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RADIOBIOLOGICAL SURVEY OF BIKINI, ENIWETOK, AND LIKIEP ATOLLS - JULY-AUGUST, 1949

Applied Fisheries Laboratory
University of Washington
Seattle, Washington

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July 12, 1950

This report is based on work performed under Contract No. W-28-094-eng-33 with the Atomic Energy Commission

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ABSTRACT

Specimens of fish, marine invertebrates, algae, plankton, land plants, land vertebrates, and water samples were collected for radio assay and identification from Bikini, Eniwetok, and the control area of Likiep. Areas adjacent to collection stations were monitored. Some of the procedures differed from those of earlier years in that frozen samples were processed in the Applied Fisheries Laboratory, ashing and plating methods were slightly changed and more carefully regulated, and samples were counted in an internal gas-flow chamber. The unit of measurement used for reporting activity was changed to disintegrations per minute per gram of wet tissue. Sample counts were corrected for geometry and backscatter, but not for self-absorption, which was kept to a minimum by preparing thin plates. The net count of a sample was calculated by deducting the background count plus three standard deviations from the gross count. Chemical separation of radioactive isotopes was not done but decay and absorption curves indicate the presence of Ce^{144} and Pr^{144}.

Samples of 369 fish were analyzed for radioactivity relative to area collected, species, tissues, and feeding habits. The greatest amount of activity in d/m/g was noted in fish found in areas close to shot centers such as the deep water of the Target Area at Bikini (345) and in the shallow waters around the islands of Aomon (703), Runit (144), and Engebi (125) at Eniwetok. The greatest concentrations of radioactivity were found in the viscera (1364) and liver (437) with less in bone (180), skin (10), and muscle (8) of most fish. The herbivorous species, such as parrot fish (572), contained much more radioactivity per gram than carnivorous feeders including plankton-feeders. The former averaged 382 in target areas while the two latter groups averaged 32. Small amounts of naturally-occurring radioactive isotopes were noted in fish from Likiep and other control areas, the d/m/g ranging from 0 to 7.5.

Radioactivity of invertebrates averaged from practically zero to as high as 1,100 at Bikini Target Area and 1,500 near Aomon-Biijiri. The most radioactive species included asteroid starfish, 5,100; hydroids, 2,100; oysters, 820; and sponges, 580. Soft parts of shellfish were usually, but

not always, more radioactive than hard parts. Plankton-feeders were on the average significantly more radioactive than non-plankton-feeders with the notable exception of corals which were low.

From the thirty-five species of algae that were identified and their habitats noted, 129 samples were ashed and counted. Average d/m/g ranged from as low as 3 at control areas through 64, for Bikini Target Area, and up to 1700 from near the Shot Islands of Eniwetok. Succulent forms tended to be more radioactive than calcareous forms. Values for 1949 were approximately one-half as great as they had been in 1948 at the same localities.

Activity of plankton samples from areas other than the Bikini Target Area and the Eniwetok Shot Islands averaged no greater than the average of the Likiep plankton samples which was about 50 d/m/g. Since the Likiep samples were collected after those from Bikini and Eniwetok, speck contamination in nets or pump might possibly account for the relatively high count of the Likiep samples. Compared to Likiep, the radioactivity of plankton samples from the Bikini Target Area was three times greater and from the Eniwetok Shot Islands, eight times greater. Samples of highest activity were from catches in fine-meshed nets. From comparable active areas, the 1949 counts were about one-half those of 1948.

Alpha activity of three-liter water samples was not significantly greater than Santa Monica Bay water and was less than laboratory tap water.

Areas adjacent to collecting stations were monitored with beta-gamma survey instruments. At Likiep counts of sand averaged 21 per minute and of vegetation 27 per minute. At Bikini the values were one to three times those at Likiep with the exception of drift items from the target fleet that counted up to 100,000 c/m. On the Eniwetok Shot Islands, activity was greater than 100,000 c/m in limited areas. Peaks of activity were found at the bomb site and in the three-hundred-yard area, and from there on decreased rapidly.

Seven specimens of birds including three species of terns were dissected and the organs and tissues ashed. The d/m/g of bird tissue, in most cases, was zero, with only one gut sample giving a count as high as 5.1.

Tissues of four specimens of Rattus exulans collected at Biijiri and Engebi Islands exhibited wide variation in activity in different tissues and in different specimens. The highest count was found in bone (1780) and was directly correlated with the background count of the habitat. The total body activity of the four specimens varied from 1 to 120.

The amount of radioactive fission products absorbed by the roots, translocated through the plant and deposited internally within the tissues of the coconut palms at Bikini and Eniwetok was not greater than twice that of control plants. High counting "fallout" material persisted externally on the dead leaf bases of coconuts. Ca^{45} created by neutron bombardment of Ca^{44} in the coral sands of Runit Island was a component of the total calcium of the plants on that Island and resumably of the plants on Engebi and Aomon. Calcium deficiency in Portulaca oleracea observed at 30 yards from the bomb site on Runit was considered to be sufficient to have caused tissue disintegration and death. The tumorous growths observed on Ipomoea Tuba on Engebi resembled those produced by an excess of indole-3-acetic acid on a geranium plant. The activity of the tumors was very low.

About one-third of the total number of plant species reported to be on the Eniwetok Shot Islands in 1944 or 1946 are not extinct. In 1949, 20 species were found on Engebi, 12 on Aomon and 19 on Runit. Of these, about one-fourth -- a total of 9 species -- were mutants. The first plants to reappear in the area where it is certain that the bomb destroyed all growing plants, i.e., out to 300 yards from the bomb site, were Portulaca oleracea and Chloris inflata.

PROGRAM OF OPERATIONS *

by

Lauren R. Donaldson

HISTORICAL

With the initiation of the atomic energy program on the Columbia River in the State of Washington in 1943, it became evident that problems of radiological contamination might arise. In an effort to provide a fund of information on the effects of radiation upon aquatic organisms, the University of Washington was asked to establish a research area to work on the problems. A contract between the Office of Research and Development and the University of Washington resulted in the formation of the Applied Fisheries Laboratory. The basic research upon radiation continued under the direction of the Manhattan Engineering District and since 1946, under the Atomic Energy Commission.

The testing program of atomic weapons at Bikini Atoll in the summer of 1946 initiated another study area, with members of the staff of the Applied Fisheries Laboratory in attendance at the tests as the Radiation Biology Unit of the Radiological Safety Section of Operations Crossroads. Studies started at Bikini during the testing program have been continued since that time with an annual field trip each year to the area to gather additional material and data. Summaries of the data collected on the field trips have been presented in reports forwarded to the Atomic Energy Commission.

Following the Eniwetok tests in 1948, the work of the Laboratory was extended to include a radio-biological survey of that area. The first Eniwetok collections were made the day following the Runit Island shot. Collections and observational data were augmented by the field expedition during August, 1948.

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*This report is based on work performed under Contract No. W-28-094-eng-33 with the Atomic Energy Commission and in cooperation with the United States Navy.

During the summer of 1949 an expedition was again in the field and like the 1948 expedition included a study of the Eniwetok area in addition to a re-check of Bikini Atoll.

The emphasis of the studies has changed from year to year as various problems and points of interest developed, but the major effort has been directed toward gathering additional information on the following basic problems:

1. The measurement of the presence or absence of radiation in the area studied.
2. The determination of the presence or absence of radiation in the various native faunal and floral systems.
3. The selection by the various organisms of radioactive materials.
4. Tissue selection of radioactive materials.
5. The effect upon biotic forms from exposure to or absorption of radioactive materials.
6. The role of the native fauna and flora in the translocation and concentration of radioactive materials.

Additional objectives of the study that possibly are less specific but are important in the over-all contribution are the development of techniques and procedures for evaluating radiation contamination of biotic systems and the training of specialists to carry on such investigations.

ORGANIZATION

The radiobiological resurvey of Bikini-Eniwetok Atoll during the summer of 1949 again demonstrated the advantages of cooperative research effort. The Atomic Energy Commission, the United States Navy, the University of Washington, the State College of Washington, and the University of Hawaii contributed personnel, equipment, and facilities to make the study possible.

The continued support of the Atomic Energy Commission in providing funds and administrative direction to the research has made it possible to continue. The Washington Office of the Commission, especially the Division of Biology and Medicine, under the direction of Dr. Shields Warren, Dr. James H. Jensen, and Dr. Paul B. Pearson of the Biology Branch, has been very helpful in planning and expediting the research. Dr. Warren's suggestion to include Likiep Atoll in the study for "control" material and native food habits proved to be a very useful addition. The Hanford Operations Office through the efforts of Mr. W. K. Crane provided local support in a very efficient and understanding manner.

The United States Navy arrangements were handled by George B. Greer, Lt. Commander, United States Navy. Commander Greer made the arrangements for transportation of men and equipment, supervised the equipping and outfitting of the laboratory vessel, arranged for supplies and numerous other items of naval support. Commander Greer's intimate knowledge of the problems of operation in the Pacific Area coupled with his fine spirit of service made him a valuable addition to the research team.

TECHNICAL PERSONNEL

The 1949 field trip followed the pattern of the previous one in the enlistment of technical personnel. The nucleus of the field party personnel was drawn from the staff of the Applied Fisheries Laboratory, University of Washington, to provide trained personnel and to carry out the continuity so essential in this type of research. Specialists were "borrowed" from other departments and universities to round out the field party.

It is to be regretted that the expansion of the work program from its initial, major, aquatic phase to a program of study on both the land mass and adjacent water areas was not accompanied by a proportionate increase in the number of scientific personnel. In previous years, a training program with the assignment of a junior scientist to work with each senior member had been productive in providing experience and training for potential workers in the field of radiation biology. With the field party limited to twelve men, it was impossible to maintain the training program because the variety of problems undertaken required experienced personnel.

MEMBERS OF THE BIKINI-ENIWETOK RADIOBIOLOGICAL RESURVEY

1949

Name	Assignment	Permanent Address And Occupation
Donaldson, Lauren R.	group leader and biologist	Prof. of Fisheries and Director, Applied Fisheries Laboratory, University of Washington, Seattle 5, Washington
Seymour, Allyn H.	general planning and plankton work	Assistant Director, Applied Fisheries Laboratory, University of Washington
Welander, Arthur D.	radiobiologist and ichthyologist	Asst. Prof. of Fisheries and Research Associate, Applied Fisheries Laboratory, University of Washington
Bonham, Kelshaw	marine invertebrates	Research Associate Applied Fisheries Laboratory, University of Washington
Lowman, Frank G.	genetics, land vertebrates	Research Associate, Applied Fisheries Laboratory, University of Washington
Palumbo, Ralph F.	marine algae	Dept. of Botany, University of Washington
Hines, Neal O.	report writing	Publications Advisor, Office of Public Information, University of Washington
Biddulph, Orlin	plant physiology	Prof. of Botany, State College of Washington, Pullman, Washington
*St. John, Harold	plant morphology	Prof. of Botany, University of Hawaii, Honolulu, Hawaii
Tinker, Spencer W.	marine invertebrates	Director, Waikiki Aquarium, University of Hawaii, Honolulu, Hawaii
Kellogg, Paul	radiation monitoring	Student, Mass. Inst. of Technology, Boston, Massachusetts

*Dr. St. John joined the field party after the collections at Bikini had been completed. His observations cover only Eniwetok and Likiep.

Greer, George B.	naval liaison	Lt. Commander, U.S.N. Pearl Harbor, Territory of Hawaii

NAVAL EQUIPMENT AND PROVISIONS

The Navy, through its various branches, provided transportation from Seattle to the Pacific Area and return for both personnel and equipment. Responsibility for outfitting of the laboratory vessel was also assumed by the Navy with financial assistance from the Atomic Energy Commission.

The LSIL 1091 was assigned to the expedition for a floating laboratory and for living facilities. This vessel, under the command of Lt. (j. g.) W. T. Wilroy, proved to be a very fine work vessel. The equipment and installations supplied under the supervision of Commander Greer provided adequate facilities for work and living.

In addition to the LSIL 1091, the Navy furnished the LST 611 to transport two landing craft (LCVPs) from Kwajalein to Bikini for work within the lagoon. Transportation of mail, supplies, and personnel between Kwajalein, Bikini, and Eniwetok was also provided by the Naval Station, Kwajalein, by PBY or PBM-type planes.

TIME SCHEDULE

The 1949 expedition spent the period from July 19 to August 31, 1949, working in the field or in transit from Seattle to the Pacific Area and return. From July 24 to August 5, collections were made at Bikini with the ship at anchor in the eastern portion of the lagoon except for one trip for collecting in the Target Area and along the southern and western rims. The LST 611 picked up the small ~~boats on August 5,~~ and the LSIL 1091 transported the expedition to Eniwetok, arriving the following day. Collections were made at six major stations at Eniwetok between August 6 and August 19, 1949.

Following the suggestion of Dr. Shields Warren, a collecting study trip was made to the Marshall Islands Atoll of Likiep where five days were spent collecting material for "controls" and gathering information on the food habits of the natives in order to make the data collected in the contaminated areas more pointed.

Section III

GENERAL PROCEDURES

by

A. H. Seymour and L. R. Donaldson

AREAS SAMPLED

As in 1948, collections were made at both Bikini and Eniwetok Atolls but in addition control material was also collected at Likiep Atoll, also in the Marshall Islands group, and about 300 miles east of Bikini. The collection of control material from an environment similar to Bikini and Eniwetok but somewhat removed from those two bomb experiment areas provides data by which a threshold can be established for determining the uptake of radioactive isotopes by biological systems in the bomb areas.

The areas sampled were as close as possible to those sampled in 1948 which included six major stations at both Bikini and Eniwetok Atolls and several minor stations. At a major station fish, invertebrates, and algae were collected from the lagoon reef, terrestrial plants were collected from the island, and a land survey for radioactivity of the adjacent area was made. At a minor station, activities were not as complete and included either dredging, fishing with hook and line, fishing with traps, fishing with a dip net by light, collecting plankton, collecting samples off buoys or a combination of more than one of these activities.

At Bikini the six major stations were distributed geographically about the atoll as shown in Figure 1 and were located at Boro, Namu, Amen, Bikini, Enyu, and Erik Islands. Plankton and water samples were collected while the LSIL 1091 was at anchor off Bikini Island and in the Target Area; dredging, which provided both invertebrate and algae samples, was carried on off the Bikini-Amen reef and in the Target Area; algae and invertebrate samples were also collected from the buoys in the Target Area; fish traps were set off the Bikini-Amen reef, in the Target Area and off Bokon Island; and fish were caught by hook and line at anchorage off Bikini Island and in Ruji Pass. Bikini samples were collected between July 25 and August 4, 1949.

Of the six major stations at Eniwetok, three - Engebi, Eberiru,

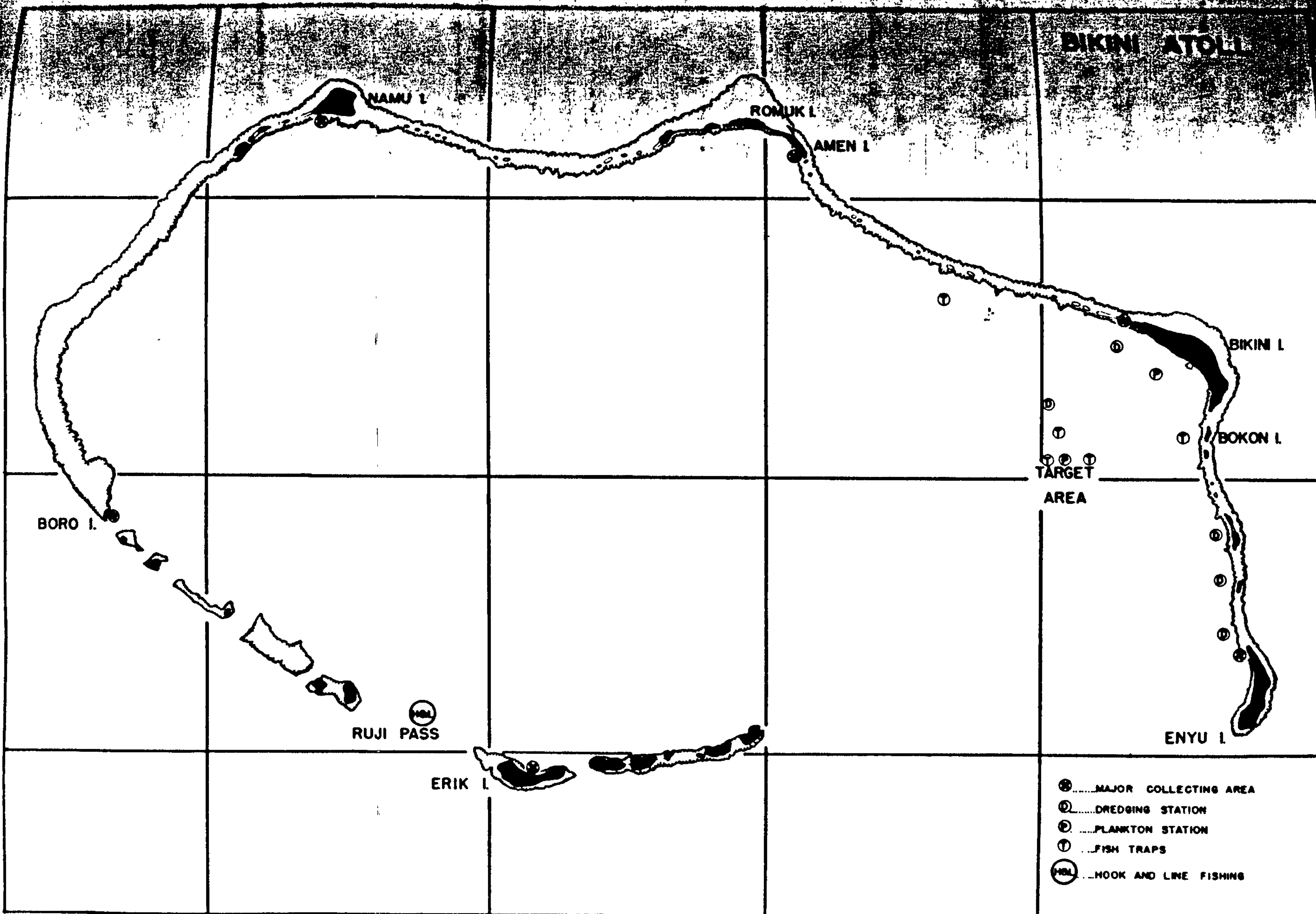


Figure - I. Map of Bikini Atoll with collecting stations indicated.

and Runit - were along the northeastern portion of the atoll near the three test sites of Engebi, Aomon-Biijiri, and Runit. The other three - Japtan, Igurin, and Rigili - were seven to fourteen miles from the test sites. Plankton and water samples were collected while at anchorage off Eniwetok, Engebi, Aomon-Biijiri, and Runit Islands. Additional algae and invertebrate samples were collected by dredging off Eberiru Island. Fish traps were set off Aomon-Biijiri Island. (For Eniwetok collecting stations see Figure 2). Eniwetok collections were made between August 8 and 15, 1949.

At Likiep Atoll major collections were made both on Lado Island and on the western end of Likiep Island. Plankton and water samples were taken at anchorage off Likiep Island. The Likiep collections were made during the period of August 19 to 22, 1949.

PRESERVATION OF SPECIMENS

A change in procedure introduced in 1949 was the ashing of all samples at the University of Washington Applied Fisheries Laboratory rather than at a temporary laboratory established aboard ship. The reasons for the change were for the purpose of increasing the accuracy of weighing samples and of controlling the ashing procedures. In order that the samples be as similar as possible to the fresh samples of former years, specimens for radio assay were frozen. From experimental work performed in 1948, it was known that samples prepared from frozen specimens were comparable to samples prepared from freshly killed tissue (see UWFL 19, pp. 10-12). Therefore, in 1949, specimens of fish, algae, invertebrates, and vertebrates that were to be ashed for counting were cooled with ice while still in the field, then were moved to a deep-freeze box aboard the LSIL 1091 for storage. During the air flight from Kwajalein to Seattle the specimens to be used for ashing were stored with dry ice in an insulated container. The specimens arrived at the University of Washington laboratory in a frozen condition and were immediately stored in a deep-freeze unit where they remained until time for dissection and ashing. An effort was made to freeze the specimens on the spot at the time of collection, using a fire extinguisher containing four pounds of carbon dioxide, but this

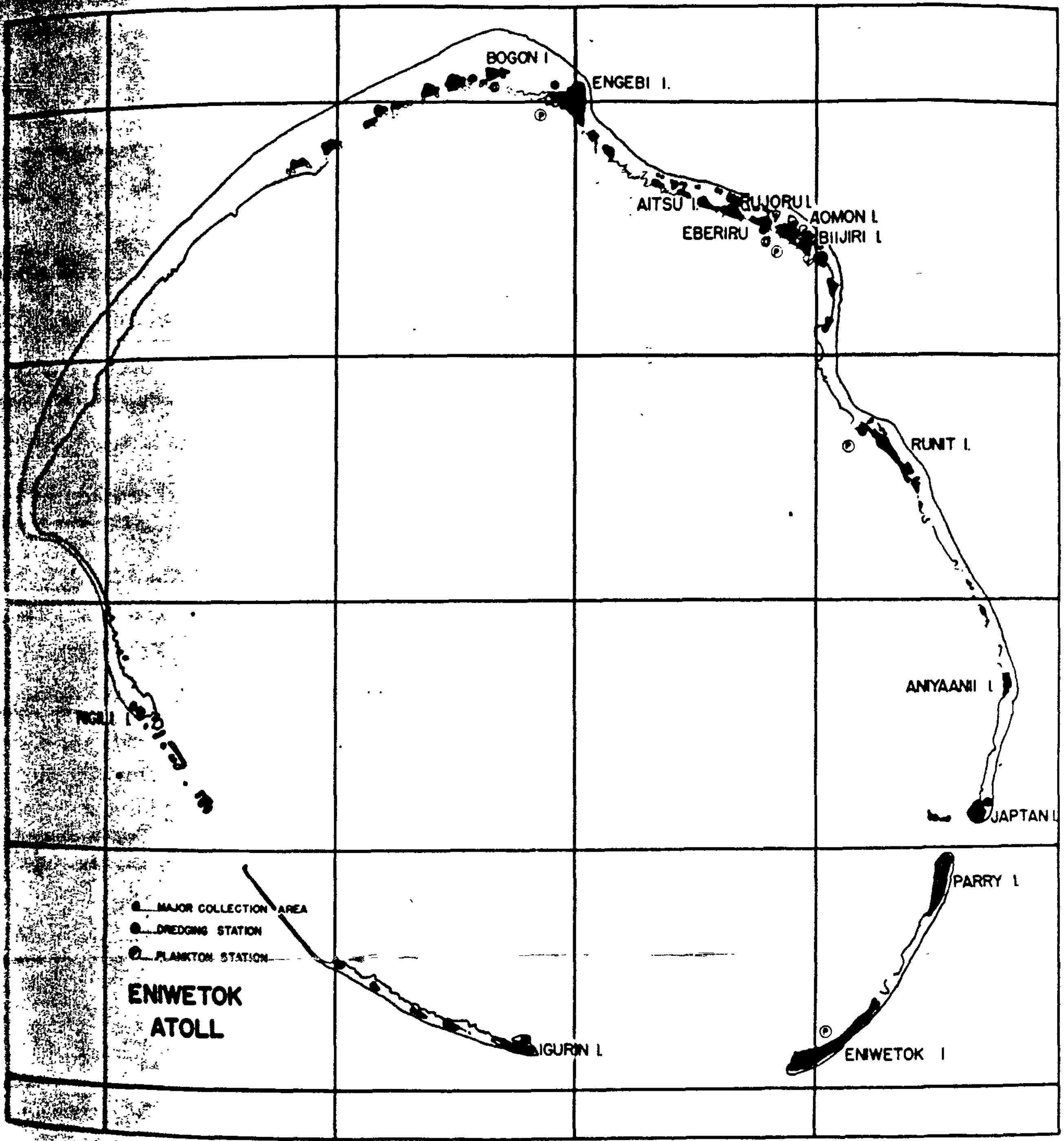


Figure 2 . Map of Eniwetok Atoll with collecting stations indicated.

proved unsuccessful as it was not possible to confine the gas enough for it to become effective.

Terrestrial plants for assay were either ashed aboard ship or brought back entire without freezing or preservation except for the coconuts which were lightly treated with formalin. Terrestrial plants and some algae were pressed as herbarium specimens. All plankton samples as well as those fish and algae specimens that were used for identification were preserved in formalin.

