. O. Lake
	8		20	12	
			76		

Vegetation sampled	Radioactivity					Collection site
Rubus sp.	Leaf	Cane	Fruit			
	92	68	20			Upper W. O. Lake
			20			
	52	72				Quadrat 4
	68					
	8					Quadrat 16
	32	24				Quadrat 6
Rosa sp.	Leaf	Vine				
	116					White Oak Creek
	180	92				
		84				
		84				
	12	32				Upper W. O. Lake
Cassia fasciculata						
Whole plant	0					Quadrat 16
Whole plant	8					Quadrat 6
Whole plant	16, 36					Quadrat 7
Whole plant	29, 24					Quadrat 5
Melilotus alba	Stem	Leaf	Flower	Seed		
	13	42	10	20		W. O. Lake Dam
		44				White Oak Creek
	100	248				Haw Gap
Amorpha fruticosa	Twig	Leaf	Bark	Wood	Fruit	
		12				W. O. Lake Dam
	32	24	12	111	29	
	34					
	52	28	(36 - flower)			Upper W. O. Lake
		52				
		4				
Lespedeza repens	Stem	Leaf				
	4	0				Quadrat 6
	20	24				Quadrat 4
Rhus glabra	Wood	Twig	Bark	Buds		
	20	84	104	20		Haw Gap
Acer rubrum	Leaf	Bark	Twig	Seed		
	4	8	14	8		White Oak Creek
	0		0			

Vegetation sampled	Radioactivity	Collection site

Acer negundo	Wood	Leaf	Bark	Twig	Seed	
	8	8	8	4	16	Haw Gap
		52	44	68		White Oak Creek
		28				

Aesculus octandra		
Bark	0, 52	White Oak Creek

Parthenocissus quinquefolia		
Leaves	0	White Oak Creek

Vitis sp.		
Leaves	40	Quadrat 19
Vine	0	

Jussiaea decurrens	Leaf	Stem	Fruit	
	92	52	60	Quadrat 5

Cornus sp.	Wood	Bark	Twig	
	252		232	Upper W. O. Creek
			296	
	38	188	276	Lower W. O. Creek

Diospyros virginiana	Wood	Leaf	Bark	Twig	Fruit	
Dead in lake	0		16	4		Silt Range 10
Alive					3	
	0	0	4	0	0	(near) Quadrat 8
	0	0			0	
					0	

Fraxinus pennsylvanica	Wood	Leaf	Bark	Twig	Seed	Buds	
	0		88	16		8	Upper W. O. Lake
			140				
		8	28	16			White Oak Creek
	28	92	172		32		
	12	132	104		36		
			64	28			
		24		48			Quadrat 7
		48					

Lippia lanceolata		
Whole plant	76	Quadrat 5

Vegetation sampled	Radioactivity	Collection site
Prunella vulgaris		
Leaf	0	Quadrat 26
Leaf	0	Quadrat 25
Flower	32	Quadrat 8
Whole plant	40	
Solanum carolinense	Leaf Stem Fruit	
	28 24 4	Quadrat 25
Campsis radicans	Leaf Vine	
	8 8	Quadrat 25
	72 36	Quadrat 26
	8 20	Quadrat 6
	40 44	
	32 37	Quadrat 7
	40 16	
	44	
	29 8	Quadrat 4
	20 16	
Galium sp.		
Whole plant	28	Quadrat 5
Diodia sp.		
Whole plant	0, 8	Quadrat 25
Whole plant	60, 60	Quadrat 5
Cephalanthus occidentalis	Twig Leaf Wood Bark Flower	
	24 24 0 28 16	White Oak Creek
	8	Upper W. O. Lake
Lonicera japonica	Leaf Vine	
	68 76	White Oak Creek
Sambucus canadensis	Stem Leaf	
	825	Settling Basin
	432 740	
	76 68	White Oak Creek
	608	
Eupatorium sp.	Leaf Flower Upper stem Lower stem	
	64 44 35 68	Haw Gap
Vernonia altissima	Leaf Stem	
	64 51	Haw Gap

Vegetation sampled	Radioactivity			Collection site
Solidago sp.	Leaf	Stem		
	0	0		Quadrat 1
	20	12		
	36	32		Quadrat 8
	4	16		Quadrat 25
Aster sp.				
Stem	16			Quadrat 1
Xanthium sp.	Leaf	Lower stem	Upper stem	
	160	100	80	Haw Gap

Section 2

Data for Mass Collections

Distribution of radioactivity in samples collected from ten sumac trees at Station 1