ASHING

The ashing procedure used in 1949 was similar to the 1948 procedure except that acid was not used, weighing of samples and of ash was more accurate, and temperatures were controlled more carefully.

At the Applied Fisheries Laboratory, specimens were identified further before they were ashed preparatory to counting. Large fish, large invertebrates, birds, and rats were dissected as to tissue, and portions were ashed in pieces, usually of from one to five grams weight. Algae and plankton were ashed whole as were some small fish and invertebrates. Terrestrial plants were processed at the State College of Washington, Pullman, Washington, and duplicate samples (coconuts) were sent to the Applied Fisheries Laboratory, University of Washington, for ashing and counting. Water samples were sent to the University of California at Los Angeles for analysis.

Data concerning ashing and counting were recorded on form sheets. The samples of wet tissue were ashed on procelain dishes or stainless steel dishes ~~or stainless~~ steel plates. About the ~~first~~ one hundred samples were ashed in porcelain dishes. However, ashing in porcelain was discontinued when it was found that the dishes alone gave a count of about 15 per minute in the proportional range of the Nucleometer. It was believed that it might be possible to contaminate the sample if the porcelain should flake off during the heating process and for that reason the use of porcelain dishes was discontinued.

Mean net weight and standard error of wet samples were 3.8 ± 0.4 grams. The tissues were dried on a hot plate under heat lamps for 2-5 hours temperature of 100° - 300°C, caution being exercised to avoid bubbling and spattering. The plates of dried tissue were then transferred to muffle furnaces for further ashing at carefully controlled temperatures of 500 - 550 (rarely 600) degrees centigrade. These temperatures were maintained until the samples were reduced to a white ash which required from 2 to 5 hours. No acid was used in the process. Mean net weights and standard errors of ashed tissues were [illegible] ± 0.06 grams.

The dry ash was ground with glass mortars and pestles. In order to reduce the possibility of contamination among samples, the Likiep samples were prepared first and the mortars and pestles were closely examined for cleanliness. Of the 50 mortar sets used, eleven were discarded when they became so badly scratched that the routine cleaning with 4 N nitric acid, water rinse, and wiping with a chamois did not seem adequate.

To prepare the ash for the counting plate, water was added to the mortars and after further grinding the mixture of ash and water was poured into a test tube and then mixed by vigorous shaking. Using a pipette, from 2 to 5 cc. of the mixture were transferred to a counting plate that had been previously flamed and weighed. Flaming of the plate to a cherry red color over a gas burner removed surface film and allowed for quick, equal distribution of the mixture on the plate. For Likiep samples, the plate diameter was 1.5 inches, but for all others, 2 inches. The plate with the mixture was placed under an infrared heat lamp, the mixture was allowed to evaporate to dryness, and the plate was removed before the dry sample began to crack from over-heating. After the plate had cooled, the plate and sample were weighed and the original plate weight subtracted to determine weight of ash on plate. The mean weight and standard error of the ash on the 2-inch counting plates were 0.08 ± 0.01 grams which is equivalent to 4 ± 0.7 mg/cm^2.

Weights and identification numbers used during the drying, ashing, and plating of samples were written on the sides of the porcelain dishes and scratched on the bottom of the stainless steel plates. Occasional samples, probably less than one-half of one percent, cracked or crumbled and failed to adhere to the metal plate. The worst of these were replated.

COUNTING

A. Equipment and Operation.

A major change from previous years in counting arrangement was made for the 1949 samples. Whereas in earlier years samples had been counted with an end window GM counter, all samples in 1949 were counted in an internal counting chamber continuously flushed with methane. The differences are that in the new arrangement, (1) the counter is more sensitive and hence alpha as well as weak beta can be counted; (2) the geometry is greater, 50 percent as compared to 18 percent; and (3) the chamber can hold a larger plate, up to 2 inches as compared to 1-1/2 inches, and thereby accommodates an 80 percent larger sample without increasing sample thickness. Stainless steel plates 2 inches in diameter and .005 inch thick were used. The counters and sealers used were two of Radiation Counter Laboratory's Nucleometers - Mark 9, Model 3 - with a continuous-flow internal counting chamber - Mark 12, Model 1.

Operating at a voltage of 4500 volts for one counter and 4700 volts for the other, alpha, beta, and gamma were counted in 1949 whereas in previous years alpha and some soft beta were not counted due to absorption by air and window. Although some alpha counts of the samples were made in the proportional range of the counter (3100 volts) and in some instances significant alpha counts were found, the results were not recorded because the ash thickness (4 ± 0.7 mg/cm^2) was too great for complete alpha counting. It is intended that a separation of the ash on the plates will be run and then a record of the alpha activity reported later as an appendix to this report.

Ashing of samples commenced at the Applied Fisheries Laboratory in mid-September, 1949, and continued off and on until the end of the counting period. Difficulty in obtaining 2-inch stainless steel plates of .005-inch thickness slowed down the ashing process and necessitated extra handling and storage of the ash. Counting of samples was delayed until arrival and testing of the Nucleometers had been completed. Practically all of the samples were counted between December, 1949, and March, 1950. A shorter counting period would have been more desirable in that decay between time of making the first and last count does not make the samples exactly comparable. However, since the time elapsed from the Bikini experiment was about 42 months, and from the Eniwetok experiment, about 20 months, the decay factor is not as important a consideration as in earlier years. Difficulties in obtaining counter gas curtailed operations to some extent and thus lengthened the counting period.

B. Background.

Backgrounds were run when samples were not being counted, including nights. After tabulation, the backgrounds were seen to have fluctuated excessively after periods of shut-off and hence the backgrounds were computed separately for each period that the counter was in continuous operation. To determine the net count of a sample, the background count for the period when the sample was counted was subtracted from the gross sample count. The range of background in counts per minute was 65 to 76 for one counter and 74 to 80 for the other.

C. Correction Factors.

Sample counting time was usually 20 minutes but occasionally 30 minutes. For a 20-minute background count ranging from 70 to 80 c/m, one standard deviation would be about 2 c/m. To be reasonably sure that all background count was deducted from the gross sample count, the background was increased by three standard deviations before calculating net sample count. For this reason the average background for the counting period was increased by 6 c/m for a 20-minute sample count and by 5 c/m for a 30-minute sample count. Because the background varied considerably even during periods when the counter was constantly daily background values were calculated only to the nearest whole count per minute, i.e., two significant figures.

Counting time in 1948 was 5 minutes per sample with a 5-minute recount being made of those samples whose net original counts were between 0 and 4 c/m above background. Activity of less than 5 m μc/kg was not considered significantly different from background. Such a value would result from a one-gram sample with a count of 2 per minute above background and with the 18-per cent counting arrangement used in 1948. Two counts for a 10-minute background of 17 c/m would be equal to 1-1/2 standard deviations. By comparison of 1949 with 1948, counting time was at least two to four times longer and the level above which counts were considered significant was raised from background plus one and a half standard deviations to background plus three standard deviations. The result of these changes is that fewer samples of marginal significance are reported in 1949.

Geometry, when defined as "the fraction subtended by the detector of the total solid angle as seen by the radioactive source", is about 50 per cent for the internal counting chamber. Therefore, the factor for correcting a sample count for geometry is 2.0.

Backscatter was determined by adapting the counter so that a sample placed on a very thin film could be counted without backing other than the film and air. To make this determination a hole was drilled through the bottom of one plate holder, the counter was supported so that the bottom of the counting chamber was backed only by air, the chamber was sealed to prevent gas leaks, and the film was coated with aquadag to insure electrical conductance. Using a dried drop of P^{32}, a pure beta emitter of 1.7 Mev, on a Formvar film that weighed .07 mg/cm^2, a count was made. Immediately following, part of the film including all of the P^{32} was transferred to a regular 2-inch counting plate and counted in the conventional manner. The difference between the count made on the stainless steel plate and on the thin film divided by the count on the film was the per cent backscatter, assuming there is no backscatter from the film. The backscatter of P^{32} from a .005-inch stainless steel plate was determined by this method as being 30 per cent. Therefore the factor for correcting a sample count for backscatter is about 0.77 and for geometry and backscatter combined, 1.54. The value used was 1.5.

No correction was made for self absorption but an effort was made to keep the ash on the plate relatively thin and as stated above, the average thickness was 4 ± 0.7 mg/cm^2 - too thick for complete alpha counting but thin enough so that beta of approximately 0.05 Mev or greater should be counted. If a single known isotope were being counted a suitable correction could be made for self absorption but since a mixture of unknown isotopes of low activity was probably being counted, the best solution seemed to be to prepare a relatively thin sample and to neglect making a mathematical correction. Weight of ash on the counting plates was not determined in 1948 but from inspection, the 1949 plates appear to be considerably thinner, a guess being that they are about one-half as thick on an average.

Units of Measurement.

Unlike the 1948 report where activity was expressed as millimicrocuries per kilogram of wet tissue, the unit of measurement used in 1949 was disintegrations per minute per gram of wet tissue, hereafter referred to as d/m/g. The change was made to avoid the use of the term "curie" which is associated with the energy of particles resulting from the disintegration of radium. The use of "disintegrations" implies total disintegration from all energies, a value which is not practically attained, but nevertheless the term is the simplest for our use.

The weight unit used is that of grams per wet weight of tissue except in the section on the land plants by Dr. Orlin Biddulph where the unit is milligrams of ash. There are advantages of reporting by wet weight and by dry weight, but the former was chosen for most of the samples since it gives the activity in terms of the living organism.. Naturally the activity per unit of wet weight is much lower than per unit of dry weight.

For the purpose of comparing the 1948 counts with those of 1949, the factor for converting m μc/kg to d/m/g was determined from the relationship that one curie equals 3.7×10^{10} disintegrations per second. This factor was 2.2 and has been used in the following sections to convert the 1948 values to d/m/g. To correct the 1948 values for decay, which was not done in the following sections, the factor is estimated to be about 1/3, assuming the activity is from 280-day half-life Ce^{144} and its 18-minute half-life daughter Pr^{144} which are in equilibrium. The combined correction factor, for units of measurement and decay, would be 2.2/3 or 0.7. For example, if a sample were counted in September, 1948, and found to be 100 m μc/kg, then the count of the same sample in January, 1950, would be about 70 d/m/g.

It is to be remembered in making a direct comparison between 1948 and 1949 that the two years include unavoidable differences in localities, in ashing and counting methods, and in some instances in species sampled.

E. Identification of Isotopes.

Because of the low activity of samples, chemical separation of the radioactive isotopes has not been done except for the work on Ca^{45} (see section on land plants by Dr. Orlin Biddulph). However, decay curves and absorption curves give some indication of the isotopes present.

The samples used for plotting the decay curves were counted with the same Victoreen GM and window tube and Victoreen scaling circuit for all counts. From samples collected near Runit Island in May, 1948, counts have been made intermittently since that time up to the present, June, 1950. In Figure 3 the counts of the most highly active samples are shown plus the count of a coral sand sample collected in August, 1948, 250 yards from the crater on Engebi Island. By visual inspection, the curves appear similar when compared section by section regardless of species or tissue. The general pattern is that of a high slope of the curves during the first few months, then a break from late 1948 to early 1949, followed by a more gradual but regular slope from early 1949 to the present. Fitting a straight line by inspection to the curves prior to the break, the slope is such that the c/m decrease by one half in approximately 15 days. Using sample XE-38 as a typical sample, a straight dotted line is fitted by inspection to that part of the curve to the right of the break (see Figure 3). The slope of this line is such that the c/m decrease by one-half in approximately 275 days, the half-life of Ce^{144}, a fission product that would be expected to be present.

For the absorption curves, the samples were placed on the first shelf of a sample holder mounted in a lead shield and were counted with a 1.7 mg/cm^2 RCL end window GM tube and Victoreen scaling circuit. It was necessary to place the sample on the first shelf rather than the second or lower shelves because of the low activities of the samples. The aluminum absorbers were placed directly on top of the plate, i.e., about 0.2 cm. from the sample and less than 1 cm. from the counter.

Absorption curves add further evidence that the energy of one of the isotopes present is approximately that of Pr^{144}, the daughter of Ce^{144}. In Figure 4 absorption curves are plotted for a Bikini bottom sample from the Target Area, for a sample of Eniwetok coral sand, and for the most active sample used for the decay curves - XE 51, a gut sample from a parrot fish collected at Eniwetok in May, 1948. The general pattern of the three curves is similar. To the left the steep slope at the very beginning of the curve suggests a weak energy isotope but there are too few points to accurately define its projection upon the abscissa. Since it is possible that some gamma is present, the range of the beta particles was determined by a Feather analysis using P^{32}, a pure beta emitter, as a stand-

[Figure] 3. Decay curves, May 1948 to June 1950, of coral sand from Engebi Island and of oyster and fish tissues from Runit Island.

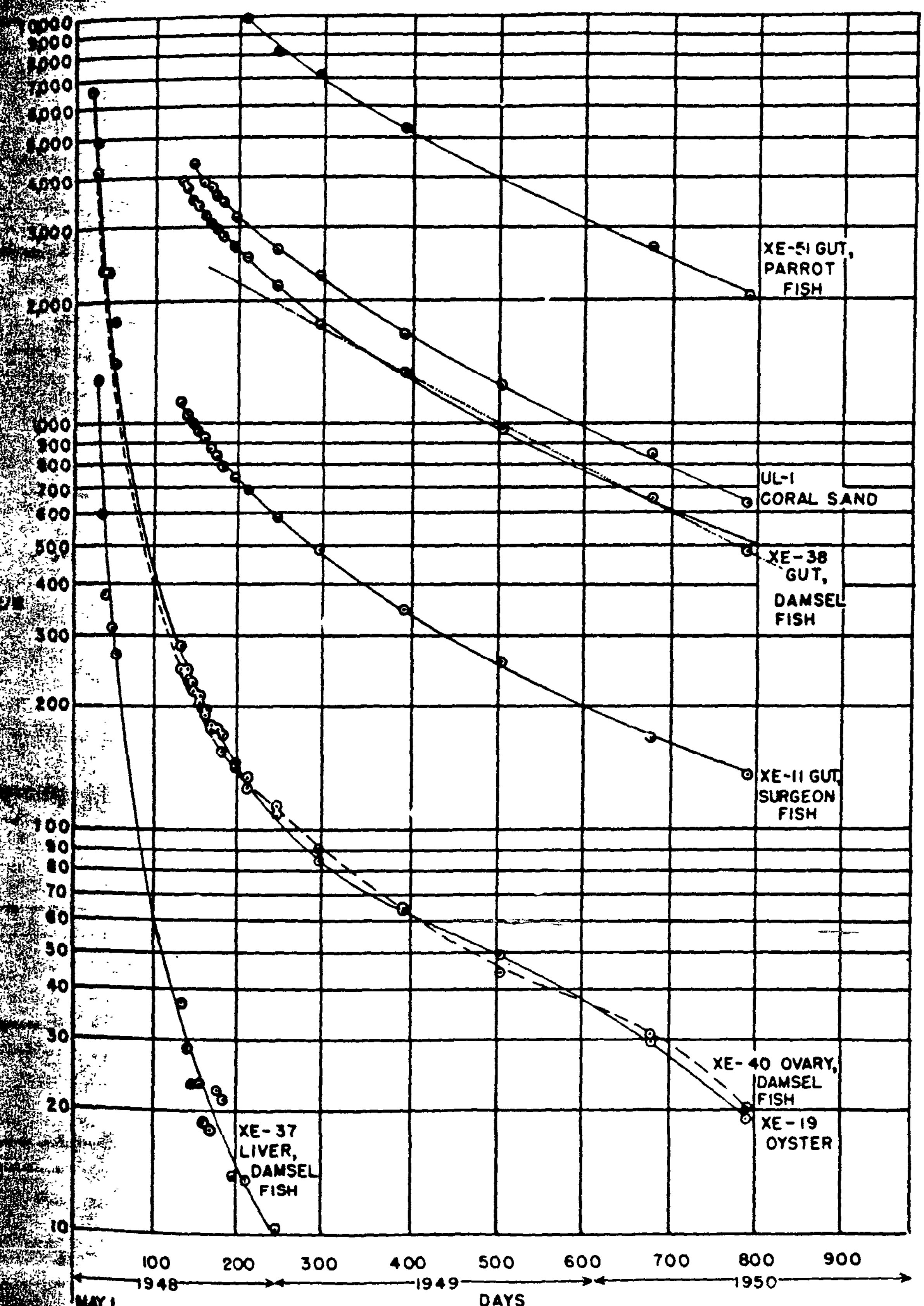
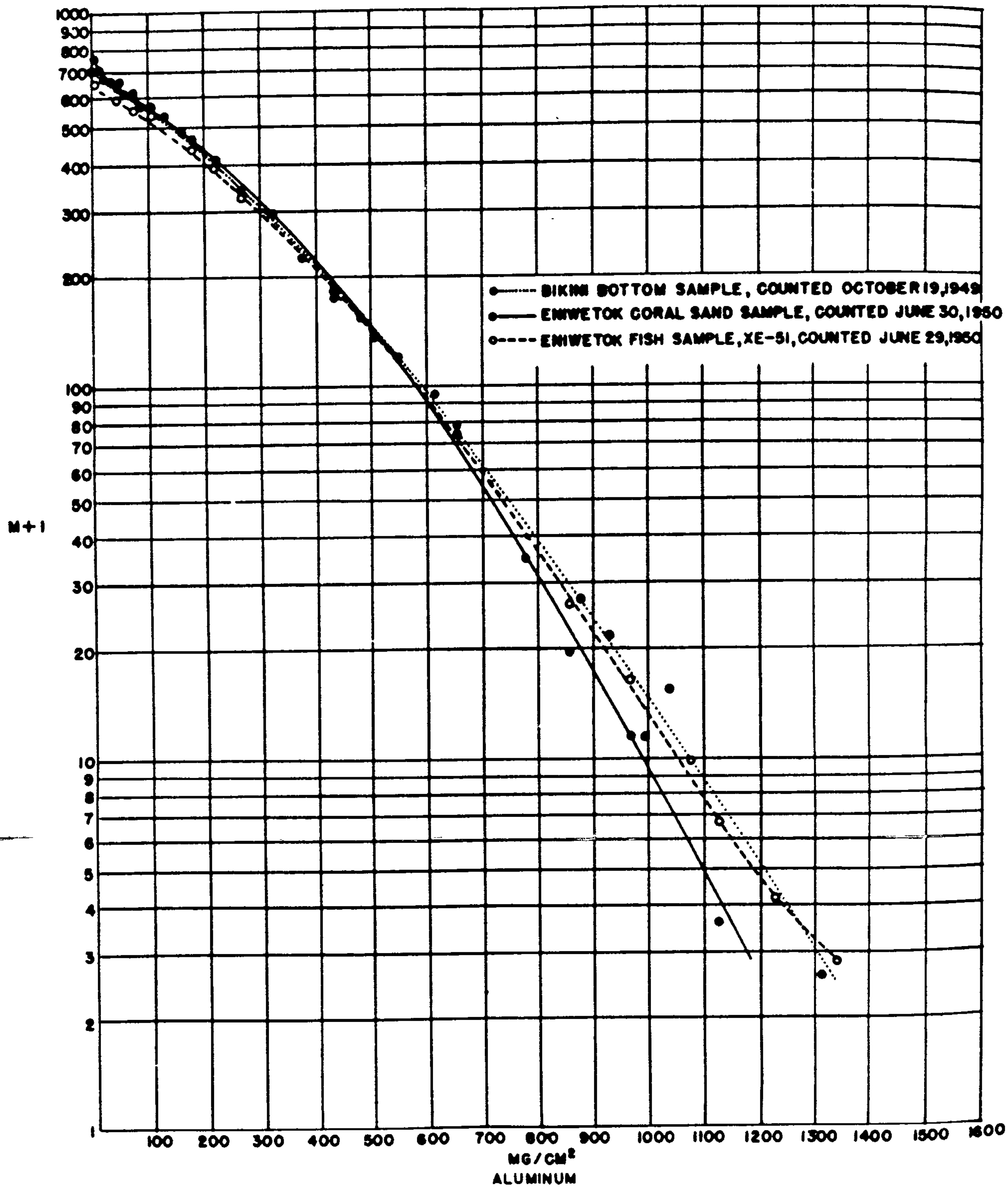


Figure 4. Absorption curves of a bottom sample dredged from Bikini Target Area and of a coral sand and a fish sample from Eniwetok Shot islands.



which gave a curve similar in shape to that of the samples. The range in mg/cm² of aluminum by Feather's analysis is approximately 1500 which is equivalent to an energy of 3 Mev. For Pr^{144} the range of energy of the beta particle is 3.07 Mev.

From the data presented in the decay curves and the absorption curves, it seems likely that Ce^{144} and its short-lived daughter Pr^{144} are present. Other radioactive isotopes, probably in lesser amounts, are undoubtedly also present.

Section IV

LAND SURVEY

by

A. H. Seymour and P. J. Kellogg

Land surveys were made near the collecting stations and the extent of the survey was determined by the amount of radiation detected. The general plan was to monitor the beach sand, drift items, the land, and vegetation in the same general area that specimens were being collected. When the counts were about 60 per minute or less the actual values were determined by counting for one minute with a stop watch.

Instruments used included two makes of GM counters - a Victoreen Model 263 A and a Beckman Model MX-5, and an ionization-type counting chamber, - a Victoreen-made Juno. Readings were made both with and without shields but unless indicated the values reported are those of the GM counters without the shield. i.e., beta and gamma. The instruments were calibrated at Hanford (June 22, 1949) before being taken to the Pacific Area and again (September 19, 1949) shortly after they were returned to Seattle. Corrections were slight.

LIKIEP

Likiep was monitored for the purpose of determining the approximate background count of an uncontaminated area of a similar environment to Bikini and Eniwetok. At Lado Island on August 20 the average of 7 readings on the beach sand near the water line was 20.7 c/m; on the beach sand near the vegetation line, the average of 10 readings was 21.1 c/m; and over dead vegetation, including pandanus, coconut and shrubs, the average of 10 readings was 26.6 c/m.

BIKINI

The activity of the atoll as a whole, as determined by monitoring, was low except for isolated spots of oil scum or wreckage from the target fleet that had drifted ashore. The count of living vegetation was about twice as great, and of dead vegetation, about three times as great as counts for beach sand. At Bikini counts over beach sand averaged about 30 per minute as compared to 21 per minute for Likiep. However, readings from patches of oil scum and of target drift items high as 100,000 c/m. Following is an area-by-area account of monitoring with notes concerning counts of special interest.

On Bikini Island, the north half of the island and part of the reef extending toward Amen Island were monitored on July 23, and July 28. While some oil spots on the coral rock of the beach registered only background count, one spot registered 100,000 c/m.

The north end of Enyu Island was monitored on July 26. The average of 14 readings on the beach was 30 c/m, and the average count on dead leaves was about [illegible] per minute with the highest single value being 120 c/m for dead pandanus leaves. As in 1948, the LCT-816 which is beached in this area was thoroughly surveyed. In the following list, the readings, translated to c/m, made with a Victoreen Model 263 A survey Meter are tabulated:

Item or portion	c/m without shield	c/m with shield
Mat, pilot house - starboard	11,000	670
Canvas, gun mount - port	10,000	800
Canvas, pilot house	6,000	
Canvas, gun mount - starboard	5,000	
Deck rust, gun mount - starboard	4,000	
Plywood, gun mount - starboard	3,400	
Deck rust, top of pilot house	3,400	400
Main deck, forward	2,500	
Main deck, gun mount - port	2,500	400
Gun mount, - port	1,200	90
Wooden box, pilot house	1,000	
Machinery, - main deck	1,000	
Ramp	1,000	
Main deck, - aft	670	
Deck rust, - aft of port gun mount	600	70
Main room - aft - starboard	400	

On July 27 the lagoon side of Amen Island was monitored. Counts per minute on the beach ranged from 18 to 27 and on vegetation growing on the island, AEC .446

... the pontoon dock at the southeast end of the island the reading ... c/m on the dock rust and 140 c/m on a piece of canvas.

Eniu Island was surveyed on both the lagoon and ocean sides of the eastern ... August 1 with special attention to monitoring the activity of the vegetation. ... higher activity was found over dead vegetation, but not any greater than ... observed previously at Bikini and Enyu. Typical c/m were 29 for dirt, grass, 44 for dead leaves and up to 50 for debris on the northeast beach.

On the following day, August 2, Boro Island was monitored. Boro Island at the downwind end of the atoll has a great collection of drift items such as, rope, life rafts, floats, logs, etc. Some of these items gave only ... counts while others, especially rope, were as high as 10,000 c/m. ... readings of activity of vegetation and of the beach were similar to found on the other islands.

The entire shore line of Namu Island as well as the island itself was ... red on August 3. The highest counts of drift items and sand were found ... the eastern shore with values as high as 44,000 c/m for drift items. Values for items found on the eastern shore were as follows: tar-covered wood, ... clothes brush, 600; tennis ball, 1,000; piece of cork, 44,000; oil scum, ... life raft, 1,300; rope, 1,100; raft, 300; wooden grill work, 5,000; box, ... 18,000; etc. Counts on the sand in this area average 5 to 10 per ... than similar counts on other parts of Namu. Along the northwest ... counts on the sand were the usual 25 to 30 per minute and the counts ... items were considerably lower than those from the eastern side of the ... On the southern shore there were a few drift pieces of low activity and the ... sand was background. Counts of vegetation and soil were of the same ... as for similar samples for the atoll in general.

In addition to the land surveys, the top surfaces of three anchor buoys ... Target Area, from which biological samples were collected, were moni- ... July 30. All measurements were made with the counter parallel to ... two inches away from the surface of the buoy with a Victoreen Model ... Survey Meter. There appeared to be no significant difference in counts be-

[illegible]ys, and the values ranged from 600 to 4,000 c/m without the shield and [illegible] c/m with the shield.

[illegible]TOK

At Eniwetok Atoll the data are sharply divided as to amount of activity. [illegible] areas in the vicinity of the test sites, counts are high; for those areas [illegible] miles removed from the test sites, counts are low - approximately background. Since the activities change rapidly with the distance from the test site, [illegible] of the survey meters translated to c/m are shown as contours for the [illegible] islands of Engebi, Aomon, and Runit (see Figure 1). Following is an [illegible]-by-island account of monitoring with the three inactive areas discussed [illegible].

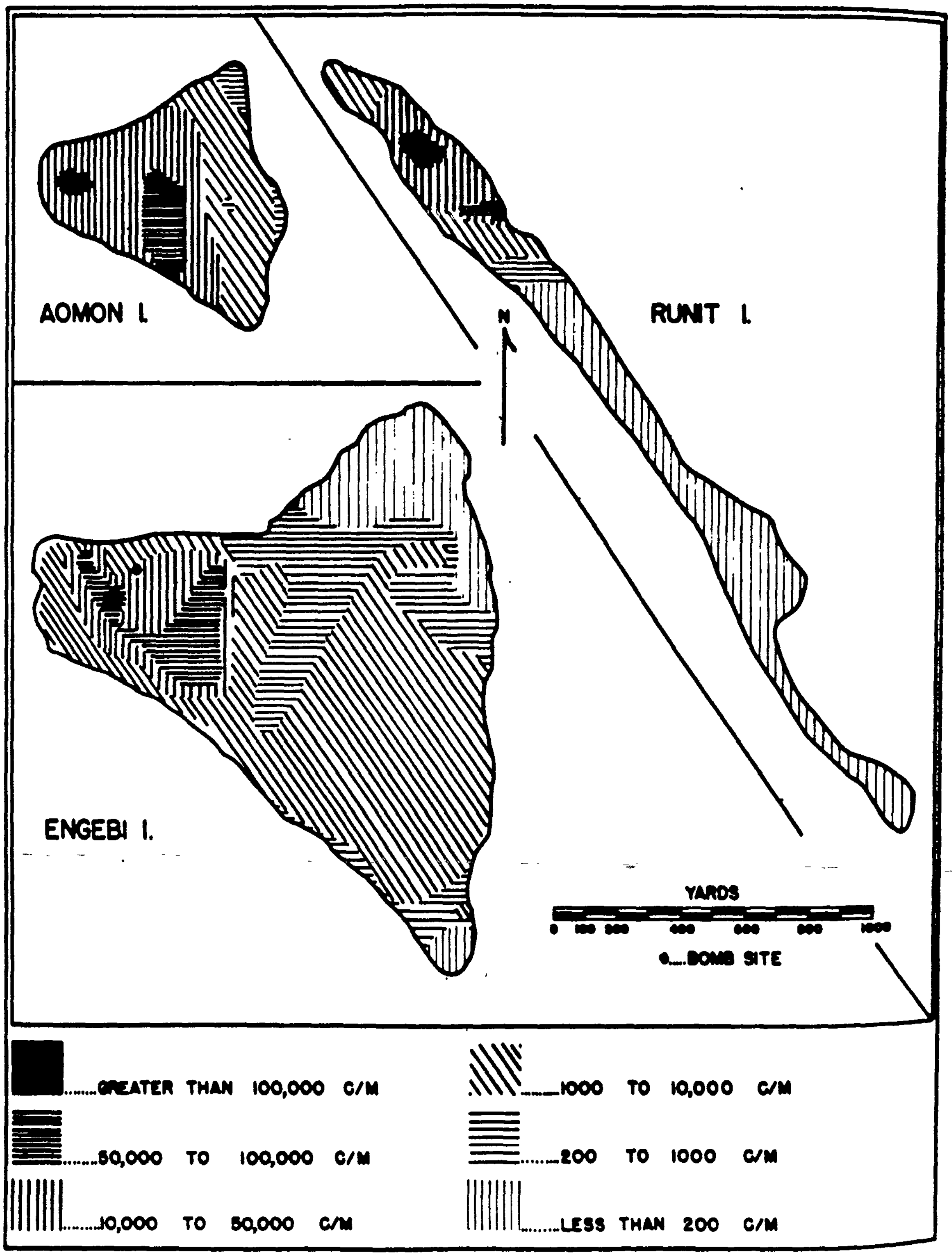
From the survey of Japtan Island on August 8 no counts greater than those [illegible] were made either on the beach or in the vegetation. All areas of the [illegible] were monitored.

The survey of Igurin Island was made on the lagoon side on August 9 with [illegible] meter encased in a plastic bag and during the period of continual rainfall. The [illegible] was not complete but the only activity suspected of being greater than background was a trace found at one point where thère was much debris near a wrecked LC[illegible].

On August 10, the survey of Rigili Island showed very slight contamination [illegible] beach (17-19 c/m), little if any contamination in the vegetation (18-37 c/m), [illegible] on debris that has drifted ashore. The most active of the drift items [illegible] coconut tree whose roots gave readings of 7,000 c/m; trunk, 2 feet above [illegible], [illegible]0,000 c/m; and trunk, 10 feet above roots, 1,600 c/m.

On Bogon Island, the closest island to the northwest of the shot island of [illegible], and a distance of 1-1/4 miles from the bomb site, a survey was made on [illegible] 11. The beach on the east side had been washed fairly free of activity ([illegible] c/m) but counts from 60 to 1,000 c/m were recorded on the other beaches. [illegible] area was more active with no counts less than 1,000 per minute being [illegible]. A small clump of dead grass that registered 30,000 c/m was the highest [illegible] found.

Figure 1. Contours of the radioactivity of Engebi, Aomon, and Runit Islands as determined by GM survey instruments.



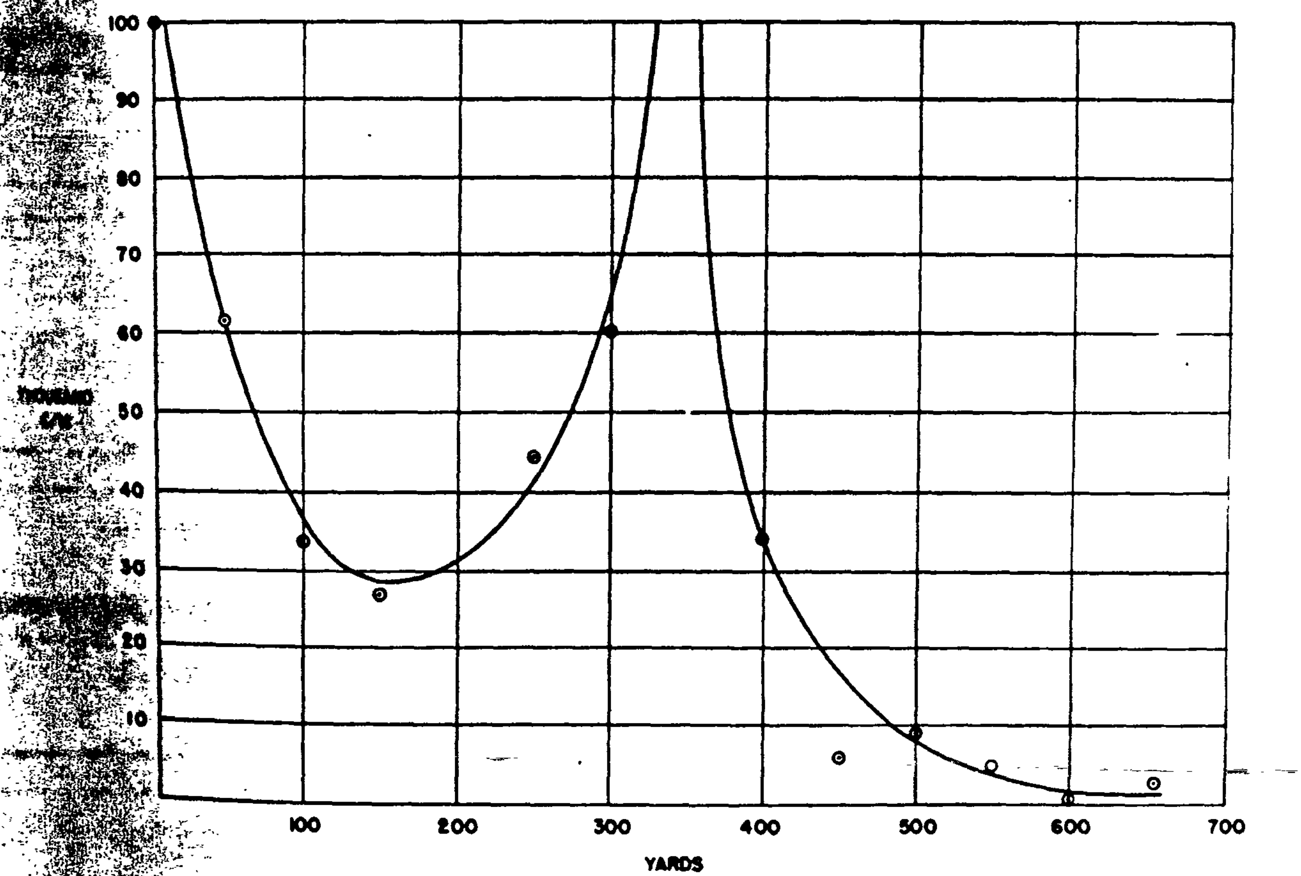
Engebi Island, a shot island, was surveyed on August 13. Activity on the island was high but changed rapidly with distance from the tower posts. At the tower posts the count was 25,000 per minute but at 200 to 300 yards from the posts it was even higher, being approximately 50,000 to 100,000 c/m or more. Activity contours of Engebi Island are shown as a portion of Figure 1. Vegetation on the island was limited to grass and low-lying shrubs, the counts of which could not be distinguished from the counts of surrounding sand.

Rujoru Island, the second island to the northwest of the shot island of Aomon, a distance of one mile from the test site, was also monitored on August 13. All areas of the island were monitored but no special pattern of activity was observed. For the beach, values ranged from 80 to 340 c/m and for the land, from 1,000 to 7,000 c/m. It was later discovered that the counter used for this survey was slightly light-sensitive and for that reason the values are a few counts per minute greater than the actual value for the area being monitored.

The shot island of Aomon was surveyed August 14. The pattern of distribution of activity appears similar to that for Engebi, especially in regard to the high activity found in the area about 300 yards from the bomb site. In Figure 2 the relationship of activity to distance from the bomb site is shown for Aomon Island. It is to be noted that the distribution is wave-like in pattern which suggests that collecting stations near bomb site areas may vary considerably as to amount of activity within short distances. Beyond the 300-yard area the counts dropped from 100,000 c/m to about 1,000 c/m within the next 100 yards. Activity contours of Aomon Island are shown as a portion of Figure 1. Because of the location of the bomb sites on Engebi and Aomon Islands, practically all land surveys were up-wind from the point of bomb detonation. However, within short distances of the bomb site, prevailing winds probably had little, if any, influence upon the distribution of fission products. Aomon like the other shot islands was stripped of vegetation other than grass and a few low bushes.

Biijiri Island, which is joined to Aomon by a causeway and is southeast of Aomon, was also monitored August 14. In general the average count was about 150 per minute but occasional points of higher activity were found, indicating speck contamination. For sand, values ranged from 90 to 320 c/m; for grass, from 50

Figure 2. Relationship of radioactivity to distance from bomb site. Counts per minute, as measured with a G-M survey meter, are average values for a given distance irrespective of direction from the bomb site.



to 200 c/m. The highest count was 700 per minute upon debris in a junk area.

The shot island of Runit was monitored August 15. The bomb site on this island was not as close to the northwest end as on the other two shot islands, and so it was possible to monitor for about 400 yards in a northwest direction from the point of detonation. The readings translated to c/m on the northwest side followed by c/m on the southeast side were 74,000 and 100,000 at 75 yards; 40,000 and 34,000 at 150 yards; 47,000 and 34,000 at 225 yards; 5,300 and 40,000 at 300 yards; and 2,100 and 64,000 at 375 yards. On the northwest side activity dropped off rapidly, while on the southeast side activity decreased and then increased again to a high of 64,000 c/m at 375 yards before beginning to decrease rapidly again. The pattern on the southeast side was similar to that found at the other shot islands, Engebi and Aomon. On Runit Island the activity at 700 yards and beyond was less than 200 c/m. Activity contours of Runit Island are shown as a portion of Figure 1.

SUMMARY

Areas in the vicinity of collecting stations at Bikini, Eniwetok, and Likiep Atolls were monitored with GM counters and ionization chambers. The values reported are those of the GM counters without shield unless otherwise noted. In the control area, Likiep, counts of sand averaged 21 per minute and of vegetation, 27 per minute. At Bikini Atoll, the counts of sand and of vegetation in general were from one to three times the Likiep values except for isolated spots where oil scum and drift items from the target fleet counted as high as 100,000 c/m. At Eniwetok Atoll the activity of areas 7 to 14 miles removed from the Shot Islands was comparable to that of Likiep. For those areas near the bomb sites, activity was greater than 100,000 c/m in limited areas. At the bomb site, activity was high but in the three hundred-yard area the activity was equally great or greater but with a rapid decrease from that area outward. Activity contours are presented for the shot islands - Engebi, Aomon, and Runit.

FLORA OF ENGEBI, AOMON-BIIJIRI, AND RUNIT ISLANDS

by

Harold St. John*
University of Hawaii

Though not a planned experiment and not under controlled conditions, each of the atomic bombings on three different islets of Eniwetok Atoll has actually produced experimental results on the natural terrestrial flora of the atoll. Observations on the resultant effects on the living plants are the most important part of the botanical studies made by the writer while a member of the Radiobiological Resurvey Party in August 1949. It is recommended that the native flora be subjected to further observation and experiment.

The three bombings, on Engebi, Aomon, and Runit Islets, took place in the spring of 1948. The observed effects of the atomic bombings were diverse, so they will be described under various categories.

IMMEDIATE EFFECTS OF BOMBING

Destruction of Sites.

Complete elimination of certain plant species in the flora may be brought about by destruction of particular habitats. From ecological descriptions recorded in 1944 by Maj. E. H. Bryan, Jr., and in 1946 by Dr. F. R. Fosberg, and observations by the writer in 1949 on untouched islets of Eniwetok Atoll, it is possible to summarize the terrestrial plant habitats. Since Eniwetok is quite dry, and the islets are small and mostly narrow, there is little diversity of habitat. The habitats were or as were as follows: outer beaches of coral rock or coral gravel, inner beaches of coral sand, small coral sand dunes, coral gravel flats, coral sand flats, central depressions close to water table and with the coral sand soil richer in organic matter.

The several atomic bombings have moved soil, blown away soil, and deposited it over existing surfaces. On the three bombed islets after the explosions, the areas adjacent to the bomb sites were regraded with bulldozers so that much of the mechanical effect of the bombing has been concealed. No well-developed sand dunes were found. No central depressions with richer soil and fresh wells were seen; so it appears that they have been covered by the bombing or by regrading.

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*The complete report by Dr. St. John on the flora of Eniwetok will be prepared for publication in another report, UWFL-24.

Destruction of Plant Communities.

The plant communities of the drier, more open sites have suffered from the bombing, but they are of a pioneer nature and their sites remain. The plants or some of the plants of these dry sand flats or gravel flats are capable of reclaiming the same sites.

Forests suffered destruction. If near to the bomb site it was complete destruction, if more remote, it was partial destruction. On Engebi no standing tree survived on the flats over the total distance of one mile. On the inner beach, slightly protected by the beach crest, 700 yards from the crater, there is a scrub of Messerschmidia argentea 4 meters tall and Scaevola frutescens 1 meter tall, as dominants, plus a solitary, small Guettarda speciosa which survived the bombing

On Aomon the forest had been largely levelled by clearing and bulldozing. No standing tree survived.

On Runit the islet had been mostly cleared by bulldozing. No trees survived within 750 yards of the bomb site. At this distance, slightly protected by the lagoon beach crest, were several trees of Messerschmidia argentea 3 meters tall, some Scaevola frutescens, and a Guettarda speciosa stump with sprouts 1 meter tall, doing poorly. At 1,200 yards there were several Coco nucifera trunks standing but decapitated and one healthy, standing tree 9 meters tall. At 1,250 yards was a thicket of Scaevola frutescens 5 meters tall that survived the blast and looked healthy. The trees mentioned and others which made up the forests on the islands gave shade and conserved moisture and humus on the forest floor which made it a distinct habitat. The mesophytes dependent upon this type of habitat perished with the destruction of the forest. For example, Pisonia grandis, a common and vigorous tree, was eliminated with the destruction of the mesophytic forest patches.

Destruction by Force.

From the center of the explosion came a blast or wind shock wave. For three-fourths of a mile radius all standing trees were levelled or broken off near the base. For a radius of one mile all or nearly all trees were uprooted or broken off. For the next one-fourth of a mile the few surviving trees were partly uprooted and stood leaning away from the bomb center with most of their crown gone and only a few branches on their distant side remaining. Obviously much of this uprooting, tilting, and decapitating was done by the mechanical force of the shock wave. This was enough to kill most of the trees and smaller plants, but the extreme heat and radiation doubtless had their destructive effect too. The observer found no means of separating these different factors.

PERSISTING EFFECTS

From the bombing, the soil and rocks in affected areas became radioactive. Other observers have recorded the kind and the decreasing amounts of this radiation. The bombing certainly destroyed all growing plants above ground within a radius of 200 or 300 yards. That it killed all seeds, sprouts, roots in the soil of nearly all species is equally evident. On all three islands a circular area, centering on the bomb tower and extending 200 yards, suffered almost complete extermination of the flora. In these circles in August, 1949, there were only two species of living plants. On Aomon and Runit there was only one, Portulaca oleracea. On Engebi there were two, Chloris inflata and Portulaca oleracea.

Though making active growth, these two species are annuals and have certainly grown up since the bombing and not survived it on the ground surface. The grass, Chloris inflata (see Figure 1)was nearest to the center on Engebi. Though there were healthy, normal plants of it, there were also many abnormal plants with the stems flattened, shortened, and with a spiral torsion that made them lie on the ground like flattened spirals. These mutants were perhaps fertile. The purslane, Portulaca oleracea, (see Figure 2) was present in the inner circle on Engebi and the only one existing on Aomon and Runit. The plants grew throughout their life cycle from seedlings to maturity. The seeds of the two species may have survived the bombing while buried in the soil, or they may possibly have been lodging nearby and later have been pushed to the center by a bulldozer; but certainly they must have survived in a spot quite nearby. The Portulaca grew into prostrate mats 2-8 dm. in diameter and in the earlier, vegetative stages looked healthy. They flowered and formed capsules and seeds. Nearly all of the larger plants were suffering a destruction which will be called "die-back." The young stem tips yellowed, then withered, as did in turn the mature leaves, then the stems and roots. All stages of die-back were seen culminating in blackened, shrivelled remnants lying in and on the light, coral sand. Many of the dead patches had pro-

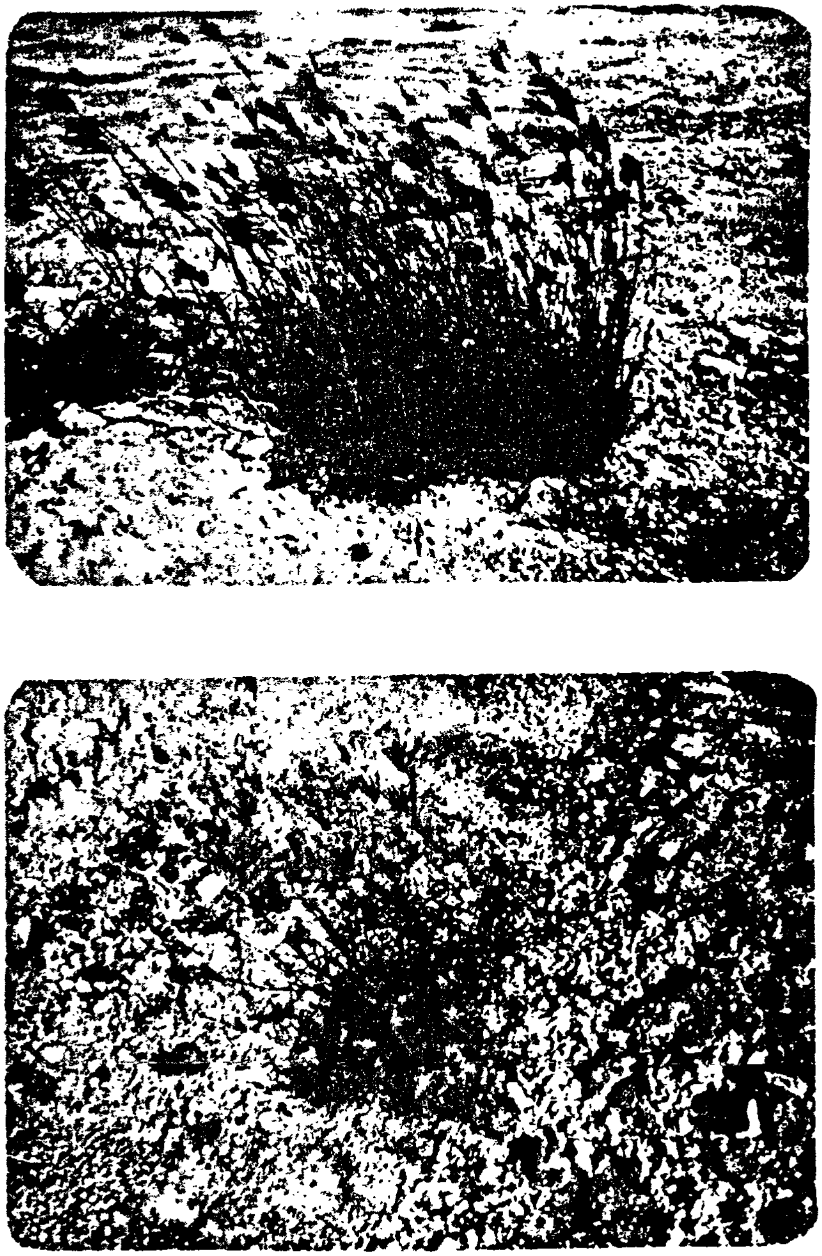


Figure 1. *Chloris inflata*, found nearest to the center on Engebi. (a) Healthy, normal plant. (b) Abnormal plant with stem flattened, shortened, and with a spiral torsion which caused plants to lie on the ground.