Tree number	Upper bark	Lower bark	Upper wood	Lower wood	Leaves	1951 twigs	1950 twigs
1	104	20	12	4	28	72	100
2	16	4	12	8	52	16	48
3	64	44	24	16	36	60	60
4	272	232	56	32	112	160	
5		96		20	56	64	32
6	92	32	32	4	20	56	36
7	76	112	16	4	36	44	
8	8	0	0	0	24	16	16
9	64		16		20	16	56
10		84		16	60	28	
Maximum	272	232	56	32	112	160	100
Mean	87	57	21	12	44	53	50
Minimum	8	0	0	0	20	16	16

Distribution of radioactivity in samples collected from ten black willow trees at Station 1

Tree number	Bark	Wood	Leaves	1951 twigs	1950 twigs
1	105	15	27	12	
2	96	19	33	45	63
3	126	19	44	63	69
4	221	25	82	113	129
5	122	16	46	70	63
6	57	6	54	67	58
7	52	12	14	23	31
8	132	100	51	71	72
9	62	32	16	21	100
10	260	52	132	172	212
Maximum	260	100	132	172	212
Mean	123	30	50	66	89
Minimum	52	6	14	12	31

Distribution of radioactivity in samples collected from ten giant ragweed plants at Station 1

Plant number	Lower stem	Upper stem	Leaves
1	52	51	53
2	55	54	56
3	58	57	59
4	61	60	62
5	64	63	65
6	67	66	68
7	70	69	71
8	73	72	74
9	76	75	77
10	79	78	80
Maximum	79	78	80
Mean	66	65	66
Minimum	52	51	53

Distribution of radioactivity in samples collected from ten little ragweed plants at Station 1

Plant number	Lower stem	Upper stem	Leaves	Soil
1		116	212	3150
2	20	60	76	1945
3	76	52	100	930
4	44	72	100	170
5	8	16	16	1925
6	20	60	36	2955
7	100	24	120	2885
8	104	88	220	3210
9	72	64	128	925
10	68	72	152	4700
Maximum	104	116	220	4700
Mean	59	63	116	2280
Minimum	8	16	16	170

Distribution of radioactivity in samples collected from ten smartweed plants at Station 1

Plant number	Lower stem	Upper stem	Leaves	Soil
1	48	80	104	0
2	100	108	168	156
3	88	64	68	1672
4	128	208	492	3553
5	144	216	524	2946
6	56	72	164	3247
7	44	56	56	58
8	56	60	108	2638
9	92	136	264	899
10	60	80	144	1459
Maximum	144	216	524	3553
Mean	82	108	209	1663
Minimum	44	56	56	0

Distribution of radioactivity in samples collected from ten wild rye plants at Station 1

Plant number	Heads	Stems	Leaves
1	28	16	72
2	32	32	76
3	32	28	128
4	32	16	72
5	16	12	48
6	44	16	56
7	56	36	144
8	28	12	52
9	48	24	164
10	36	40	80
Maximum	56	40	164
Mean	35	23	89
Minimum	16	12	48

Distribution of radioactivity in samples collected from ten ash trees at Station 1

Tree number	Bark	Wood	Leaves	1951 twigs	1950 twigs
1	100	24	20	24	28
2	40	20	24	4	16
3	48	4	24	16	24
4	56	8	16	28	32
5	96	32	24	24	36
6	72	4	24	20	28
7	76	8	12	20	12
8	76	0	16	12	16
9	88	8	20	20	40
10	76	20	8	12	32
Maximum	100	32	24	28	40
Mean	73	13	19	18	26
Minimum	40	0	8	4	12

Distribution of radioactivity in samples collected from ten button-ball trees at Station 2

Tree number	Bark	Wood	Leaves	Fruit	1951 twigs	1950 twigs	Soil
1	100	0	8	8	16	16	
2	52	4	0	0	8	16	3675
3	180	4	0	16	20	8	7360
4	120	0	20	0	8	12	5340
5	168	0	16	12	12	24	5370
6	100	4	4	0	0	8	5400
7	124	8	64	16	0	16	5800
8	96	0	12	8	4	0	4860
9	104	0	12	0	8	8	
10	80	12	0	12	28	28	
Maximum	180	12	64	16	28	28	7360
Mean	113	3	14	7	10	14	5400
Minimum	52	0	0	0	0	0	3675

Distribution of radioactivity in samples collected from ten submerged willow trees at Station 2