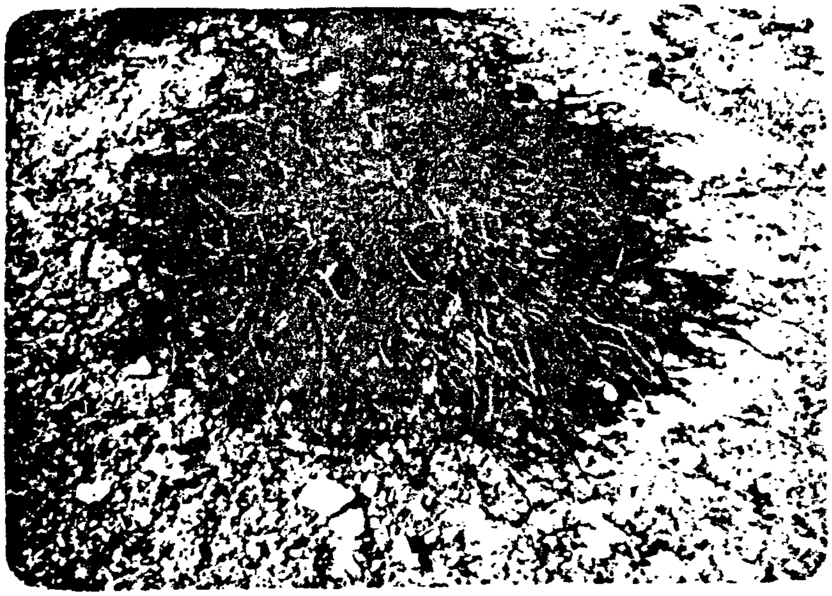


Figure 2. *Portulaca oleracea*, present on inner circle on Engebi and only one existing on Aomon and Runit. (a) Healthy plant from Oahu. (b) Plants growing in prostrate mats 2-8 dm. in diameter. Look healthy in earlier, vegetative stages - flowered and formed capsules and seeds. Nearly all larger plants suffering from a destruction called "die-back".

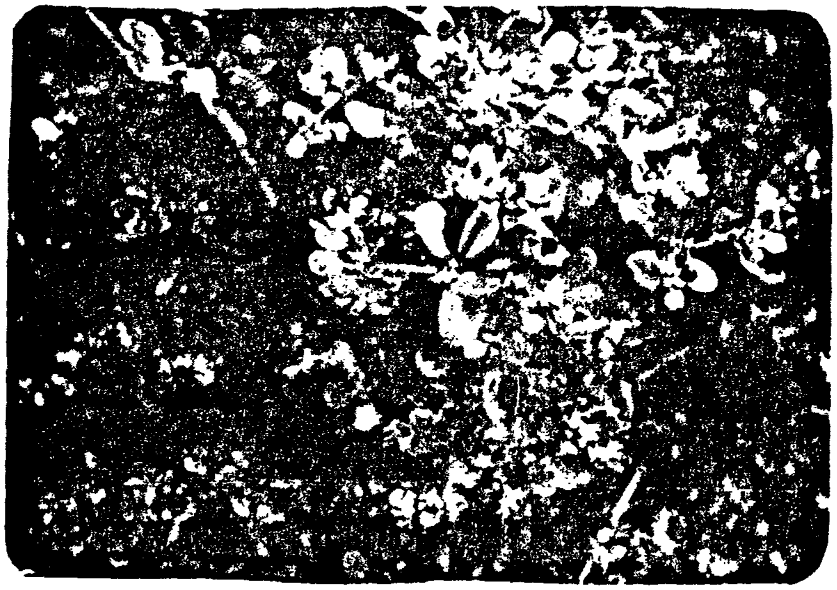


Figure 2. Portulaca oleracea. Plants showing "die-back" culminating in blackened, shrivelled remnants lying in and on the light, coral sand. Many of the dead patches produced viable seed. The seedlings grew vigorously and apparently would live through to fruition.

duced viable seed, for masses of new young seedlings could be seen germinating between the dead remnants of the original patch, while the areas between the patches were devoid of vegetation. These seedlings grew vigorously and would apparently live through to fruition. No phenotypic mutants were observed on Engebi in *Portulaca*, but there were certainly differential effects upon the plants. Some were nearly, if not wholly, sterile, producing many seeds that were shrivelled, empty, and sterile (St. John 23, 785), and very few seeds that were plump and apparently fertile. Most of the plants, however, had demonstrated their fertility, before succumbing to die-back, producing numerous good seeds which germinated and produced an abundant crop of apparently healthy seedlings. In the time elapsed, none of this second crop had been exposed long enough to be affected by the die-back. On Aomon, a few *Portulaca oleracea* plants showed pale and chlorotic leaves. Signs of die-back were also common in *Cenchrus echinatus* (see Figure 3) on Engebi at 440 yards from the center. One could only wish that this pestiferous sandbur would completely die out here and elsewhere. Unfortunately there were many healthy, fertile plants also.

The hard seeds of the *Portulaca*, buried in the soil, apparently survived the bombing unharmed, but when they grew into mature plants, they soon succumbed. It is clearly indicated that they were suffering from persisting effects of the bombing. Continuing radiation from soil particles must be the cause.

PHENOTYPIC MUTANTS.

The farther one travelled from the bomb center, the more numerous were the species of plants found, but at all distances up to a mile there were evidences of the drastic, destructive effects on the vegetation. Also there were alternating bands or patches of well-vegetated areas and those completely bare, probably due to unequal distribution of radiant soil particles. These bare areas were found at random from 200 to 1,150 yards from the center.

Stem abnormalities were seen in several species. *Ipomoea tuba* showed extreme atrophy with the stem which might have been 10 meters long, shortened to 1 dm. in length, thickened, swollen to 8 cm. in diameter, cancerous with numerous warts, and bearing reduced, linear blades. Several like this were collected by Dr. O. Biddulph on Runit. Another on Engebi had the blades asymmetric,

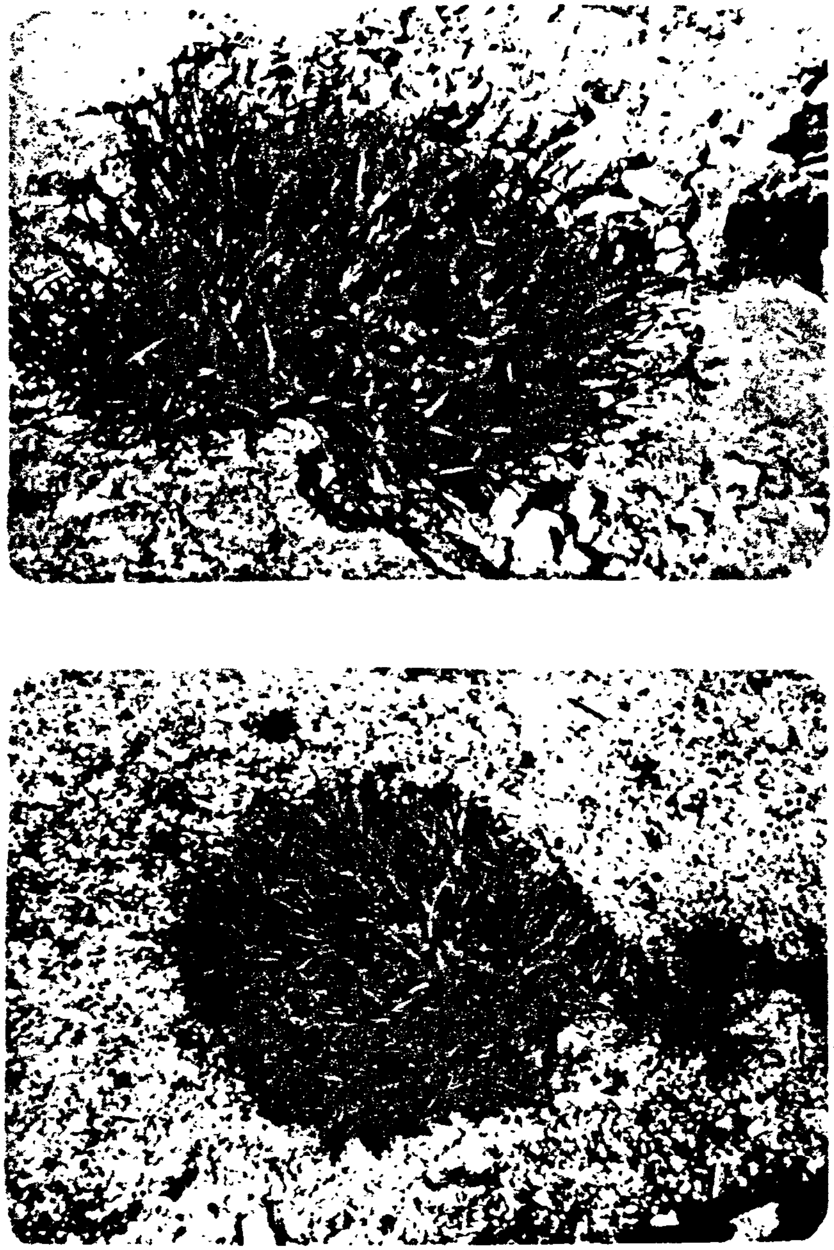


Figure 3. Cenchrus echinatus, found on E_n gebi at 440 yards from center. (a) Healthy plant. (b) Plant showing signs of "die-back". Complete sterility noted in some plants (St. John, 23, 783).

crumpled, suborbicular-deltoid. Fleurya ruderalis (see Figure 4) had been nearly exterminated, only one plant being found on Biijiri Islet (adjacent to Aomon). This specimen had abnormally bright red stems (chromatism) and leaves reduced in size, firm and almost dry, the halves inrolled to the midrib (heteromorphy) (St. John 23, 817). The plant appeared very unhealthy, and it is very doubtful if it will survive or produce viable seed. The spiral torsion of stems in Chloris inflata has been discussed above.

Leaf abnormalities were found in Fleurya and Ipomoea tuba mentioned above. Morinda citrifolia rarely survived the bombing. On Engebi there were two or three small bushes, at 1,000 yards from the center, and the largest one 1.5 meters tall, had abnormal leaves, thick, asymmetric and somewhat crumpled. Its fruits were small, the end shrivelled and twisted like cones of Pinus sylvestris. Ipomoea pes-caprae (see Figure 5) survived on Engebi as a single, large plant, making a patch 10 meters in diameter, at the extreme southern end, one mile from the center. The plant had enlarged, fleshy stems, narrowed leaves, red petioles, and the plant was sterile (St. John 23,778). Scaevola frutescens (see Figure 6) on Engebi had the leaves crumpled.

Leaves and other vegetative parts showed loss of chlorophyll (albinism or chlorosis) in Morinda citrifolia (see Figure 7) in a sprout 4 dm. tall on Biijiri Islet, 1,300 yards from the Aomon center. So did the Fleurya discussed above. Portulaca oleracea (St. John 23,834) from Aomon showed pale chlorotic leaves. The only surviving plant of Ipomoea pes-caprae at 1,000 yards, formed a large patch 7 meters in diameter, but the whole plant was pale and chlorotic (St. John 23,831).

Flowering or fruiting modifications were not seen so often. Boerhavia diffusa var. eudiffusa (see Figure 8) was found as a single large plant, 500 yards from the center, forming a mat 5 meters in diameter. the stems pink, fleshier, leaves on the lower surface white with red veins, the inflorescences (cymes) much enlarged, bearing 11-53 flowers each with about 20 open at a time in each cyme, fruits few, these seeming good (St. John 23,779). Instead of the very inconspicuous clusters of 2-4 flowers in the normal plants, this mutant had the many flowers massed in bright pink balls.

Figure 4. Fleurya ruderalis, nearly exterminated - only one plant found on Biijiri Islet. Bright red stems (chromatism); leaves reduced in size, firm and almost dry, halves inrolled to midrib (heteromorphy) (St. John, 23, 817). Appeared very unhealthy.

[illegible] *Ipomoea pes-caprae.* Normal plants.

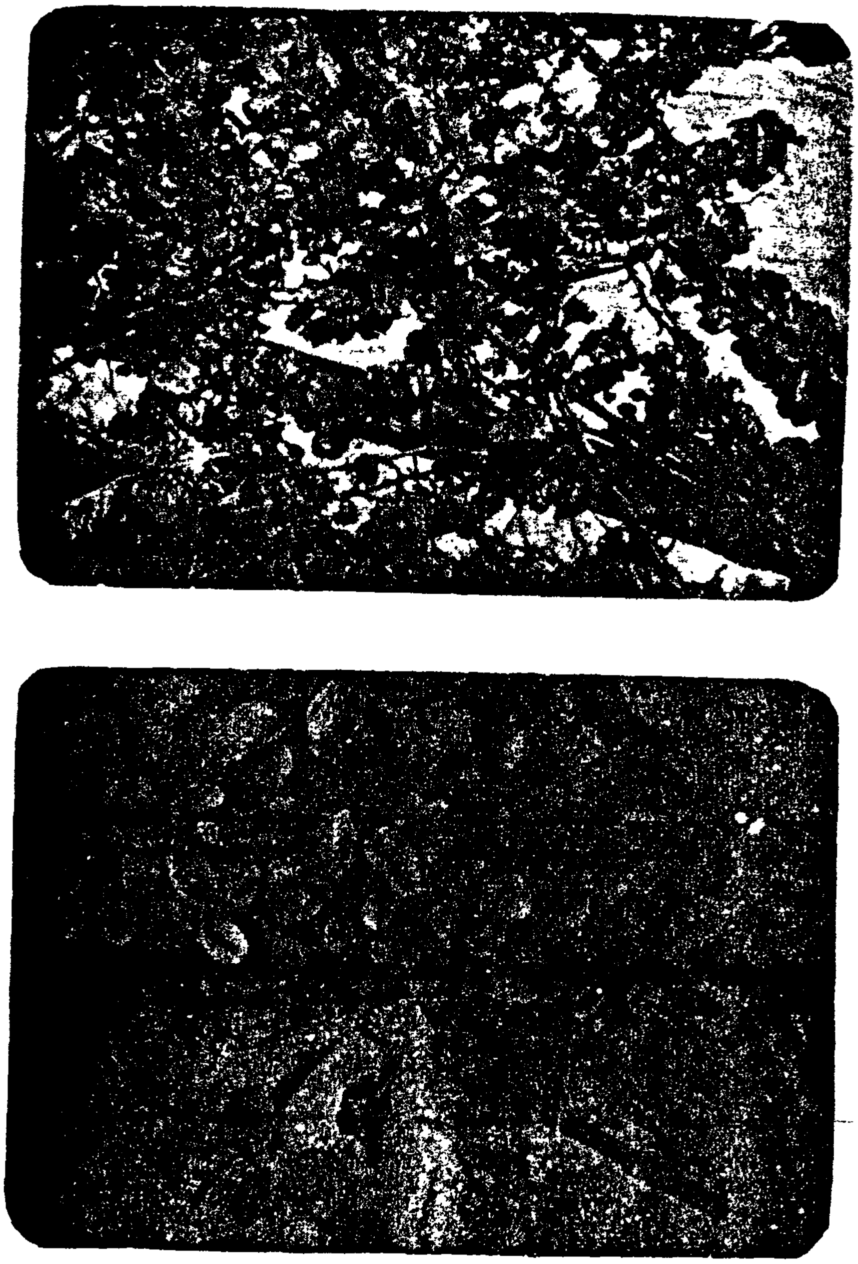
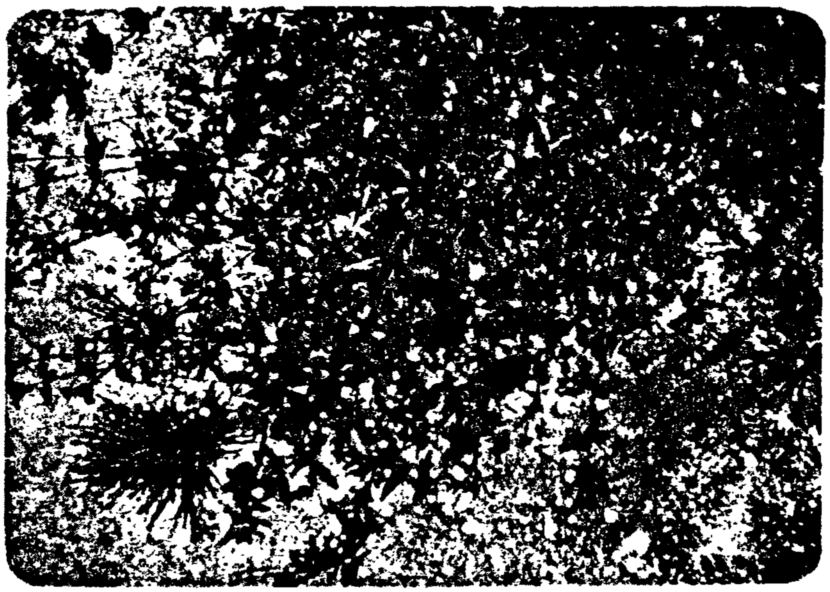


Figure 5. Ipomoea pes-caprae, found one mile from center on Engebi. (a) Survived as single, large plant, making patch 10 meters in diameter. Enlarged, fleshy stems, narrowed leaves, red petioles; plant was sterile (St. John, 23, 778). (b) Plant found 1000 yards from center, formed large patch 7 meters in diameter. Whole plant was pale and chlorotic (St. John, 23, 831).

Figure 6. Scaevola frutescens, found on Engebi, leaves crumpled.

Figure 7. Morinda citrifolia, found 1300 yards from the Aomon center on Biijiri Islet in sprout 4 dm. tall. Leaves and other vegetative parts showed loss of chlorophyll (albinism or chlorosis). Partial fruit sterility with small, shrivelled fruits noted.



[illegible] Boerhavia diffusa var. eudiffusa, found 500 yards from center. Single, large plant, forming mat 5 meters in diameter. Stems pink, fleshier; leaves on lower surface, white with red veins; inflorescences much enlarged; fruits few, seeming good (St. John, 23,779). Instead of very inconspicuous clusters of 2-4 flowers in the normal plants, this mutant had the many flowers massed in bright pink balls.

Partial fruit sterility was noted in Morinda citrifolia with small, shrivelled fruits, as mentioned above. Complete sterility was noted in some plants of Cenchrus echinatus (St. John 23, 783).

FEATURES OF THE FLORA OF ENGEBI.

The original flora of Engebi may not now be clearly reconstructed. Long ago, because of economic exploitation, much of the area had been cleared and planted to coconuts. Then the Japanese military forces developed a base on the island with roads, a railroad, barracks, warehouses, trenches, artillery positions, pillboxes, and an airbase with airstrip running from the northwest point the full width of the islet to the east beach. In the war, American bombing and shelling did much destruction. Then the American military forces captured and occupied it and redeveloped it as an airbase and, with bulldozers, nearly completed clearing the area. Not until after these destructive actions was the vegetation studied briefly by Bryan in 1944 and by Fosberg in 1946.

Omitting the cultivated garden plants, the following species observed or collected by Bryan are now apparently extinct:

Pandanus
Cocos nucifera
Pisonia grandis
Wedelia biflora ("a yellow composite vine")

Similarly the following species collected in 1946 by Fosberg seem now to be extinct:

Eleusine indica
Setaria verticillata
Fleurya ruderalis
Pisonia grandis
Portulaca samoënsis
Euphorbia Atoto
Tribulus cistoides
Pluchea odorata
Vernonia cinerea

The atomic bombing brought further destruction and in 1949 only twenty species were found on the islet. Of these, specimens of the following seven species

... found altered by the bombing to phenotypic mutants, or thirty-five per cent. ... mutants were:

Cenchrus echinatus
Chloris inflata
Boerhavia diffusa var. eudiffusa
Portulaca oleracea
Ipomoea pes-caprae
Morinda citrifolia
Ipomoea tuba

...ATURES OF THE FLORA OF AOMON

This islet was not visited by Maj. Bryan, so the first account of it is that ... Fosberg in 1946. He described it as mostly of "flats of coral sand, chang-... broken coral rock as outer beach is approached; entirely planted to coconuts, ... portion clear and grassy beneath, nearer outer beach a brush of Scaevola ... Pisonia is beneath trees." His collections included the following now extinct ... the islet:

Digitaria sp.
Boerhavia diffusa
Pisonia grandis
Portulaca lutea
Achyranthes aspera
Cassytha filiformis
Cordia subcordata
Guettarda speciosa
Morinda citrifolia

After the atomic bombing, there were only twelve species found, of which ... showed mutants, or twenty-five per cent. These mutants were:

Fleurya ruderalis (on nearby Biijiri Islet)
Portulaca oleracea
Ipomoea pes-caprae

...TURES OF THE FLORA OF RUNIT

...ither Bryan nor Fosberg visited Runit Islet. Dr. W. R. Taylor did visit it in 1946. Six species that he collected have been seen, but his botanical section of the Crossroads Expedition Report has not been made available to the writer. Of these six, the following one appears to be extinct:

Eragrostis amabilis

In 1949 after the bombing, the writer found an existing flora of nineteen species. Of these, three species furnished mutants, or sixteen per cent. These species were:

Portulaca oleracea
Ipomoea tuba
Guettarda speciosa

PHYSIOLOGY OF LAND PLANTS

by

Orlin Biddulph

State College of Washington

The survey was conducted during the last week of July and the first two weeks of August 1949 and was under the supervision of Dr. L. R. Donaldson, Director of the Applied Fisheries Laboratory of the University of Washington. The elapsed time from the Bikini explosions was then 37 months from the aerial explosion and 36 months from the under water test. The elapsed time from the Eniwetok tests was 17 months from the Engebi test, 16 months from the Aomon and Biijiri test, and 15 months from the Runit test.

The survey was limited in scope to the occurrence of radioactivity in or upon the plants. Such effects as mechanical shock, heat and direct gamma radiation were not considered. The scattering of fission products and their consequent uptake into the plants constituted one major part of the investigation while the accumulation by plants of radioactive materials induced in place by the neutron shower accompanying the explosion constituted another major part of the investigation.

The choice of plant material for study was dictated by existing circumstances. Both the nature of the plans for the survey and the widespread occurrence (and use) of certain plants aided in narrowing the selection of plant material for detailed study to several species. The coconut was selected as the most suitable material for study on those islands not directly used for "tests". The criteria considered in the selection were as follows:

(1) Permanence of plants. Plants must have been present before, during, and after the explosions.
(2) Exposed parts. Plants must have exposed living tissues removed from possible ground contamination as well as dead tissue, equally removed, upon which adsorbed fission products might persist over a number of years.
(3) Internal tissues. Plants must have internal tissues which are amply

protected by external tissues of sufficient thickness and impermeability to exclude the possibility of confusing externally deposited materials from those which are deposited within the tissues as a result of absorption and translocation by the roots.

(4) Distribution. Plants must be present on most of the islands to be surveyed in order to give comparable results from each site.

(5) Economic importance. It would be preferable, for reasons of human ecology, if the plant studied entered into the economy of the peoples of the area.

The coconut fulfills these criteria admirably. It possesses a stem primordia surrounded by many leaf bases, a flower which is formed encased in a heavy floral bract, fruits with parts which develop within a thick husk, and which include a thick hard shell encasing a fatty nucellus (when dried, called copra, and herein called "meat")and a liquid nucellar fluid in the drinking nut stage (herein called "milk"). The older leaf bases split apart as growth of the stem tip proceeds and the dead fibrous vascular tissue persists, like so much burlap, until the whole leaf, or frond, falls from the tree. (Absorption of airborn fission products could be expected here.)

The leaves and floral parts of the coconut are born from twenty to eighty feet above the ground, depending on the age of the plant, reducing the possibility of ground contamination. An apparently universally indulged-in drink is also made by tapping the tip of the unopened inflorescence, allowing the escaping sap to drip into a suitably supported bottle, and when properly "ripened" by naturally occurring yeasts, consumed at leisure.

EQUIPMENT AND METHODS OF COLLECTING SAMPLES.

Landings were completed from the ship to the beaches or coral reefs by means of rubber life rafts, hence the minimum of equipment was transported and used: a machete in a wooden sheath, a collecting can (five-gallon, tin coffee can in canvas with carrying straps), cellophane bags, paper sacks, etc. were adequate. The site for collection of samples was chosen on the lagoon side of the various islands but inward a distance of approximately twenty to fifty yards from the beach. A healthy coconut tree was selected which bore fruits and flowers in a variety stages of development. The tree was felled (by machete) and samples from the following parts taken:

1. Lower trunk - external and internal tissue.
2. Median trunk - external and internal tissue.
3. Primordium (heart of palm).
4. Green leaf base.
5. Dry leaf base.
6. Midrib of leaf.
7. Leaflets, median.
8. Mature nuts.
9. Green nuts (drinking stage).
10. Small nuts, 1 inch in diameter.
11. Female flowers, large, from unopened sheath.
12. Female flowers, small, from unopened sheath.
13. Male flowers, large, from unopened sheath.
14. Male flowers, small, from unopened sheath.
15. Male and female flowers, primordial, from unopened sheath.

Numbers 8 and 9 were subdivided into:

8A	Husk	9A	Husk
8B	Meat	9B	Meat
8C	Milk	9C	Milk

Tissue from each sample was placed in numbered cellophane bags and returned to the ship. Numbers 8 and 9 were processed on board ship. Here each sample was prepared and placed in aluminum dishes, dried under heat lamps, sealed in cellophane bags, and returned to the laboratory in Pullman, Washington, for further processing.

Each island was surveyed similarly. In addition, plant material from each different species of plant was taken for possible analysis should results warrant a more detailed study. Bikini Atoll:

BIKINI ISLAND

500 Boerhavia repens L.
501 Cassytha filiformis L.
502 Cordia subcordata Lam.
503 Crinum asiaticum L.
504 Guettarda speciosa L.
505 Lepturus repens R. Br.
506 Messerschmidia argentea (L. f.) I. M. Johnston
507 Ipomoea Tuba G. Don.
508 Pandanus sp.
509 Portulaca oleracea L.
510 Scaevola frutescens (Mill.) Krause
511 Suriana maritima L.
512 Triumfetta procumbens Forst. f. Konop.

ENYU ISLAND

513 Guettarda speciosa L.
514 Suriana maritima L.
515 Ipomoea Tuba G. Don.
516 Cassytha filiformia L.
517 Pisonia grandis R. Br.
518 Pandanus sp.
519 Tacca Leontopetaloides (L.) Ktze.
520 Messerschmidia argentea (L. f.) I. M. Johnston
521 Lepturus repens R. Br.
522 Triumfetta procumbens Forst. f. Konop.
523 Guettarda speciosa L.
524 Scaevola frutescens (Mill.) Krause

ERIK ISLAND

525 Lepturus repens R. Br.
526 Guettarda speciosa L.
527 Suriana maritima L.
528 Tacca Leontopetaloides (L.) Ktze.

[illegible] Boerhavia repens L. (B. diffusa L.)
530 Pemphis acidula Forst.
531 Terminalia litoralis Seem.

BORO ISLAND

532 Suriana maritima L.
533 Triumfetta procumbens Forst. f. Konop.
534 Pisonia grandis R. Br.
535 Messerschmidia argentea (L. f.) I.M. Johnston
536 Cassytha filiformis L.
537 Lepturus repens R. Br.
538 Scaevola frutescens (Mill.) Krause
539 Guettarda speciosa L.
540 Portulaca oleracea L.

RADIOACTIVITY OF BIKINI SAMPLES:

A preliminary survey of the plant materials collected showed the activity to be of very low order; consequently, it was considered desirable to convert the expression of all results to an ash basis rather than to a dry weight basis. This would remove the effects of the relatively variable carbohydrate or fatty material from consideration and place comparisons on a strictly ash basis, which is the fraction in which the radioactivity resides. On this basis better comparisons with control material could be made.

As the counting was to be done in an "internal" sample counter, K^{40} would contribute to the total counts but would not, of course, have its origin in the bomb material. Other radioactive materials are present in small quantity in all plants grown in a natural environment where uranium and its decomposition products are present. In some plants grown on the soils of the Columbia Plateau of Washington, it has been found that K^{40} constitutes about one-half of the naturally-occurring radioactive material in the plants. Uranium and its decomposition products make up the remaining one-half.

Control material was acquired from the Pacific area at the Island or Likiep in the Marshall Islands. This was an inhabited island and the control plant was selected at the direction of the island leader. It came from an area frequented constantly by the inhabitants whose habits are such as to permit relatively larger amounts of human wastes to become available to the plants than was the case for coconuts grown in plantations, or on islands which are not permanently inhabited. In this manner it is possible that the control material from Likiep is relatively richer than the majority of coconut samples in certain ash constituents such as potassium and hence K^{40}.

It was considered desirable to include some plant materials which were grown in soils commonly used for agricultural crops, and to be still more cautious, to include some seeds which are known to have been confined in stoppered glass bottles since before the beginning of the atomic age. i.e., about 1938 at the State College of Washington. Clover and parsley leaves and spinach and sweet clover seeds were selected for this comparison.

The coconut tissues were selected and prepared for ashing at the State College of Washington and were ashed, weighed, and counted at the University of Washington (under the same counting conditions as were used for the aquatic forms). The procedure for preparation of coconut samples for radioactivity assay was as follows:

(1) Dry material to constant weight at 85°C.
(2) Cool in dessicator.
(3) Weigh out a representative sample of 1 gm.
(4) Place in a porcelain crucible of known weight in a cold muffle.
(5) Ash to constant ash weight at 500°C to 550°C.
(6) Cool in a dessicator.
(7) Weigh to get ash weight (usually around 15 mg/gm dry matter).
(8) Transfer solid ash to a 1-1/2" stainless steel counting plate.
(9) Dissolve remaining ash in a minimum of 1:9HCl. (1 pt. conc. HCl:9 pts. H_20) transfer to the ss. plate. Evaporate the HCl. Repeat the washing twice.
(10) Spread the ash uniformly on the plate.
(11) Dry under a heat lamp, removing all HCl.
(12) Count.

[illegible] those coconut tissues which were strategically located so as to give [illegible]tative picture of the activity were counted and reported at this time [illegible]). In all cases, results have been corrected by subtracting the equi- [illegible] Likiep values from the activities observed. The excess activity above the [illegible] values are then reported. This excess is assumed to be due to scattered [illegible] products from the various explosions. The Likiep values are within the [illegible] range for naturally-occurring radioactivity within land plants, as is shown [illegible] included analysis for four plant parts from Washington's agricultural soils.

[illegible]

[illegible] results of the coconut studies are expressed as the excess counts/ [illegible]/100 mg. of ash above the corresponding counts made on the Likiep control [illegible]. The actual counts/minute/100 mg. of ash for the Likiep material are [illegible] as are the values, similarly expressed, for agricultural crops (see [illegible]. All samples were treated in the same manner, except for slight varia- [illegible] the amount of ash per plate. In all cases, the samples counted were "thin", [illegible] the order of 1 to 4 mg/cm^2. No correction for self absorption has been [illegible]. Self absorption factors, if applied, would range from 1.0 to 1.5. The Likiep [illegible] agricultural materials would be similarly increased. Since the activity en- [illegible] in the internal tissues of the coconut is so low, no useful purpose would [illegible] in making corrections for self absorption.

TABLE 1

COCONUT STUDIES

COMPARATIVE COUNTS ON SIMILAR MATERIAL

	Stem primordia		Coconut meat		Coconut milk
	1	2	1	2	1
Bikini 1	27	-	38	41	7
Bikini 2	36	25	23	29	4
Bikini 3	34	35	46	26	5
Enyu	-	-	22	18	1
Romuk	33	28	44	-	8
Erik	28	26	34	18	8
Namu	19	23	21	22	14
Japtan	30	31	22	24	6
Igurin	25	16	30	32	5
Rigili	30	21	28	21	3
Bogon	31	20	44	44	4
Aitsu	36	21	33	28	3
Likiep	32	25	27	36	4

1. Counts made by Orlin Biddulph December 1949.
2. Counts made by University of Washington January 4-5, 1950.

Not corrected for decay, geometry, self absorption, or backscatter.

TABLE 2.

Radioactivity of parts of coconut plants and soil expressed as c/m/100 mg. ash. For localities other than Likiep, values are in excess of those for Likiep.

	Primordia	Green leaf base	Dry[1] leaf base	Leaflet	Coconut meat	Pistillate flowers	Debris in leaf axils	Soil
[illegible] 1	0	0	0	0	5	18	-	-
[illegible] 2	0	0	0	0	0	0	-	-
[illegible] 3	10	0	0	0	0	0	369	-
[illegible]	-	-	-	7	0	-	-	0
[illegible]	3	0	8,100	11	0	5	-	0
[illegible]	0	0	0	8	0	0	-	0
[illegible]	0	0	0	0	0	0	-	0
[illegible]	6	0	0	0	0	0	-	0
[illegible]	0	0	0	1	0	0	23,700	0
[illegible]	0	0	188	3	0	0	0	0
[illegible]	0	0	45	0	8	22	25,400	0
[illegible]	0	0	530,000	644	0	0	-	846
[illegible]	25	30	0	6	36	24	-	-

[illegible] Fibrous material, not living tissue when collected.

[illegible] counts were made of State College of Washington plants and they [illegible] following values: parsley leaf - 16; clover leaf - 22; spinach seed - [illegible] clover seed - 40.

No correction for geometry or backscatter was made. The combined factor for the University of Washington counter was 1.54 and for the Washington State College counter was 1.56. Both were calculated from P^{32}. No decay factor was employed for reasons stated above.

INTERPRETATIONS

Bikini Atoll - Activity, where present in the internal tissues of the coconut, is of extremely low order. It is doubtful if, within those coconuts studied, there resides any activity greater than twice that which might be found in mainland truck crops normally consumed without question as to the amount of activity present.

There is, however, significant activity on the dead leaf bases and within the accumulation of debris located in the axils of the leaf bases in those areas where "fallout" of radioactive materials was to be expected. Counts run as high as 8,100 cpm/100 mg. ash. This particular count was made on the dry leaf base of a coconut palm on Romuk Island. The retention of the adsorbed fission products through the years of constant leaching by rains is surprising and certainly is worthy of special note. In all cases where significant activity was encountered, dead organic matter served as the carrier.

Significant counts made at the site of collection with the survey meter provided were recorded in the dead leaf material collected at the north tip of Bikini Island (Area 2406), and at Enyu Island (Area 2894), and at Romuk Island (Area 1014). In addition, laboratory counts are herein reported for Bikini Island (Area 2506).

Eniwetok Atoll - Similar studies on coconuts were carried out at Eniwetok Atoll on those islands where significant results were to be expected, but not on those islands where actual tests were conducted. Japtan was least affected while other islands gave very significant activity (see Table 2).

There are several instances of probable internally collected radioactivity in the Eniwetok studies as was the case for Bikini Atoll studies. There are no instances, however, where internally collected activity is more than twice the Likiep activity, or twice the activity found in truck crops.

Significant activity was detected on the dry leaf bases, and debris in the

the leaves at Igurin, Rigili, Bogon, Aitsu. On Aitsu an activity of 530,000 c/m/100 mg. of ash was recorded. This was the highest recorded activity; it was present on the dead organic matter of the dry leaf base. It is to be interpreted as adsorbed material having fallen on the plant, rather than absorbed material which was translocated to this site.

INDUCED RADIOACTIVITY - ENIWETOK TESTS

The explosions at Eniwetok occurred above the islands rather than over (or under) water as was the case for the Bikini tests. For this reason, additional factors had to be considered. Foremost among these was the possibility of Ca^{45} being formed by the n-γ reaction of Ca^{44}. Ca^{44} has a relative abundance in nature of approximately 2 per cent.

A careful examination of the plants growing closest to the crater revealed the presence of a disturbance closely resembling calcium deficiency as it is produced in the laboratory by withholding calcium from the nutrient solution. A tentative hypothesis was then formed, that if Ca^{45} were present, it would tend to be found in highest concentrations in those tissues which first showed breakdown with true calcium deficiency. This would then explain tissue breakdown which resembled calcium deficiency, but was due to radiation damage by Ca^{45}

For this study Portulaca oleracea plants were taken at different distances proceeding away from the bomb crater to a distance of one thousand yards where possible. Samples of coral sand were taken from the soil surface layer, and from three-inch and six-inch depths, to correspond with the plants collected at a distance of two hundred yards from the crater. Both the coral sand and the plant material were subjected to a chemical treatment which was designed to separate calcium from all other elements.

The possible formation of Ca^{45} from Ca^{44} by the n-γ reaction:
Assume 1 Kg U^{235} with 1% fission i.e., 10 gms fission
4.25 x 10^{-2} gm. atoms = 4.25 x 10^{-2} x 6 x 10^{23} = 2.5 x 10^{22} atoms

Assume U^{235} produces 2 neutrons, one escaping

$$\text{Flux at 200 meters} = \frac{1}{4\pi(2 \times 10^{4})^{2}} \times 2.5 \times 10^{22}\ n/cm^{2}$$

$$= \frac{2.5 \times 10^{22}}{.5 \times 10^{10}} \times 5 \times 10^{12}\ n/cm^{2} \text{ (fast neutrons)}$$

Using = 0.6 b for $Ca^{44}(n\gamma) = Ca^{45}$ (for slow neutrons)

$$N = 1\sigma n = 5 \times 10^{12} \times 0.6 \times 10^{-24} \times n = 9 \times 10^{8} \text{ atoms } Ca^{44}/gm$$

$$n = \frac{6 \times 10^{23}}{40} \times .02 = 3 \times 10^{20}$$

$$-\frac{dn}{dt} = \lambda N = \frac{0.7}{150 \times 24 \times 60} .9 \times 10^{8} = \frac{6.3 \times 10^{8}}{2 \times 10^{5}}$$

$$= 3 \times 10^{3} \text{d/min/gm(Sand) / 10 gms of fission (at 200 meters)}$$

It is apparent from the above results that the presence of Ca^{45} may be expected in the coral sands within a radius of the crater corresponding to the length of the path of neutrons in the air.

The method used in the separations of calcium from other elements is outlined below. A simplified method and a more detailed method are included. They differ in regard to the extent of the "scavenging" procedures employed to remove fission products. The first is referred to as Procedure I; the second as Procedure II. Procedure II gave the lowest values for Ca^{45}/Ca so was regarded as the most satisfactory procedure.

PREPARATION OF SAMPLE

The dry plant material of the coral sand was digested in a kjeldahl flask with 15 ml of concentrated nitric acid, evaporated almost to dryness, another 15 ml of nitric acid added and refluxed until all material was in solution; 10 ml hydrochloric acid was then added and the mixture was evaporated until the volume was about 2 ml. The material was transferred quantitatively to a 125 ml erlenmeyer flask and the digestion flask washed with dilute hydrochloric acid and the washings added to the solution. Total volume about 50 ml.

SCAVENGING Procedure I

Ten milligrams of arsenic as As_2O_5 was added and the solution was heated almost to boiling and saturated with H_2S. The precipitate of As_2S_5 was removed by centrifuging.

Ten milligrams of iron as $Fe(NO_3)_3$ was added and the solution was made alkaline to methyl red. One ml excess of conc. NH_4OH was added, the solution was heated almost to boiling, cooled, and the $Fe(OH)_3$ removed by centrifuging and transferred to a counting disk. Ten milligrams of Fe^{+++} was added and the precipitation repeated.

After the second ferric hydroxide precipitation the solution was acidified with HCl using methyl red indicator, one ml more of HCl was added, the solution was heated almost to boiling and, while hot, 10 ml of ammonium oxalate solution (40 g. per liter) was added dropwise, then ammonium hydroxide 1:5 was added dropwise from a burette to the hot solution until alkaline to methyl red. The solution was allowed to stand on a hot plate for one hour and the precipitate of calcium oxalate was removed by centrifuging and washed with 0.1% ammonium oxalate solution made slightly alkaline with a few drops of NH_4OH. The $CaC_2O_4 \cdot H_2O$ was transferred to a counting disk and weighed.

After counting, the calcium oxalate was dissolved in dilute HCl, 1:4, diluted to 50 ml, one ml of 4% ammonium oxalate solution was added and the calcium oxalate was again precipitated by treating with NH_4OH as above. The solution stood for one hour on the hot plate after which the precipitate was separated by centrifuging, washed until chloride free with water to which a few drops of ammonium hydroxide had been added.

The precipitate was dissolved in 10 ml of hot dilute H_2SO_4 transferred to a 125 ml erlenmeyer flask, diluted to about 50 ml, heated to 80°C and titrated while hot with standard potassium permanganate solution.

The solution after titration was neutralized with NH_4OH, acidified with HCl, 10 mg of Fe^{+++} was added, and the solution was neutralized with NH_4OH; one ml excess of concentrated NH_4OH was added and the solution was heated almost to boiling and saturated with H_2S. The iron and manganese precipitates were removed by centrifuging, the calcium was precipitated as oxalate, separated by centrifuging, dissolved in a minimum amount of sulfuric acid and the oxalate was removed by treatment with permanganate solution. Another ten milligrams of Fe^{+++} was added to the solution and the precipitation of iron and manganese repeated. The calcium was again precipitated as oxalate in the solution acidified with HCl, the precipitate was washed with 0.1% ammonium oxalate solution, and the calcium oxalate was transferred to a stainless steel counting disk, weighed, and counted.

SCAVENGING: Procedure II[1] (Revised Procedure including more vigorous scavenging.)

Element Separated: Calcium, from all other elements.

(1) To aliquot of the HNO_3 digested soln. add 10 mg each of Ru, Fe, and La. Make 0.5N in HCl and ppt. with H_2S.

(2) Add 10 mg Ru and 10 Bi to supn. and repeat H_2S pptn.

(3) Boil out H_2S and ppt. with NH_3.

(4) Add 10 mg Fe and 10 mg Y to supn. and repeat NH_3 pptn.

(5) Boil down to approx. 5 ml, add 10 mg Ba and 10 mg Sr and ppt. with cold Fuming HNO_3.

(6) Add more Sr and Ba to supn. and repeat pptn. 3 times.

(7) Add Sr alone and repeat 2 times more.

(8) Boil down to approx. 5 ml, add 5 ml sat. $(NH_4)_2C_2O_4$ and make basic with NH_3.

(9) Dissolve CaC_2O_4 ppt. in HNO_3, destroy $C_2O_4^=$ with $KClO_3$ and make basic with NH_3. Add 10 mg each of Fe, La and Y. Centrifuge.

(10) Add more Fe, La and Y to supn. and repeat pptn. Centrifuge.

(11) Repeat step (5).

(12) Boil supn. down to approx. 5 ml make basic with NH_3, heat, add 5 ml sat. $(NH_4)_2C_2O_4$ slowly. Stir 2 min., centrifuge, wash 3 times with 5 ml H_2O, 3 times with 5 ml 95% EtOH, 3 times with 5 ml ether.

(13) Transfer the total ppt. onto stainless steel disk and spread uniformly over 9 cm^2 area, dry and count.

[1] W. W. Meinke, UCRL 432, Aug. 30, 1949. Chemical Procedure used in bombardment work at Berkeley.

A decay curve of the calcium oxalate isolated from the coral sands of Runit Island collected 200 yards from the crater and counted in a RCL nucleometer is shown in Figure 1 . From this data the half-life of the radioactive substance isolated is 180 ± 5 days. This corresponds to the accepted half-life for Ca^{45}

The results obtained from the chemical separation and the decay curve indicate the presence of Ca^{45}. That it is present in sufficient quantity to be a definite factor in the survival of the plants in the immediate vicinity of the bomb crater is yet to be proved. It is quite evident that Ca^{45} constitutes a significant fraction of the total radioactivity to which the plants are subjected. This fraction has been deposited within the plants by the normal process of absorption and translocation These plants are short-lived and consequently have grown from seed since the "test", their normal complement of calcium having been acquired from the coral sands irradiated by the neutron shower. This acquisition of radioactive material is in sharp contrast to the acquisition of fission products on the surface acquired by direct fallout or by particles "splashed" upon the plant by the action of raindrops on the surface of the soil containing the fission products.

The specific activity (Ca^{45}/Ca) of plant material and coral sand collected at thirty and two hundred yards from the crater on Runit Island is shown in Table 3.

Two facts become evident after study of Table 3: (1) Procedure I with limited scavenging is insufficient to remove all fission products as is shown by the lower specific activity following the additional scavenging or Procedure II; and (2), the specific activity of the calcium in the plant material decreases with distance from the crater. When corrections are made for the angle of incidence of the soil surface with the geometric center of the explosion[1], the observed results at the two sites agree within 15% of the calculated expected results based on adherence to the inverse square law. Under the circumstances of: (1) the elapsed time to collection of samples, (2) the possibilities of mechanical redistribution, (3) irregularities of soil surface and (4) bomb peculiarities, this result is regarded as being highly gratifying. It lends much weight to the general conclusions regarding the presence of Ca^{45} in the plants.

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[1] Based on the assumption that the explosion was initiated atop a 200-foot tower.

Figure I. Decay curve for Ca^{45} from Runit coral sand.

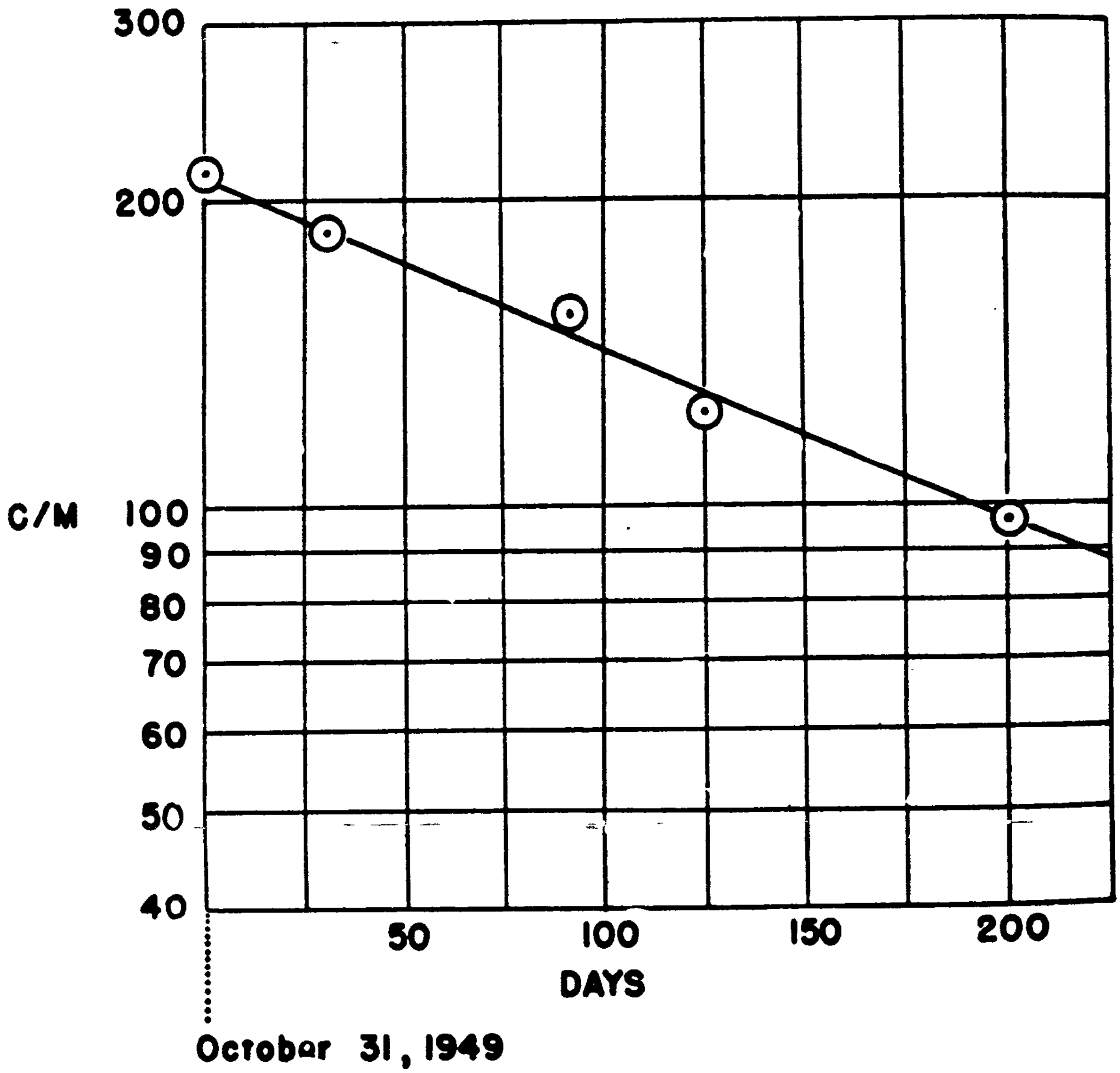


TABLE 3

Specific activity (Ca^{45}/Ca) of plant material and coral sand as determined by Procedures I and II.

Scavenging Procedure	Material	Distance Yards	Dry matter gms.	Ca Ox. gms.	Total Ca mgs.	obs. c/m	Correction Factors: Decay correct to 3/14/50	Correction Factors: Self Abs.	Correction Factors: Back-scatter and geom.	Sp. Act. d/m/mg. Ca
I	plant 574	30	.874	.0295	8.126	1385	1	1.38	1.56	367
II[1]	574	30		.0108	2.956	375	1.275	1.09	1.56	274
II	578	200	.9489	.1646	45.0	21	1.176	3.32	1.56	3.11
II	coral[2] sand	200		.0189	5.17	26	1.32	1.26	1.56	13.0

1. Procedure II was repeated on material from Procedure I. No attempt was made to recover all Ca in this step.

2. Surface layer.

Autoradiographs of Portulaca oleracea plants collected from selected distances from the bomb crater on Engebi, Aomon and Runit Islands are shown in Figures 2, 3, and 4 respectively. They show graphically the same type of information as is contained in Table 3. The intensity of the general background activity within the tissues, due largely to Ca^{45}, decreases with distance from the crater. The same trend is evident in the autoradiographs from all three islands.