Tree number	Bark	Wood	Leaves	1951 twigs	1950 twigs
1	84	24	64	92	108
2	96	29	84	128	56
3	128	32	60	72	84
4	116	32	66	112	96
5	108	32	72	88	96
6	84	32	76	96	112
7	228	12	44	72	44
8	124	28	68	92	64
9	80	24	32	60	32
10	244	16	68	96	96
Maximum	244	32	84	128	112
Mean	129	26	63	91	79
Minimum	80	12	32	60	32

Distribution of radioactivity in samples collected from ten submerged ash trees at Station 2

Tree number	Bark	Wood	Terminal leaves	Terminal twigs
1	120	16	40	28
2	176	32	40	40
3	280	20	32	44
4	84	28	48	60
5	216	36	96	48
6	496	20	24	64
7	160	16	44	48
8	192	40	52	60
9	228	8	48	56
10	244	56	12	44
Maximum	496	56	96	64
Mean	220	27	44	49
Minimum	84	8	12	28

Distribution of radioactivity in samples collected from ten swamp hemlock trees at Station 2

Sample number	Lower stem	Upper stem	Leaves	Flowers	Soil
1	40	36	36	28	720
2	28	28	48	36	1310
3	20	20	28	28	2340
4	20	24	56	24	1010
5	28	36	28	34	440
6	24	24	32	40	1080
7	12	24	24	36	500
8	24	40	36	64	3525
9	32	44	60	20	1925
10	28	48	28	40	1930
Maximum	40	48	60	64	3525
Mean	26	32	38	35	1478
Minimum	12	20	24	20	500

Distribution of radioactivity in seven samples of *Juncus effusus* stem collected at Station 2, based on ten-gram samples

Sample number	Stem	Soil
1	Lost	556
2	Lost	266
3	Lost	204
4	26	4697
5	20	4796
6	48	4786
7	46	6657
8	56	9587
9	30	4444
10	68	7527
Maximum	68	9587
Mean	42	4362
Minimum	20	204

Distribution of radioactivity in samples collected from ten submerged black willow trees at Station 3

Sample number	Bark	Wood	Leaves	1951 twigs	1950 twigs
1	96	16	44	40	52
2	48	4	32	84	80
3	76	28	44	100	96
4	68	20	36	64	44
5	60	8	52	36	80
6	52	16	80	104	16
7	72	16	272	304	252
8	112	28	52	92	108
9	92	16	128	160	60
10	52	16	32	40	152
Maximum	112	28	272	304	252
Mean	73	17	77	96	94
Minimum	48	4	32	36	16

Distribution of radioactivity in samples collected from the center limb of ten sycamore trees at Station 4

Sample number	Bark	Wood	Leaves	1951 twigs	1950 twigs
1	32	24	36	24	20
2	60	28	36	32	32
3	132	32	36	44	32
4	56	28	12	40	24
5	12	4	12	4	4
6	116	0	2	10	18
7	20	2	8	8	8
8	4	12	0	6	16
9	304	12	20	24	28
10	0	0	0	4	2
Maximum	304	32	36	44	32
Mean	74	14	16	20	18
Minimum	0	0	0	4	2

Distribution of radioactivity in samples collected from ten black willow trees at Station 4

Sample number	Bark	Wood	Leaves	1951 twigs	1950 twigs
1	276	40	76		92
1A	228	44	60		76
2	9	9	6	8	16
2A	28	16	12		2
3	80	20	56	60	44
3A	92	32	40	40	76
4	140	28	52	60	76
4A	144	28	52	56	58
5	152	24	80	92	92
5A	132	28	76	76	116
Maximum	276	44	80	92	116
Mean	128	30	52	76	65
Minimum	9	9	6	8	2

Distribution of radioactivity in duplicate samples collected from five bushes of false indigo at Station 4

Sample number	Bark	Wood	Leaves	Fruit	1951 twigs	1950 twigs
1	152	8	20	8	32	24
1A	111	12	24	29	32	34
2	152	28	76	16	64	56
2A	260	28	64	32	68	76
3	488	64	124	64	160	236
3A	476	52	132	68	160	236
4	56	8	24	12	32	28
4A	60	0	20	12	32	24
5	64	8	24	0	36	20
5A	56	4	20	12	40	20
Maximum	488	64	132	68	160	236
Mean	188	21	53	25	67	75
Minimum	56	0	20	0	32	20

Distribution of radioactivity in samples collected from ten beggar-tick plants at Station 4

Sample number	Upper stem	Lower stem	Leaves
1	16	60	40
2	96	60	116
3	20	24	32
4	44	32	36
5	88	76	72
6	104	128	152
7	116	152	180
8	48	92	48
9	152	104	154
10	108	88	80
Maximum	152	152	154
Mean	79	82	81
Minimum	16	24	32