The specks of high activity material are presumably fission products lodged at random over the plant. As the distance from the crater decreases the intensity of the individual spots does not increase accordingly. This indicates a rather wide particulate distribution of high activity fission products with a more limited but more uniform occurrence of Ca^{45}. The limits of the Ca^{45} zone should correspond with the maximum range of neutrons in air and the concentration with the neutron flux, unless scattering of Ca^{45} coral sand by mechanical means has occurred.

The presence of Ca^{45} in the tissues of the plants adjacent to the bomb crater is considered to be well established. The approximate concentration, however, was not sufficient to cause more than 734 d/m/gm of fresh tissue[1] (or per cc of volume) on March 14, 1950, in those plants only 30 yards from the center of the bomb crater on Runit Island. The total activity in and upon the plant collected at 50 yards from the tower base (#575, Portulaca oleracea, see Figure 4) amounted to 676 d/min/gm fresh material (assuming 20% dry matter) on May 29, 1950. This cannot be corrected for decay since the half-life is unknown. Assuming Ca^{45} made up an appreciable amount of the activity, the corrected figure might be near 1500 d/min/gm fresh material. Activity, then, is not excessively high.

Radiation values are low enough to warrant a search for another contributing cause for the tissue ~~damage~~ and death ~~of plants in this zone. A reference~~ to Table 3 will show the total calcium content of plants collected at 30 yards (Runit) to be only 9.3 mg Ca/gm dry matter, while at 200 yards the plants contained 47.5 mg Ca/gm dry matter. This latter figure corresponds to the normal calcium content of many plants. It is then evident that the plants near the crater are suffering from a severe calcium deficiency. Experimentally grown plants do not survive at lesser calcium

[1]Calculated from data in Table 3 and assuming 20% dry matter content in the fresh tissue and using scavenging Procedure I, which gives the highest results.

Figure 2a. Autoradiograph of Portulaca oleracea (#542) from Engebi Island. Plant taken 25 yards from tower base. Exposure 51 days to No-Screen X-ray film.

Figure 2b. Autoradiograph of Portulaca oleracea (#544) from Engebi Island. Plant taken 100 yards from tower base. Exposure: 51 days to No-Screen X-ray film.

Autoradiograph of *Portulaca oleracea* (#546) from Engebi Island. Plant taken 250 yards from tower base. Exposure: 51 days to No-screen X-ray film

Figure 3a. Autoradiograph of Portulaca oleracea (#590) from Aomon Island. Plant taken 20 yards from tower base. Exposure: 42 days to No-Screen

...utoradiograph of Portulaca oleracea (#592) from Aomon Island. ...lant taken 100 yards from tower base. Exposure: 42 days to ... Screen X-ray film.

Figure 3c. Autoradiograph of Portulaca oleracea (#593) from Aomon Island. Plant taken 250 yards from tower base. Exposure: 42 days to No-

Autoradiograph of Portulaca oleracea (#575) from Runit Island. Plant taken 50 yards from tower base. Exposure: 51 days to No-Screen X-ray film.

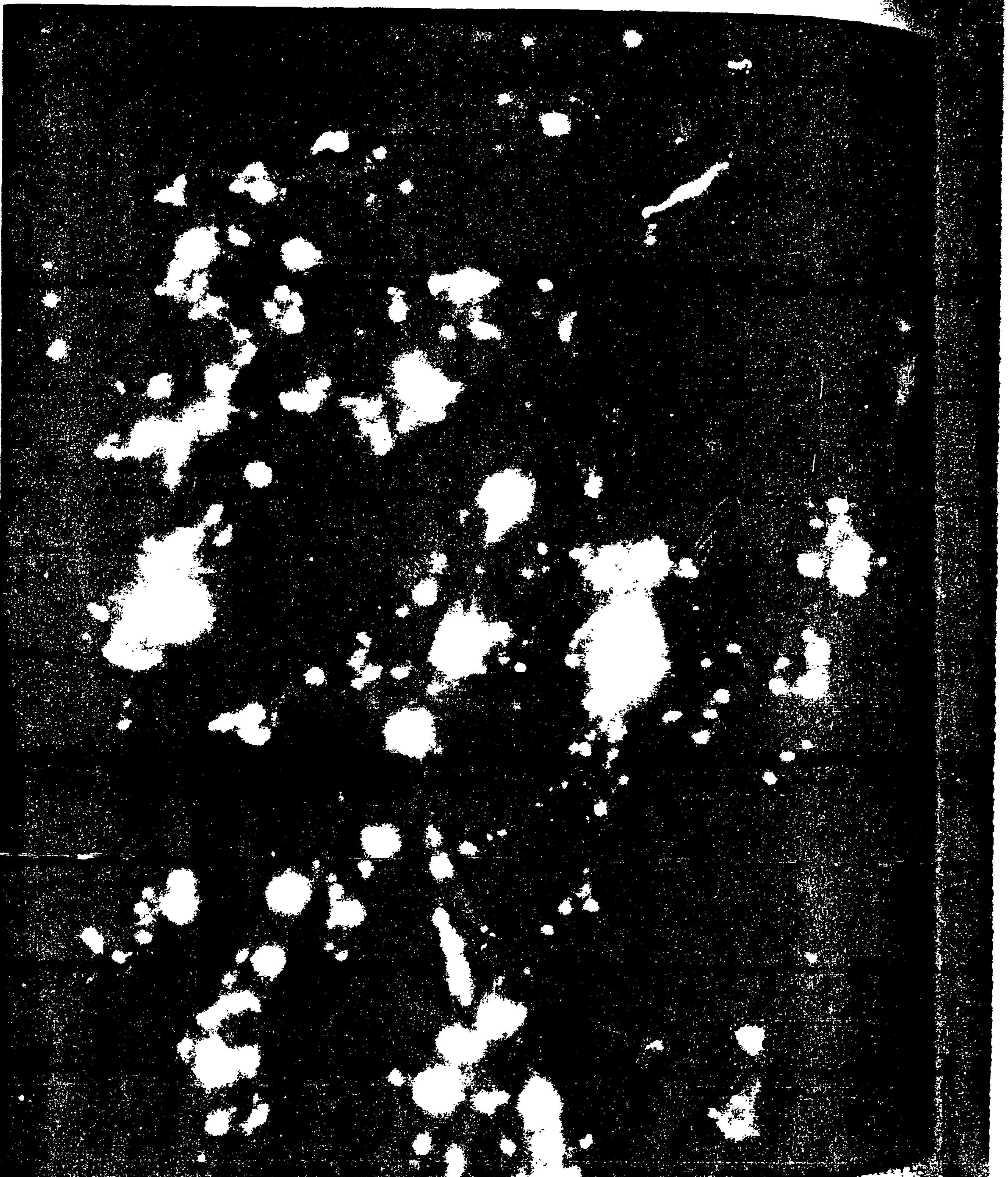
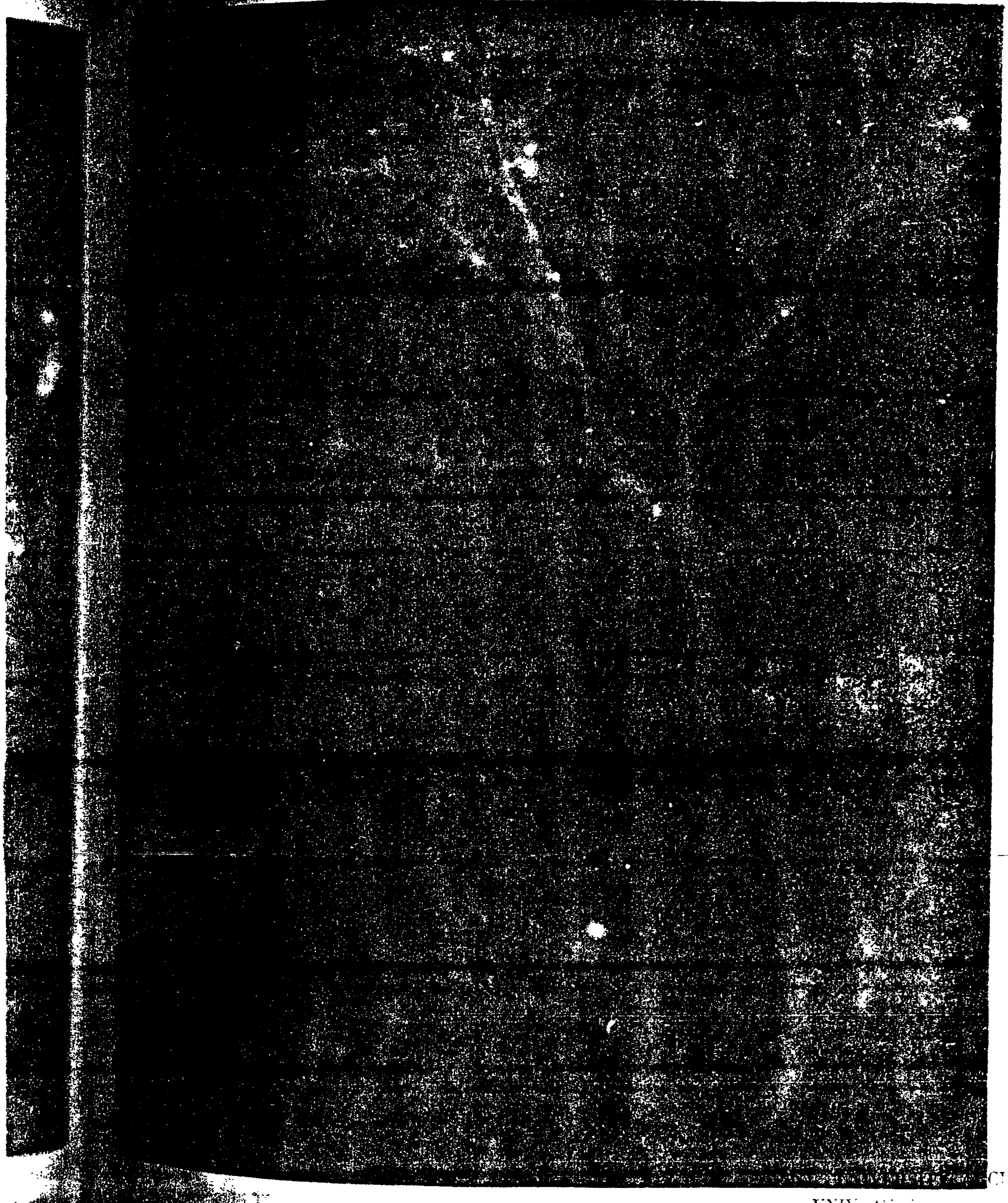


Figure 4b. Autoradiograph of Portulaca oleracea (#576) from Runit Island. Pl[...] taken 75 yards from tower base. Exposure: 51 days to No-Screen X-ray film.



Autoradiograph of Portulaca oleracea (#579) from Runit Island. Plant taken 250 yards from tower base. Exposure: 51 days to No-Screen X-ray film.

2

values. How plants growing in coral sand can be calcium deficient is somewhat of an anomaly and certainly warrants further study. The relative importance of calcium deficiency and radiation damage in producing the observed symptoms has not been determined.

MORPHOLOGICAL DEFORMITIES

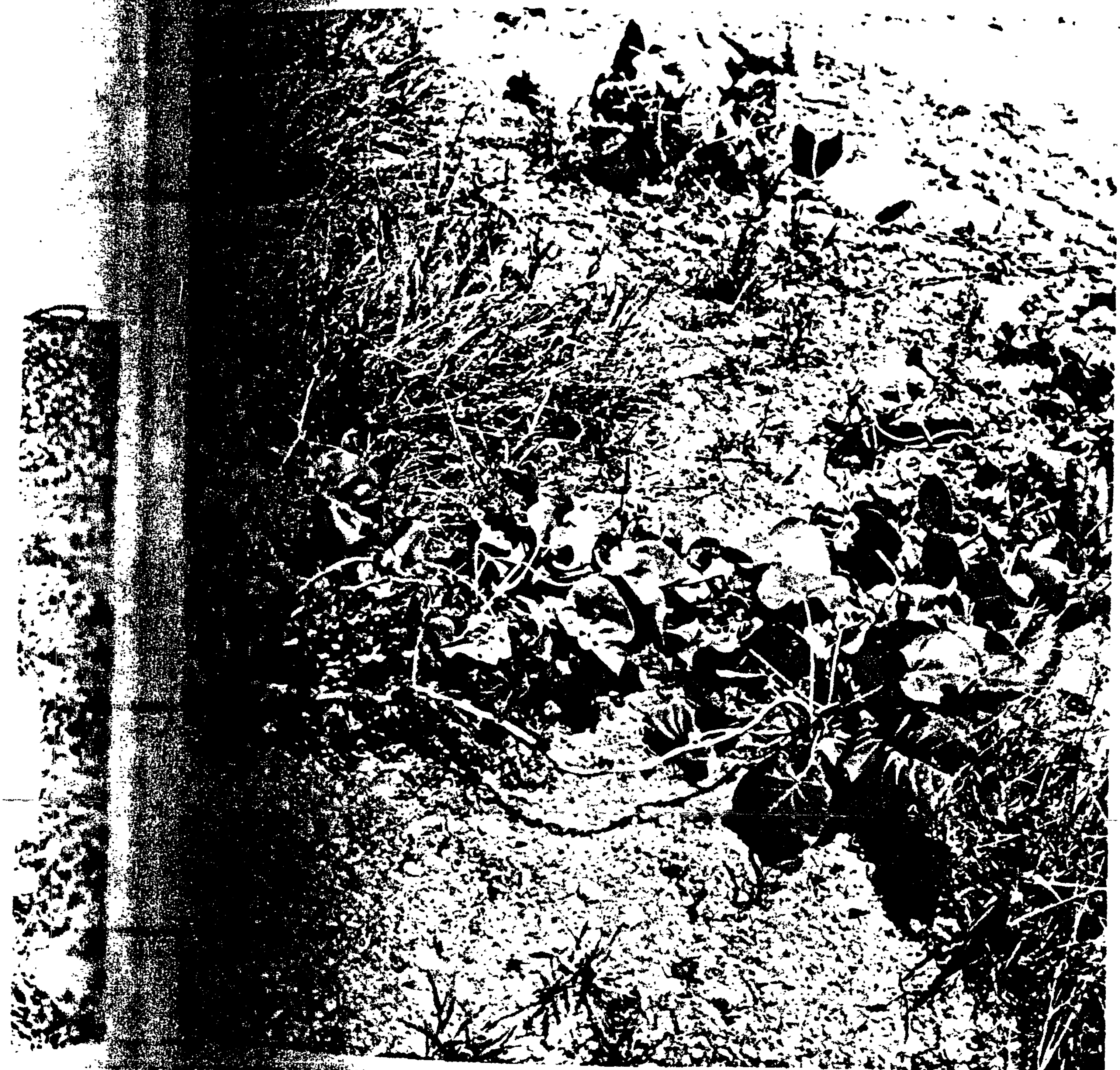
The most striking morphological deformities were found on Ipomoea Tuba growing on Engebi Island. A series of photographs comprising Figures 5, 6, 7, 8, 9 and 10 shows this species of plant in all degrees of severity in the deformations observed. Figure 5 represents the control, or normal material; Figure 6 shows areas wherein deformities occurred. These areas have not been fully covered by the dense growth of Ipomoea which surrounds them, but have persisted in grasses with stumps of deformed Ipomoea occurring, within the areas. Figure 7 shows a close-up of the grass and Ipomoea with tumorous growths at the basal nodes of the stem. Figure 8 is a close-up of the tumorous growths. Figure 9 shows a fasciation of the stem. This type of deformity is not rare in nature and should not be strictly considered as a peculiarity induced by the unusual environment of the "bombed" island. It may occur anywhere and with rather high frequency in some plants. Figure 10 shows the most severe deformation encountered. There is exposed on the clubby stem a mass of tumorous growths some of which have regenerated rudimentary leaves from the proliferated tissues. How such a deformed plant can manufacture sufficient carbohydrate to produce the clubby stem tissue is an anomaly.

The nature of the injury shown by these plants closely resembles that produced, in a number of species, by an excess of growth hormones or accessory growth-stimulating substances. An excess of these substances, above that which is required for normal growth, induces such deformities as is shown in the accompanying Figures. Figure 11[1] shows a geranium plant, the stem of which has been severed and the wound smeared with a mixture of indole-3-acetic acid in lanolin. The same tissue proliferation with partial regeneration of leafy shoots is observed. The similarities in the appearance of the tumorous tissues on the two species of plants lead one to suspect a common causal agent. If the condition in Ipomoea

[1]Unpublished results of O. Biddulph.

Ipomoea Tuba, Engebi Island. Normal plant.

Figure 6. Ipomoea Tuba, Engebi Island. Area in which abnormal plants were found



were ... Ipomoea Tuba, Engebi Island. To the left, tumorous growths at the ... nodes of the stem.

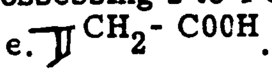
Figure 8. Ipomoea Tuba, Engebi Island. Tumorous growths.

Ipomoea Tuba, Engebi Island. Fasciation of the stems.

8

Figure 10. Ipomoea Tuba, Engebi Island. Tumorous growths and regenerat[e]
rudimentary leaves.

ium plant showing tumorous growth induced by indole-3-acetic

Engebi Island is induced by radiation, one would immediately look for a link between radiation damage and indole-3-acetic acid production in the injured tissues. This is an intriguing possibility. The problem could be attacked rather directly and should be of immediate interest to many people. In this regard, it should be ascertained if any weed-eradicating chemicals have been employed on the island, or if any equipment used for such substances has been employed there. Any chemical substance possessing an unsaturated bond in a ring supporting a carboxyl group on a side chain possessing 2 to 4 carbons could logically be suspected to produce similar effects, i.e. 

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The radioactivity in the tumorous tissue is low. This species is deep rooted and normally absorbs from a depth below that penetrated by neutrons, hence little Ca^{45} would be expected in the root feeding zone of this species. Fission products, on the other hand, may be expected on the surface of such plants, having been splashed upon it by the action of raindrops on the soil surface. Time did not permit a more thorough investigation of this problem.

A second species showing deformations was encountered on Aitsu, one of the islands within the fallout zone of Aomon. Figure 12 shows a coconut palm with spirally-twisted leaves. A number of other coconut palms in the same vicinity showed similar but less severe symptoms. This spiraling of leaves is perhaps caused by a disturbance in the pattern of cell division in the meristematic zone. It is not as severe a disturbance as that leading to complete disruption in the organization of cell cleavage patterns, as is the case for tumors, but the disturbance is in the same direction.

GENERAL OBSERVATIONS

The overall impression gained from the examination of the three "test" islands is that growth of certain plants has been largely impossible because of the destruction of their natural habitats. In addition, the crater formed by the bomb presents additional problems. The mechanical removal by the blast of the surface layer of soil has taken away the accumulation of what might be termed the "top soil" of that immediate area. This may be a contributing factor to the calcium deficiency observed in the vicinity of the crater.

From the center of the blast outward there exists a marked zoning of

Coconut palm, Aitsu Island showing spirally-twisted leaves.

vegetation, the general pattern of which is similar for each of the three islands. The radius of similar zones, however, on the three islands varies. In brief, the zones occur as follows: (1) a zone of little vegetation: Engebi to 400 yards radius, Aomon to 300 yards radius, Runit to 250 yards radius; (2) a zone of scattered clumps of plants: Engebi - 400 to 500 yards, Aomon - 300 to 400 yards, Runit - 250 to 300 yards; (3) a zone of rather continuous plants, many of which show chlorosis (not sharply delimited on the outer edge); (4) a zone where disturbed ecological habitats are a more important factor in exclusion of plants than bomb effects.

SUMMARY

(1) The amount of radioactive fission products absorbed by the roots, translocated through the plant and deposited internally within the tissues of the coconut palms at Bikini and Eniwetok Atolls is very small. Activity was not encountered which was in excess of twice that found in the control material from [illegible] or in crop plants grown in the agricultural soils of the Columbia Plateau in Washington State.

(2) Significant radioactivity persists on the dead leaf bases and in the accumulation of debris located in the axils of the leaf bases in those areas where "fallout" of radioactive materials was expected. Counts ran as high as 8,100 cpm/100 mg of ash on Romuk Island, the highest encountered on Bikini Atoll and 530,000 c/min/mg ash on Aitsu, the highest for Eniwetok Atoll. This weight of ash corresponds to approximately one gram of dry plant material. The persistence of externally deposited fission products on the dead leaf bases is worthy of special note.

(3) Ca^{45} was formed by the n-γ reaction with Ca^{44} in the coral sands of Runit Island, and therefore presumably on Engebi and Aomon. Ca^{45} was then absorbed by the plants and resides within them as a component of the total calcium of the plants. The activities within Portulaca oleracea due to Ca^{45} were 734 d/min/gm of fresh tissues on March 14, 1950, or approximately 1500 d/min/gm of fresh tissue in August, 1949. (Plant taken 30 yards from tower base.)

(4) Fission products are scattered at random over the low-growing plants in the vicinity of the bomb craters. Their origin is presumably from the soil surface, having been splashed upon the plants by the action of raindrops on the soil,

scattering dust particles, etc. The total activity measured in and upon Portulaca oleracea plants 50 yards from the tower base on Runit Island was approximately 1500 d/min/gm of fresh tissue.

(5) An extreme calcium deficiency was observed in the Portulaca oleracea plants growing in the bomb crater on Runit Island, the severity of which was sufficient to cause the tissue disintegration and death of plants observed in this area.

(6) Morphological deformities were observed in three species of plants. The most striking was on Ipomoea Tuba on Engebi Island and consisted of a mass of tumorous growths over a much deformed stem. The tumorous growths resembled those produced by an excess of indole-3-acetic acid on some species of plants. The radioactivity of the tumorous masses was very low.

Other deformities occurred on several coconut palms on Aitsu Island; these consisted of twisted fronds, in some cases severe enough to cause spiraling or coiling of the fronds. The highest radioactivity counts were observed on coconut palms in this vicinity (see 2, above). Twisting or spiraling in the growth habit of one species of grass was observed on Engebi Island.

(7) It can be concluded that most fission products are poorly absorbed by plant roots and that high concentrations of these products will not be accumulated by plants. Fallout of fission products on the plants, however, can be expected to result in the retention by absorption on dead organic matter of such materials over many years.

(8) Future investigations should include: 1. the mechanism whereby calcium deficiency is induced in plants growing in the bomb crater; 2. the mechanism whereby tumor formation is induced, if it is caused by radiation; 3. the relationship, if any, of observed chlorosis in many plants to the bomb tests. Other probable causes include the disturbed ecological habitat under which the plants now persist due to clearance of the island.

LAND VERTEBRATES ENIWETOK

by

Frank G. Lowman

RATS

Rats of the concolor group, Rattus exulans (Peale, 1848), were collected at Eniwetok Atoll on Biijiri and Engebi Islands. Although this species has the same generic name as the "Old World" rats, it is probably not congeneric with them. R. exulans differs from the Norway and Black rats by having a shorter head and body, a difference in the mammae formula, and different coloration and texture of the pelage. R. exulans differs from the concolor rats of the Malay Archipelago and the Hawaiian rat in having a relatively longer tail.

The rats were caught in tin can traps. These were made by mounting a mousetrap in the open end of a tin can and attaching a lid to the trap jaw in such a manner that the lid springs shut when tripped by the animal. It is not possible to greatly alter the sensitivity of this device, and as a result, a greater number of hermit crabs and crickets were caught than rats

The traps were set near the openings of the rat burrows or in the runways, which were usually situated in medium to dense growths of morning glories (Ipomoea grandiflora) and sandbur (Cenchrus echinatus). In areas where there were no plants, R. exulans was not found.

The diet of this rat consists mainly of insects and grass seeds. Coconut meat and pandanus fruit are eaten when available. Oatmeal and "Post Toasties" breakfast foods were used for bait in the traps. The use of bacon or other greasy foods for bait was not successful.

The specimens collected for ashing were quick-frozen in a deep-freeze unit; others were killed by decapitation and the tissues fixed in Bouin's fixative. After fixation, the tissues were washed in 50 per cent alcohol and preserved in 70 per cent alcohol. In preliminary histological examinations of the liver, stomach d gut of rats collected near the Target Area at Engebi and from Biijiri Island, detectable effects of radiation were observed.

The amount of radioactivity found in the organs of the rats varied with amount of radioactive material present in the immediate area of the site of pping (see Table 1). The counts found in bone samples were the highest of y of the tissues and exhibited close correlation with the radioactivity of the itat. The correlation of the liver counts with habitat was somewhat less. That exulans on these islands probably does not migrate far from its burrow is strated by the three specimens from Engebi. Rat_1 was collected in an area ch registered 37,000 c/m on a Victoreen #263 survey meter and had a bone t of 1780 d/m/g. Rat_2 and Rat_3 were collected at another site only 650 feet that of Rat_1 in an area which registered 600 c/m on the same meter. Their counts were respectively 163 d/m/g and 153 d/m/g.

The counts found in the liver samples of the rats were relatively low in parison to those of the alimentary tract and the bone samples. The amount radioactivity in the digestive tract was variable although in all cases the animals not eaten contaminated food for at least twelve hours before being killed.

In lung and kidney samples, counts were found only in Rat_1 from Engebi nd. These were 25 d/m/g and 312 d/m/g, respectively.

The determination of d/m/g of total body weight (see Table 1) was computed the percent of total body weight for each organ. The amount of radioactivity gram of total animal was correlated somewhat with the amount of radioactivity area of trapping. Rat_1 from Engebi had 116 d/m/g of total animal and was t in an area which registered 37,000 c/m on a Victoreen-type #263 meter. and Rat_3 from the same island, had 15.2 and 10.7 d/m/g respectively of animal and were trapped in an area which registered 600 c/m on the survey . The rat from Biijiri had .6 d/m/g of total animal and was caught in an which registered 140 c/m on the meter.

The organs selected make up 33 per cent of the total body weight since cle, nervous tissue, blood, spleen, pancreas, heart, and connective tissue than bone was not sampled. The non-sampled tissues were considered to be ero activity and hence the d/m/g of total body weight is a minimum value.

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TABLE 1

Radioactivity in d/m/g by area and by tissue of four rats collected at Eniwetok Atoll, 1949.

Area Collected	Liver	Stomach	Gut	Bone	Lung	Kidney	Skin	Total Animal
Biijiri Island	3.69	21.3	9.0	*	0	-	-	0.86
Engebi Island$_1$	128.0	189.0	172.0	1780.0	25	312.0	-	116.0
Engebi Island$_2$	3.75	57.6	110.0	164.0	0	0	6.15	15.2
Engebi Island$_3$	2.7	1.11	20.0	153.0	0	0	7.05	10.7

* Ash lost

Per cent of body by weight of the tissues and organs of the rat *Rattus exulans*.

Liver	Stomach	Gut	Bone	Lung	Kidney	Skin
4.37	0.457	4.22	5.57	0.54	0.8	17.1

SUMMARY

From four rats collected on the Eniwetok Shot Islands, samples of seven different tissues were ashed and counted. There was considerable variation between tissue and between rats, but all rats showed some activity. The highest tissue count was in the bone, 1780 d/m/g, of the rat which also had the greatest amount of total body activity, 116 d/m/g, and was caught in an area with a very high background count, as determined by field survey instruments.

BIRDS

Three types of birds, all of which were terns (Fam. Laridae), also known as "sea swallows", were collected at Eniwetok on the islands of Igurin, Rigili, Bogon, and Runit. Within this family the fairy tern (*Gygis alba*), the white-capped noddy tern (*Anous minutus*), and the common noddy tern (*Anous stolidus*) were taken.

The three species of terns collected usually nest in areas having a sparse to medium growth of "Kilgin" or "Beach Magnolia" (*Scaevola*) bushes. The fairy tern does not build a nest but lays a single egg in the fork or on the broken end of a branch. The white-capped noddy tern and the common noddy tern make a nest of sticks and coarse grass in the branches of bushes or small trees. The fairy tern, and to some extent the two species of noddy terns, usually remain close to the nesting area thus facilitating the collection of specimens.

The amount of radioactivity found in the organs of these birds, whose diet consists mainly of fish, was small (see Table 2). The tendency of these forms to forage over a considerable area instead of confining themselves to one island, may, in part, account for this.

In those specimens collected, the liver contained detectable amounts of radioactivity more consistently than did the other organs. However, the amount found in the liver of a fairy tern at Igurin Island was equal to or greater than that found in birds collected at the islands in close proximity to the Target Area.

If the birds were picking up speck contamination with sand for the gizzard, one would expect the counts in the proventriculus and gizzard to be relatively high. In five specimens there was zero count and in two specimens only trace quantities

TABLE 2.

Radioactivity in d/m/g by area, species, and tissue of seven terns taken at Eniwetok Atoll, 1949.

Common Name	Area	Liver	Gizzard and Preventriculus	Gut	[illegible]
Fairy tern	Igurin Is.	2.6	0	0	[illegible]
White-capped noddy tern	Rigili Is.	0	0	0	[illegible]
Fairy tern	Bogon Is.	1.4	0	0	[illegible]
Noddy tern	Bogon Is.	1.8	0.6	5.1	[illegible]
White-capped noddy tern	Runit Is.	2.6	0	0	[illegible]
Noddy tern	Runit Is.	0	0	0	[illegible]
Noddy tern	Runit Is.	2.4	2.7	0	[illegible]

Although there was partially digested material in the gut of all birds collected, only one gut sample had any radioactivity present and in it only a small amount (5.1 d/m/g).

No counts were found in any of the bone samples of the birds.

SUMMARY

The counts of ashed tissue samples from seven terns of three species collected at Eniwetok ranged from 0 to 2.7 d/m/g. Because of the low values, possibly due to natural-occurring radioactive isotopes, the birds sampled are not considered as having acquired significant amounts of bomb-created isotopes.

Section VI

PLANKTON AND WATER SAMPLES

by

Allyn H. Seymour

PLANKTON

Samples of the lagoon plankton were collected by pumping the water from various depths through plankton nets. This method produced quantitative samples from a known depth with a minimum of effort. Other samples were collected from the ship's salt water supply, from towing small plankton nets, and from night collections using an underwater light and dip nets. Plankton collecting was a part-time assignment for two men and was scheduled for evenings and off days for field collections. The records of the plankton collections are presented in Table 1.

The pump was mounted on the afterdeck, starboard side of the LSIL. It was originally intended that a pump supplied by a 2-inch rubber hose would be used, but the pump placed in operation was capable of lifting 10,000 gallons of water per hour from a depth of 200 feet and was supplied by standard, reinforced, Navy fueling hose, a heavy, rubber-coated, 4-inch iron pipe.

The intake line led over a guide welded onto the stern and afterdeck up to a 3-inch reducing unit that led into the pump. From the Carver pump, Model 318, turned by a Wisconsin air-cooled motor, type AHH, the water either went through a line with a meter or a line that by-passed the meter, to a cylindrical tank in which plankton nets were hung. The tank was about 5-1/2 feet tall and 18 inches in diameter and was attached to the stern so that the bottom of the tank was about 2 feet above the ship's water line and the top of the tank about 2-1/2 feet above the level of the afterdeck. After a net had been suspended within the tank, water was pumped slowly through the net until the water level in the tank approached the top of the net. Then the valve in the outlet at the bottom of the tank was opened, and at the same time, the flow of water into the net was increased and the two adjusted so that as much of the net as possible was supported by the water, but with the water level remaining below the top of the net.

TABLE 1

PLANKTON COLLECTION RECORDS, 1949

Bikini

SAMPLE NUMBER	COLLECTED BY	AREA	SAMPLE DEPTH IN FT	DATE	HOUR From To	TIME IN MIN.	GALS PUMPED	MESH SIZE** NUMBER	#/m/g	CATCH AND REMARKS
I	Pump	Bikini Is. 2506	15	July 28	10:50a-12:28p	95	18000	0 & 25	0 & 70	#0 net practically no catch. About 10 gms in #25 net including copepods & invertebrate larvae.
II	"	"	"	"	1:55p-3:37p	105	18800	6 & 25	8 & 184	Fair catch in #6 net. #25 catch similar to I. Depth 6 to 7 fms (36-42 ft).
III	"	"	"	"	3:45p-5:50p	127	15800	12 & 25	6 & 84	Catch in two nets about equal.
IV	"	"	"	"	5:55p-7:35p	100	14800	6	0	#12 torn, no catch; small catch in #6.
V	"	"	"	"	7:41p-10:01p	140	20000	25	6	#12 torn, no catch; smaller catch than expected. Using light when not in use for night fishing.
VI	"	"	"	"	10:05p-10:45p	40	4000	6	0	Slowed engine down
VII	"	"	"	28-29	10:55p-12:34a	100	14400	6 & 25	0 & 3	
VIII	"	"	"	29	12:35a-12:45a	10	825	20	0	Engine stopped
IX	"	Target 2501	140	"	11:47a-1:15p	88	11800	25	218	Very small catch. Practically nothing in #6 net; Both catches combined.
X	"	"	"	"	3:50p-5:55p	125	14800	12 & 25	128 & 205	Engine would not start; replaced distributor; small catches.
XI	"	"	70	"	6:45p-9:05p	137	16800	6 & 25	0 & 279	
XII	"	"	15	29-30	10:25p-1:15a	172	21800	6	0	#25 torn, no catch; fish in #6 net.
XIII	"	"	"	30	2:17a-7:17a	300	36000	6 & 25	66 & 0	Fish in #6 net. Net unattended after 2:30am. Meter not used to avoid clogging while unattended.
XIV	"	"	"	"	8:45a-10:45a	120	13800	20	66	Some fish in catch. Depth 27-29 fm (162-174 ft).
XV	"	2505	"	31	8:52a-9:34a	42	4000	20	38	
XVI	"	"	"	"	9:35a-11:27a	112	9400	20		Sample lost.
XVII	"	"	"	31-Aug 1	11:27a-7:00a	1167	80000	20		Net overflowed at 4am. Changed net and valve. Sample lost.
XVIII	"	"	"	Aug 4	10:15a-12:51p	152	7600	20	12	Overflowed some.
XIX	"	"	"	"	1:15p-2:15p	60	3800	20	3	
XX	Towing	"	0-25	"	10:25a-11:25a	60		0	0	Dragged on bottom and filled with sand. No catch. Towed in circles around LSIL.
XXI	"	"	0-50	"	1:25p-2:25p	60		0 & 20	4 & 0	Combined catches, both small. Towing within 150 yds of LSIL 1091.
XXII	Night Fishing	"	0-5	Aug 5	12:15a-2:20a	125		20	15	With underwater light, lifting net by hand.

Eniwetok

SAMPLE NUMBER	COLLECTED BY	AREA	SAMPLE DEPTH IN FT	DATE	HOUR From To	TIME IN MIN.	GALS PUMPED	MESH SIZE** NUMBER	#/m/g	CATCH AND REMARKS
1	Pump	Eniwetok Is.	15	August 7-8	2:05p-8:25a	1222	61000	Pl.&20	- & 0	Overflowed twice, afternoon and morning. Depth 22 fm(132 ft).
[illegible]	"	Engebi Is.	40	11-12	2:22p-7:12a	1000	13800	20	305	Overflowed at 7am. Depth 12 fm(72 ft).
[illegible]	"	"	"	12	7:12a-12:32p	320	4300	20	306	
[illegible]	"	Aomon-Bijirii	"	13-14	10:35a-2:35p	900*	9000	20	1503	Net at bottom of tank at 2pm. Bridle broke. Replaced with new net at 2:20pm. Ran out of gas. Couldn't get started until 11:45am, then stopped 12:45, started 1:30.
[illegible]	"	Rumit	15	14-15	3:50p-8:00a	970	6800	20	404	Depth 12 fm(72 ft).
16	"	"	"	15	8:15a-10:00a	105	4800	25	94	80 gals/min, 8:15-9:15.
17	"	"	"	"	10:45a-12:15p	90	4800	25	258	Started at 90 gals/min, then gradually reduced to 6 gals/min.
18	"	"	"	15-16	12:45p-12:15a	700*	12800	25	464	Ran out of gas shortly after midnight.
[illegible]	Shower head	Eniwetok Is.	6	9-10	6:00p-7:30a	810	3200	20	10	Intake through ship's pumping system. No overflow of net.
[illegible]	"	Engebi Is.	"	10-11	5:05p-2:05p	1260	3000	20	0	3 gals/65 secs.
[illegible]	"	"	"	11-12	7:02p-7:02a	720	1470	20	195	
[illegible]	"	"	"	12	7:45a-3:45p	480	1150	20	507	
[illegible]	"	Aomon-B	"	12-13	4:50p-8:23a	933	2240	20	81	Depth 12 fm(72 ft).
[illegible]	"	"	"	13-14	8:30a-11:45a	1545	3100	20	348	Off from 2:05pm to 3:35 pm.
[illegible]	"	Rumit	"	14-15	4:00p-7:00a	2000	4800	20	265	Off a total of about 6 hours during this period. Flow varied from 3 gals/42 Sec to 3 gals/93 secs.
[illegible]	Night fishing	Engebi Is.	Surface	12	9:30p-11:15p			Pl.	1	Fishing with light and plastic cone deep net. Macroplankton showed well for a few minutes at first, but not again during fishing period.
10	"	Aomon-Bijirii	"	"	9:30p-11:00p			Pl.	5	Fishing with light. Fair fishing; 1 jar fish, 1 jar plankton, 1 jar annelid worms (Nereis). 6 atherinids & 1 half beak to Tinker, 2 priacanthids to Welander.
[illegible]	"	"	"	13	9:40p-11:20p			Pl.	2	Mysids abundant. Fish put in #10.
[illegible]	"	Rumit	"	14	9:50p-10:50p			Pl.	7	Mysids abundant.

Likiep

SAMPLE NUMBER	COLLECTED BY	AREA	SAMPLE DEPTH IN FT	DATE	HOUR From To	TIME IN MIN.	GALS PUMPED	MESH SIZE** NUMBER	#/m/g	CATCH AND REMARKS
22	Pump	Likiep	30	20	1:45p-11:59p	600*	9000	25	84	Ran out of gas in night. Net then broke. Most of catch saved. Leak in outlet drained tank as valve was closed.
23	"	"	"	21-22	7:10p-11:40a	1050	12600	20	18	Net overflowed at 11:40am (Aug 22). Hole in net at 7:15am (Aug 22).
21	Shower head	"	6	19-22	8:30a-11:30p	4500	9000	20	38	Depth 8 fm(48 ft).
24	"	"	"	22	11:30a-2:00p	150	300	20	66	
20	Night fishing	"	Surface	20	12:05a-2:10a			Pl	3	Little plankton; many fish of all sizes.
	"	"	"	20	9:30p-11:20p					Caught no plankton, other than fish and larvae. Few species but abundant.
	"	"	"	21	10:10p-11:00p					Observed only small fish which were well represented in sample #22. Some luminescence in water.

*See Catch and Remarks column.

**Pl - Plastic flyscreen, #0 - 38 meshes per inch, #6 - 74 meshes per inch, #12 - 125 meshes per inch, #20 - 173 meshes per inch, #25 - 200 meshes per inch.

[illegible] the amount of water pumped could be closely estimated. The amount of water passing from the pump to the net was measured with a Sparling meter, but once a constant flow was established, the water was usually shunted around the meter to protect the meter from unnecessary damage. The water flow through the net hung on the shower outlet was 2 to 3 gallons per minute.

Since the nets were re-used, contamination of one sample by another depended upon removing the entire sample after each catch. With the fine-meshed nets, this required special attention. All nets were thoroughly washed down and those that had become clogged were vigorously rubbed together by hand in water. On some occasions, the meshes were microscopically examined to determine if they were clogged. The wash water was saved, allowed to settle, and the residue after decantation, added to the sample. All samples were preserved in formalin.

Plankton activity in disintegrations per minute per gram of wet drained sample, by area, by sampling method, and by mesh size is given in Table 2. Two general conclusions may be made from the data presented in the Table: (1) Catches from the fine-meshed nets, 125 or more meshes per inch yielded the highest counts. Catches of macroplankton from the night collections were low in activity. Therefore, in comparing catches between areas, or depths, or time of day, it would appear that only counts from the fine-meshed nets should be used. (2) Activity was greatest near the Eniwetok Shot Islands and next greatest in the Bikini Target Area. If the definition of the term "background" is extended to mean the count of a similar type of sample at a control station, in this case from Likiep Lagoon, then the activity in the plankton immediately off Bikini Island was "background"; in Bikini Target Area, about three times background; off Eniwetok Shot Islands, about eight times background; and off Eniwetok Island, background.

At a depth of 15 feet, catches made in the fine-meshed nets in the same area during daylight hours gave higher average counts than those collected during hours of darkness. Values in d/m/g for Bikini Island during the day were 70, 164, [illegible], 84, 38, 12, and 3; at night, 6 and 3; and for Bikini Target Area, day, 86; night 0. Other catches were not comparable by the criteria established above.

To find out if the activity of the plankton varies with depth of sample, activity of catches comparable as to mesh size, time of day, and area were compared. For Bikini Target Area the radioactivity expressed as d/m/g of three

TABLE 2.

Radioactivity of plankton by area, by sampling method and by mesh size expressed as d/m/g of wet drained sample, 1949.

Method		Pump				Shower head		Night fishing		Towing			
Mesh Size		fine*		coarse**		fine		coarse		fine		coarse	
Atoll	Area	d/m/g	n	d/m/g	n	d/m/g	n	d/m/g	n	d/m/g	n	d/m/g	n
Eniwetok	Aomon-Biijiri	1503	1			214	2	3	2				
	Engebi	350	2			134	3	2	1				
	Runit	304	4			266	1	8	1				
	Eniwetok	0	1			10	1						
	Average	427				149		3					
Bikini	2201, Target	151	6	22	3					0	1	2	2
	2505, Bikini	48	7	0	5			16	1				
	Average	100		3				16		0		1	
Likiep	Likiep	51	2			52	2	3	1				

* 125, 173 or 200 meshes per inch.

** 38 or 74 meshes per inch.

n= number of samples.

samples from 140 foot depth averaged 181; one sample from 70 feet, 279; and one sample from 15 feet, 86. This would suggest higher counts from the deep samples compared to the 15-foot sample, but since the counts of samples taken at a depth of 15 feet off Bikini Island ranged from 6 to 164 d/m/g, the differences should not be considered significant with the limited data presented. If the water off the Shot Islands at Eniwetok can be considered as one mass, the samples from 49 feet taken off Engebi and Aomon-Biijiri can be compared with samples from 15 feet off Runit. Three samples from 49 feet off Engebi and Aomon-Biijiri Islands averaged 618 d/m/g and four samples from Runit at 15 feet averaged 304 d/m/g.

The 1948 and the 1949 estimates of radioactivity in the plankton from comparable areas are given below. The 1948 values were expressed as millimicrocuries per kilogram of wet tissue and have been converted to disintegrations per minute per gram of wet tissue by multiplying by 2.2.

	1948	1949
Bikini Island	55	48
Bikini Target Area	290	151
Aomon Island	2858	1503
Engebi Island	990	350

SUMMARY

During July-August, 1949, 46 plankton samples were collected from Bikini, Eniwetok and Likiep Atolls. Samples were collected by pumping from various depths, from the ship's shower supply, from towing nets, and from night collections. Radioactivity of the plankton samples from Likiep, the control station, average approximately 50 disintegrations per minute per gram. Compared to the control stations, radioactivity of plankton samples taken off Bikini Island was the same; in Bikini Target Area, three times greater; and off the Eniwetok Shot Islands, eight times greater. As in 1948, the highest counts in 1949 were from catches in the fine-meshed nets. For comparable areas in which counts were greater than the control station, the d/m/g of plankton in 1949 was approximately one half the 1948 value.

WATER SAMPLES

Water samples were collected and prepared in the field by Paul J. Kell[illegible] Analysis for alpha activity was done at the laboratory of the Atomic Energy [illegible] University of California at Los Angeles, by Kermit H. Larson, Assistant Chi[illegible] Alamogordo Section.

The technique used in the field to bring back a large sample in a small container was to evaporate 3 liters of sea water to about 450 cc. on a hot plate and then pour the hot concentrated sea water into a glass-stoppered 500 ml. [illegible] The evaporating dish was then washed out with 50 cc. of the same sea water [illegible] which 5 cc. of technical grade HNO_3 had been added. It was assumed that the [illegible] washing with dilute HNO_3 dissolved only a negligible amount of the enamel evapora-tion dish. This technique left almost no precipitated salt in the dish.

The activity extracted from the water samples, as such, is not signific[illegible] especially when compared to the amount of alpha activity contained in tap water at the University of California at Los Angeles Laboratory and from surface sea water from Santa Monica Bay (see Table 3). Also, it is interesting to note that the alpha activity obtained by using a nitric acid wash on the sample bottles after a thorough water rinse was sometimes greater than the sample itself.

The problem of absorption by glass of alpha emitters, as well as isotopes, is not thoroughly understood. Recently a group at Rochester reported that the amount of uranium absorbed by glass is 1 p.p.m. For plutonium the value is [illegible] known, but Larson reports that his results indicate that some does absorb.

SUMMARY

The 3-liter samples of sea water from Bikini, Eniwetok and Likiep that were evaporated to 1/2 a liter and then sent to the laboratory at the University of California at Los Angeles for counting did not show significantly greater alpha [illegible] vity than a sample from Santa Monica Bay and showed less alpha activity than a sample of laboratory tap water.

TABLE 3.

Alpha activity of water samples from Bikini, Eniwetok, Likiep, Los Angeles, 1949.

Region	Location	Depth feet	Original sample volume liters	Ml. HNO_3 added to collected sample	Alpha activity obtained Dis/hr/liter	Total alpha activity from HNO_3 rinse of sample bottle Dis/hr/total rinse
Eniwetok Atoll	Engebi Island	49	3.10	10	10	0.0
	Aomon-Biijiri Is.	49	3.05	5	24	16.0
	Aomon-Biijiri Is.	49	3.05	5	12	0.0
	Runit Island	15	3.05	5	31	4.0
Bikini Atoll	Bikini Is., Area 2505	15	3.15	10	39	112.0
	Bikini Is., Area 2505	15	3.05	5	16	0.0
	Target Area, Area 2201	140	3.02	4	36	24.0
		70	3.05	5	24	98.0
		0	3.05	5	23	0.0
Likiep Atoll	Likiep Island	15	3.05	5	42	38.0
Los Angeles	Santa Monica Bay	0	-	-	18	-
	Laboratory tap water	-	-	-	59	-

The ferric hydroxide procedure was used in above determinations. At present, it is not known whether or not thorium and/or uranium (naturally occurring) is picked up by this method. (This table was prepared by Kermit H. Larson).

AECD-3446

ALGAE

by
Ralph F. Palumbo

OCCURRENCE, HABITAT AND IDENTIFICATION

Algae were collected for the most part in the same area as that chosen for the collection of the fish samples, and usually at about the same time. Thus the bulk of the samples of algae were derived from localities similar to those for the fish, and should provide a good comparison between the two, as in many cases, the fish collected might have been feeding on the algae in that area. The majority of the algae were collected in water the depth of which ranged from six feet to the shore line of the inner reef, in pounding surf or in fairly rough water. The remainder of the collecting was done while wading along the shore line of the inner and outer reefs, in the tide flat between the reefs, and in small pools left along the shore among the rocks. Some specimens were picked up on the beach and on debris floated ashore. Samples were also obtained from the bottom of the lagoons by means of dredging from a small boat; other samples were obtained from buoys anchored in the Bikini Target Area.

Various habitats were included in the collecting. In deep water, samples were obtained mainly from coral heads and from the sandy bottom where the light was not strong. In other cases, the samples were located in very shallow water in strong light, either in tide pools or on the reef in the strong surf. In certain cases, the algae were found in crevices or on the under side of the rocks hidden from view, but in the path of constantly surging water.

Several different methods were attempted to facilitate the collecting and storage of the specimens for further study. Due to the depth of water involved, it was difficult to swim with much equipment attached to the person; so it was necessary to put all specimens into a capped jar and to transfer the separate species of algae to smaller bottles upon reaching shore. Because of the difficulty of submerging repeatedly with such a container, a small bag made of plastic screen was substituted and the collecting was made simpler and more effective. Collections along the shore were made without much trouble, requiring only a bucket and small sample bottles with the proper labels. A knife or scraper was often used to pry it samples away from the rocks. These in turn were placed in sea water for fer to the appropriate containers. Once the samples were returned to the ship as headquarters, they were sorted, preserved in an alcohol-formalin solution, ressed for drying and later mounting. A complete sample of the collection was -frozen for radiological assay at the University of Washington laboratory.