Distribution of radioactivity in ten samples collected from fog fruit plants at Station 4

Sample number	Total plant
1	208
2	236
3	124
4	248
5	244
6	252
7	240
8	214
9	205
10	201
Maximum	252
Mean	217
Minimum	124

Section 3

Seasonal Study in Trees

Winter Condition 1/5/52

	Dead bark	Active bark	1951	T. cork	Wood
Sweet Gum #1	4	12	20	32	8
Sycamore #1	4	280			20
Sycamore #2	24	52			20
Sycamore #3	44	52	20		0
Sycamore #4	8	12	24		0
Sycamore #10	102	48	36		12
American Elm #1	40	220	36		56
American Elm #2	16	72			20
American Elm #3	12	80	200		0
Black Willow #1	16	32			16
Black Willow #2	12	52	28		0
Hackberry #1		12	8		0
Hackberry #2	60	40	64		16
Alder #1 ♂ aments	0	4	24		0
Alder #2	32	68	72		12
Dogwood Beside Sycamore #3		188	276		36
Black Walnut #1	44	32	32		8

Early Spring 3/26/52

	Dead bark	Active bark	Flowers	1951	Buds	Wood
Sweet Gum #1		0		0	0	0
Sycamore #1		216				12
Sycamore #2						
Sycamore #3		12		28	0	
Sycamore #4		0		0	0	0
Sycamore #5	0	0		0	0	0
American Elm #1		240		96		40
American Elm #2		48				4
American Elm #3		88		0	16	
American Elm #4						
American Elm #5	36	140	20	36	64	20
American Elm #6	8	48				8
Black Walnut #1		8		24	0	0
Black Walnut #4	8	20		8	0	

1952 Growth

Removed from Wood and Bark by Scraping

	Wood	Bark
Black Willow	17	0
American Elm	18	
Winged Elm	0	84
Ash	40	122

Total Samples

	Wood	Bark
Black Willow	4	56
American Elm	0	
Winged Elm	4	44
Ash	36	224

Late Spring 5/25/52

	1952 growth	1952 twigs	Bark	Leaves	Buds
Sweet Gum #1			4	0	
Sweet Gum #3	8	24			
Sycamore #1			228		
Sycamore #2			80		
Sycamore #3	0	0			
Sycamore #10	8				
American Elm #1			100	24	
American Elm #2			160		
American Elm #3		0	88		16
Black Willow #1		24	64	68	
Hackberry #1	0				
Alder #1	28				

Section 4

Study Below Waste Lagoon

Vegetation sampled	Date	Radioactivity
Honeysuckle		
Leaves	October 10, 1951	3,700
	October 10, 1951	2,990
	January 18, 1952	1,860
	January 18, 1952	1,550
	March 26, 1952	390
	May 28, 1952	165
Stem	October 10, 1951	200
	October 10, 1951	110
	January 18, 1952	190
	March 26, 1952	270
Trumpet vine		
Leaves	October 10, 1951	320
Stem	October 10, 1951	16
American elm number 1		
Leaves	October 10, 1951	1,180
	October 29, 1951	2,290
	October 29, 1951	2,030
	May 28, 1952	1,260
Bark	October 10, 1951	16
(small limb)	October 29, 1951	20
(large limb)	October 29, 1951	8
(dead)	January 18, 1952	12
(active)	January 18, 1952	60

Vegetation sampled	Date	Radioactivity
American elm number 1 (continued)		
Wood	October 10, 1952	30
(small limb)	October 29, 1951	12
(large limb)	October 29, 1951	8
Twigs (1951)	October 10, 1951	160
	January 18, 1952	770
(older)	January 18, 1952	105
(1951)	March 26, 1952	1,000
(older)	March 26, 1952	190
(1951)	May 2, 1952	1,370
American elm number 2 (75 feet below number 1)		
Active bark	January 18, 1952	Background
Maple (growing beside elm number 1)		
Leaves	October 10, 1951	20
	May 28, 1952	90
Bark	October 10, 1951	Background
Wood	October 10, 1951	4
Twigs	January 18, 1952	90
	May 2, 1952	110
Ironweed		
Leaves	October 10, 1951	180
	October 10, 1951	200
Stem	October 10, 1951	Background
Ash		
Bark	October 10, 1951	Background
	January 18, 1952	140

Vegetation sampled	Date	Radioactivity
Sycamore		
Leaves	October 29, 1951	135
Wood	October 29, 1951	Background
Bark	October 29, 1951	Background
Twigs (1951)	October 29, 1951	Background