The collecting of algae was separated into two phases. The first phase idered the collection of ten specific algae from each of the collection stations, the second phase consisted of a general collection of any algae available. As hole, most of the algae were not present at all the stations, or could not be d in the time allotted; in fact, the majority of the algae were to be found in but of the stations chosen. This statement holds true for all of the algae with the ption of the genus Halimeda, which was found in abundance at all the spots in ch collections were made. At three of four stations no more than three different cies of algae were obtained for further study because of the paucitv of the flora these points.

The ten algal groups selected were chosen because they were most abundant the collections of former years and because they are probably used for food by fish of the area. The genera in certain cases included more than one particular species; this was allowed because of the confusion and similarity between the pecies of the same genus and the difficulty involved in separating one from the her. The genera collected included species from different phylogenetic groups the algae, but for the most part the algae were fleshy and undoubtedly eaten the fauna of the region.

The genera chosen, their occurrence at the collecting stations, and their abitat are given in Table 1. The habitats of the various algae differed from one nother in addition to the fact that their distribution was dissimilar. In most cases e same algae were found in the same habitat. As an example Halimeda was sually found attached to the bottom and to coral heads under water, whereas ctocarpus was usually found attached to the reef at the water line.

As a whole the number of algae at Eniwetok Atoll is meager as compared to at at Bikini. This is undoubtedly a result of destructive forces and not a natural ondition. As an example to illustrate this point, the collection made off Engebi

TABLE 1

Occurrence and habitat of ten common algae at collection stations.

	Station																	Habitat
	Bikini-inside	Enyu-channel	Amen-general	Rokar-dredge 60-100'	Rokar-dredge 150'	Erik-inside	Boro-inside	Namu-general	Japtan-inside	Igurin-inside	Rigili-inside	Engebi-inside	Eberiru-inside	Eberiru-Amon dredge 40-60'	Runit-N. W. tip	Likiep-inside	Likiep-outside	
Halimeda	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	Attached to the bottom or to coral heads in all depths of water.
Udotea	P	P	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	Growing singly in small clumps in conjunction with Halimeda.
Microdictyon	P	P	P	P	P	P	P	P	P	P	-	-	-	-	P	P	P	Attached usually to other algae or to rocks at varying depths.
Cladophora	P	-	P	-	-	P	S	S	-	-	-	P	P	-	P	-	-	Found free floating or attached to rocks in low water.
Dictyosphaeria	P	P	P	-	-	P	-	-	-	-	-	-	-	-	-	P	-	Attached to coral heads in large clumps in 3-6' water.
Turbinaria	P	-	-	-	-	P	-	S	-	-	-	-	-	-	-	-	-	Attached always to the bottom in sandy areas.
Caulerpa	P	P	P	-	P	P	P	P	P	P	P	P	-	-	P	-	P	Attached to coral heads in deep water in large masses, or in shallow water in fast running water.
Polysiphonia type	P	-	P	P	-	-	-	S	P	-	-	P	P	-	P	-	-	In fast flowing deep water with low light.
Liagora	-	P	P	P	-	-	-	-		-	-		-	-	-	P	P	Attached to the bottom at varying depths
[illegible]			P	-			S			P	-		-	-		-	-	Usually found in low water with plenty of light at the shore line.

P = collected for study   - = not present   S = present, but not in sufficient quantities for sampling nd in the vicinity of the debris resulting from the blast consisted of two algae, dophora and Lyngbia. These algae are primitive in type and could be expected e the first to reappear after the flora had been exterminated. Other more ad-ced forms were not present in this area but were found in abundance at the r islands not exposed to the effects of the blast. The algae were found in great bers at Bikini, Enyu, Amen, Erik, Namu, and Likiep Islands, even though number of different species was not great.

The second phase was to collect all algae that were found. Following is a mary of these algae including name, location, and usual habitat:

1.	Lithothamnion sp.	Bikini I., Likiep (Lado) - on outer reef, forming part of the reef itself, giving the characteristic red color to the reef.
2.	Lithopyllum sp.	Bikini I., Amen I. - on outer reef, and also making up the reef.
3.	Avrainvillea sp.	Bikini I., Enyu I. - found only in isolated spots attached to coral heads similar to Udotea.
4.	Scytonema Myochrous	Enyu I., Amen I., Runit I. - attached to rocks, found on LCT 816 at the water line.
5.	Padina sp.	Amen I., Eberiru-Aomon (dredge 40-60') - attached to rocks and barge at varying depths.
6.	Hydroclathrus sp.	Amen I. only - attached to the bottom, sparse growth.
7.	Lyngbia semiplena	Amen I., Erik I., Eberiru-Aomon (dredge 40-60') - in fast-flowing water attached to rocks.
8.	Valonia sp.	Igurin I., Rigili I., Eberiru-Aomon dredge, Likiep I. (outside) - attached on the under side of rocks usually in low water.
9.	Dictyota sp.	Rokar-Enyu dredge (60-100'), Eberiru I., Eberiru-Aomon dredge - attached to rocks at varying depths.

10.	Laurencia sp.	Rokar-Enyu (dredge 60-100'), Erik I., Japtan I., Likiep (inside)-attached to the bottom in large tuft s.
11.	Asperogopsis Sanfordiana	Japtan I., Igurin I. - in tufts attached to the sandy bottom.
12.	Hormothamnion enteromorphoides	Rigili I., Eberiru I. - in fast-flowing water on bottom or attached to rocks.
13.	Lyngbia majuscula	Rigili I., Engebi I., Eberiru I. - attached to debris on bottom in fairly deep water.
14.	Bryopsis pennatifida	Attached to rocks in large clumps at the water line.
15.	Pockockiella sp.	Eberiru-Aomon dredge, Likiep I. (inside) attached to the under side of rocks in low light.
16.	Neomeris sp.	Likiep I. (outside) - attached to the bottom and to the reef in low, fast, running water.
17.	Hydrocoleum confluens	Boro I. only - on outer reef in fast water, forming a slimy cover.
18.	Chlorodesmis comosa	Amen I. only - on rocks and inner reef in large clumps at water line.
19.	Jania sp.	Amen I., Japtan I., Engebi I., Eberiru I., Runit I. - may be confused with Poly... attached to rocks and coral heads in shallow water in tufts covering large areas.

This list does not include certain algae sent out for identification, nor does it include the different species of some of the genera, such as Halimeda and Caulerpa, of which there are several. A completed list of all of the species collected will be compiled as soon as all the information is gatherea.

Dried specimens of the algae have been mounted, and a set will be available at the herbarium of the University of Washington. Preserved specimens will be kept at the Applied Fisheries Laboratory for future reference.

Aid in verification and identification of the samples has been given by the

...ing people:

Dr. Francis Drouet of the Chicago Natural History Museum.
Dr. Lois Eubank of Mills College, Oakland, California.
Dr. Isabelle Abbott of the University of California at Berkeley.
Dr. G. J. Hollenberg of Redlands University, Redlands, California.
Dr. G. F. Papenfuss of the University of California at Berkeley.

...DIOACTIVITY

Radioautographs of Halimeda, Lyngbia, Udotea, Dictyota, Microdictyon ... Bryopsis have been made but are not shown in this report.

The frozen algae samples were ashed and counted by the standard procedure ...lined in an earlier section. After counting, the algae samples were grouped by ..., by species, and by phylogenetic relationship, and the activity of the samples ...pressed as d/m/g - was tabulated.

In Table 2 the average count of all algae samples from the same locality ... listed according to descending order of activity. The four areas at the top of ... list are in the vicinity of the Eniwetok Shot Islands and are followed by two ...mples from the Bikini Target Area.

The average d/m/g for each species from all areas combined are listed ... descending order of magnitude in Table 3. This listing indicates that the ...ore succulent forms contain the highest activity. These algae as a rule were ...ound in low water close to the shore line. As an example, Bryopsis was found ...long the shore on Engebi Island; it is succulent and had a high activity. The ...ame can be said of Lyngbia, Scytomema, and Hormothamnion. In contrast, the ...orallines such as Halimeda, Lithothamnion, and Lithophyllum showed hardly any ...ctivity even though also found along the shore.

Table 2 does not necessarily give a true picture of the algae activity by ...ocality nor does Table 3 necessarily give a true picture of the algae activity by ...pecies because all species were not collected in all areas. The range in values ...rom a common area and the variation in values between species are shown in the ...abulation below of the activity of the algae samples collected from Engebi, Eberiru, ...nd Runit Islands, Eniwetok Atoll:

TABLE 2

Activity of algae samples by locality, 1949.

Locality code	Atoll	Island	n	1949 average d/m/g
M	Eniwetok	Eberiru	7	2412
O	"	Runit	6	2289
L	"	Engebi	6	1224
N	"	Eberiru-dredged	4	270
E	Bikini	Target buoys	5	79
DD	"	Target-dredged	6	51
D	"	Rokar, dr. 2795	5	13
C	"	Amen	13	9
A	"	Bikini, 2407	10	9
F	"	Erik, 0390	7	7
B	"	Enyu, 2895	13	4
Q	Likiep	Lado (outside)	10	3
P	"	Lado (inside)	12	2
H	Bikini	Namu (W. tip)	4	1.5
J	Eniwetok	Igurin (inside)	7	1
I	"	Japtan (inside N. end)	6	1
K	"	Rigili (inside)	4	0
G	Bikini	Boro	4	0
		Total	129	

TABLE 3

Activity of algae samples by species, 1949.

Code No.	Name	n	Average d/m/g
42	Lyngbia majuscula	2	3366
28	Scytonema Myochrous	3	2238
41	Hormothamnion enteromorphoides	2	1668
23	Polysiphonaceous type	6	1525
43	Bryopsis pennatifida	1	1386
36	Dictvota major	3	1330
8	Cladophora lutoela	4	798
3	Microdictyon japonicum	10	249
30	Padina commersoni	2	114
1	Halimeda sp.	15	103
15	Caulerpa racemosa var. clavifera	9	100
35	Valonia fastigiata	3	30
12	Turbinaria ornata	2	24
29	Ectocarpus sp.	2	21
5	Microdictyon Okamurai	8	19
9	Dictyosphaeria cavernosa	4	18
39	Caulerpa Urvilliana	1	16
38	Laurencia	3	9
6	Lithothamnion sp.	2	7
14 and 21	Caulerpa racemosa var. uvifera	7	6
19	Udotea orientalis	2	4
7	Lithophyllum sp.	2	3
2	Halimeda tuna	2	1
26	Liagora farinosa and app.	4	1
10	Halimeda sp.	2	0
20	Avrainvillea sp.	1	0
24	Halimeda sp.	1	0
25	Halimeda sp.	1	0
31	Polysiphonaceous red alga	1	0
32	Hydroclathrus clathratus	1	0
33	Cladophora sp.	1	0
40	Asperegopsis sp.	1	0
44	Udotea sp.	1	0
45	Laurencia sp.	1	0
46	Pocockiella Papenfussii	1	0

	Alga	d/m/g
1.	Ectocarpus sp.	6255
2.	Lyngbia majuscula	3366
3.	Hormothamnion enteromorphoides	3334
4.	Dictyota major	3 309
5.	Microdictyon japonicum	2392
6.	Polysiphonaceous type	2287
7.	Bryopsis pennatifida	1386
8.	Cladophora luteola	1060
9.	Caulerpa racemosa var. uvifera	901
10.	Halimeda sp.	426
11.	Caulerpa racemosa	42

Although most of the succulent forms appear at the top of the list, an exception is Caulerpa. It might be expected that Halimeda, a coralline alga, would be of relatively low activity because of its high percentage of calcareous material.

There is little correlation of activity with phylogenetic sequence as shown in the present data (see Table 4). However, the relationship may be obscured by the fact that all species were not available in all areas, and the data are from collections in all areas, both active and inactive. A more extensive collection would be necessary before any valid conclusions could be made.

A comparison between algae activity in 1948 and that in 1949 is given below:

ALGAE ACTIVITY, 1948 AND 1949

		1948		1949	
Atoll	Area	n	average d/m/g	n	average d/m/g
Eniwetok	Shot Islands	23	2710	23	1700
	Other	32	174	17	1
Bikini	Target Area	15	425	11	64
	N to E reef: Uku to Amen to Bikini to Rokar	97	45	28	10
	Other	54	20	28	4
Likiep	Lado	-	-	22	3

The 1948 values were converted from millimicrocuries per kilogram to d/m/g by multiplying by 2.2.

SUMMARY

To date, thirty-five algae types have been identified from samples collected at eighteen stations at Bikini, Eniwetok, and Likiep Atolls during July and August, 1949. One hundred and twenty-nine frozen samples were ashed and counted. The average d/m/g for Likiep, the control area, was three. For Bikini Atoll, the average count for the area from the north to east reef - Amen I., Bikini I., Rokar I. - was two to three times the Likiep average; for the Target Area, about ten times the Likiep average; and for the remainder of the atoll, approximately the same as Likiep. For Eniwetok, the average algae count of samples collected in the vicinity of the blast areas was five hundred to six hundred times the average Likiep value, but for the rest of the atoll, the average values were equal to or less than the Likiep average. Of the various types of algae, the succulent forms were usually the most active. The 1949 value for the active areas was roughly one-half the 1948 average value for the same area.

TABLE 4

Activity of algae arranged as to phylogenetic sequence, 1949.

			d/m/g
I. Schizophyta - Blue Green Algae			
	A. Rivulariaceae		
		Calothrix	3366
	B. Oscillatonaceae		
		Lyngbia	1668
II. Chlorophyta - Green Algae			
	A. Valoniaceae		
		1. Valonia	30
		2. Dictyosphaeria	18
		3. Microdictyon	19
	B. Cladophoraceae		
		1. Cladophora	402
	C. Bryopsidaceae		
		1. Bryopsis	1386
	D. Caulerpaceae		
		1. Caulerpa	61
	E. Codiaceae		
		1. Avrainvillea	0
		2. Udotea	192
		3. Halimeda	75
III. Phaeophyta - Brown Algae			
	A. Ectocarpaceae		
		1. Ectocarpus	1260
	B. Asperococcaceae		
		1. Hydroclathrus	0
	C. Dictyotaceae		
		1. Dictyota	1330
		2. Padina	114
		3. Pocockiella	0
	D. Fucaceae		
		1. Turbinaria	24
IV. Rhodophyta - Red Algae			
	A. Helminthocladiaceae		
		1. Liagora	1
		2. Asperegopsis	0
	B. Corallinaceae		
		1. Lithophyllum	7
		2. Lithothamnion	3
	C. Rhodomelaceae		
		1. Polysiphonaceous Red Alga	1306
		2. Laurencia	0

INVERTEBRATES

by

Kelshaw Bonham

Ideally the basis for evaluation of intensity of activity at the various localities from invertebrate tissue counts would consist of a comparison of the same species from all the localities. Since it was not feasible to collect identical species from all localities, the comparison was made on the basis of available specimens.

Identification of sponges and sea cucumbers was undertaken by Mrs. Margaret E. Dunn who isolated the microscopic skeletal elements by dissociation of soft parts. Sponges were identified at least as to order and some to genus. Most of the sea cucumbers were identified as to species. Most of the other invertebrates were identified by Mr. Spencer W. Tinker. Some of the more difficult identifications of crustacea were made by Dr. C. H. Edmondson of the Bishop Museum, Honolulu. When several small specimens of a species were available they were combined for ashing, or, if the specimens were large, only one or portions of one were used. Numbers of specimens as identified for ashing are tabulated by stations in Table 1.

Invertebrate samples were ashed in September, 1949, and in accordance with the policy of counting control area samples first, the ashed Likiep invertebrates and algae were plated and counted from November 22 to December 9, 1949, while the invertebrates and algae from other localities were counted from February 23 to March 10, 1950. Counting was done in the Nucleometers as described earlier in the report. Counts per minute per gram of ash above background plus 3 standard deviations were corrected back to wet tissue for each sample and averaged (c/m/g) to obtain the average count for the area. Average c/m/g were converted to disintegrations per minute per gram (d/m/g) by using a factor of 1.5. Values given are for entire organisms unless otherwise stated. The averages for different localities are based upon various species and numbers of specimens and include all ashed samples (see Table 2). The distribution of radioactivity of ashed invertebrates among the localities sampled was much as would be expected, being greatest

Table I. Numbers of specimens of invertebrates from the indicated localities used in ashing

Name of organism: Common	Scientific	Lado, 8-20	Likiep, 8-22	Bikini 2207, 7-25	Lege 2891-5, 7-26	Aomen 1213, 7-27	Dr. 2306, 7-28 *	Boro, 0799, 8-2	Nam, 9314-15, 9414-15, 8-3	Dr. 2795-7-9, 7-29 a.m. *	Dr. 2803-4, 7-29 p.m.	Romuk, 2201, 7-30	Erik, 0790, 8-1	Japtan, 8-8	Ygeria, 8-9	Rigili, 8-10	Dr. Bogon, 8-12 *	Dr. Eberiru, 8-14 *	Lagabl, 8-11	Eberiru, 8-13	Rumit, 8-13
Anemone									1											1	
Barnacle			7																		1
Clam, giant	Tridacnidae			1	1	1							1			2			3	1	1
"	Hippopus	2							1					1	1						
"	Pinna			1																	
"	Calliarca							1													
"	Barbatia															1					
"	Codakia															1					
"	Navicula ventricosa	1																			
"	Arca [illegible]		1																		
"	Veneridae									5											
" others							1														
Coral, staghorn	Acropora									1						1		3	1		1
" "	Porites												1		1				1		
"	Pocilloporidae				1	1				1		1								1	
"	Madreporaria			1		1			2												
"	" , Favia																		1		
" soft	Zoanthus													1							
" "		1														2					
"	[illegible]	1																			
" other		1													1		5	2			
Crab, hermit	Coenobita perlatus			1	1	1		1	2					2	2	1				1	1
" "	Dardanus punctulatus							1													1
" "	Aniculus				1																
" "	Calcinus			3																	
" " , other		8		1	1	6			7	4			2	4	1				10		10
Crab	Ocypoda			1	1			1	1				1	1		1			1		1
"	Eriphia laevimana	1			1	1							1	1	1	1			1	1	1
"	Grapsus grapsus	1		1	1				1				2	1	1				1	1	1
"	Zosimus				1	1									1						
"	Petrolisthes	2																		1	1
"	Portunidae & Xanthidae									5								4			
" other			1		2	4		1	3						2					1	3
Cricket																			1		
Cucumber, black	Holothuria atra	1			1	1		1	1					1		1	1	1	1		1
"	Holothuria fusco-rubra			1									1							1	
"	Holothuria pardalis																				1
"	Holothuria sp.									1											
" large, brown	Actinopyga mauritiana			1																1	1
" giant	[illegible] sp.	1																			
"	Euapta godeffroyi				1		1														
" other		1	1													1			1	2	
Gephyrean		1																			1
Hydroid		1	1				1					1		1					1	1	
Nereid,	Eurythoe pacifica	1														1				1	6
Octopus					1														1		
Oyster	Isognomon	8						1	2					6		8			21	4	6
"	Pinctada					1						2			4			4	12	6	6
"	Chama				1														1		
"	Ostrea					2							3						1		
" other																		4			
Sand dollar						1	1														
Shrimp , snapping & other																1			8	1	6
"	Stomatopoda	1				1															3
Slug			1												1				2		1
Star, brittle	Ophiocoma- like							1													
" "	[illegible]	1																			
" " other									2				1	1	1	2				1	1
Star, asteroid	Linckia- like														1				3		1
" " other		1											1			1				1	
Snail, horn	Cerithium														1	1			1		
" cone	Conus ceylanensis				1								1			1					
" "	Conus ebraeus	8			1										1						
" "	Conus flavidus				1	1															6
" "	Conus marmoreus																		1		
" "	Conus sp.			1	1																
" cowry	Cypraea caputserpentis															1			1		
" " money	C. moneta	10							3				6	8	6				11		9
" "	Cypraea sp.				1									2						1	
" knobby	Drupa horrida				1																
" "	Drupa ricinus												1						5		
"	Engina mendicaria							3													
" periwinkle	Littorina sp.			7		4															
"	Mitra sp.															2	2				
"	Morula tuberculata							1							1	6					
Snail, sea	Nerita albicilla			3		1							1	8		2				3	
Snail, sea	Nerita polita	3						1						9							
" "	Nerita sp.								6				1						5	4	
" olive	Oliva sp.									3											
"	[illegible] sp.																1				
" spider	Pterocera chiragra																				1
" scorpion	Pterocera lambis																		1		
" knobby	Purpura armigera				1																1
" "	Purpura hippocastanum	2						2					1								
"	Strombus gibberulus									4							1	1			
" auger	Terebra maculata									2											
" top	Trochus sp.				1								2								1
" turban	Turbo sp.				1											1					
" knobby	Vasum turbinellus	2			3	1							1		2	3			1		1
Sponge		4	5	1	2	3			2	1	6	2	6	1		3		1	2	3	2
Tunicate, compound																					1
Urchin, others	Eucidaris metularia																	2	1		
" poison	Centrechinus [illegible]	1																			
" "	Echinothrix calamaris					1								1		1				1	
" oval	Echinometra mathaei	1			1	1								1	2	1		1	1	1	2
" slate pencil	Heterocentrotus trigonarius			1	1	1			1							1				1	1
" short-spined	[illegible] sp.																			1	
" black, short-spine	Tripneustes gratilla					1															
" heart	Brissus sp.									1	1						1	1			

* dredge

TABLE 2

Average d/m/g wet tissue of all ashed samples of invertebrates from 1949 collections at Marshall Islands arranged according to activity within the three atolls.

Bikini Atoll	Locality in order of increasing activity										Average for Atoll
Island	Boro	Enyu	Namu	Bikini	Erik	Amen	Inside Bikini	Inside Rokar, Ion, and Enyu	Target buoys	Target area	
Date collected	8-2	7-26	8-3	7-25	8-1	7-27	7-28	7-29 am	7-30	7-29 pm	
Area	8799	2894-5	9514 9614-5	2407	0390	1213	2306	2795, -7, -9	2201	1904, 2003-4	
Habitat	shore	shore	shore	shore	shore	barge and shore	dredge 30' 100 yd	dredge 80'	buoys	dredge 150'	
d/m/g wet	0.6	1.3	1.7	3.3	5.8	6.6	30	68	104	1080	37
Eniwetok Atoll											
Island	Japtan	Igurin	Rigili	Inside Bogon	Inside Eberiru	Engebi	Runit	Eberiru			
Date collected	8-8	8-9	8-10	8-12	8-14	8-11	8-15	8-13			
Habitat	shore	shore	shore	dredge 50'	dredge 55'	shore	shore	shore			
d/m/g wet	0.6	0.7	1.8	110	140	480	750	1500			480
Likiep Atoll											
Island	Likiep	Inside Likiep	Lado								
Date collected	8-22	8-20	8-20								
Habitat	shore	dredge 40'	shore								
d/m/g wet	0	0	1.2								0.9

near the blasts at Eniwetok and in the samples from the Target Area at Bikini and practically absent at the control atoll of Likiep.

In Table 3 invertebrate counts are given for the three atolls separating relatively active and inactive stations. Asteroid starfish, hydroids, the oyster, Isognomon, and sponges had higher average counts than algae which are included for purposes of comparison.

In attempting to decipher the pattern of the distribution of activity among the invertebrates, food seems the most likely single variable to account for differences. Because food was not studied, a separation into sessile plankton-feeders and mobile non-plankton-feeders was expedient. Average disintegrations per minute per gram of wet tissue for the animals in the three most radioactive areas (Eberiru, Engebi, and Runit) were compared for the two food categories using the *t* test. At these 3 collecting areas 23 plankton-feeding animals, excluding the corals (whose relative lack of radioactivity may in some way be associated with the fact that the soft parts are overwhelmingly outweighed by inorganic material) averaged 2300 d/m/g while 71 animals that feed otherwise averaged 600 d/m/g (see Table 4). The difference is significant beyond the 1 per cent level of probability.

A comparison for shellfish of the activity in skeletal parts and soft parts is presented in Table 5. Soft parts contained more activity than hard parts on the average, but numerous exceptions prevent the difference from being clear-cut. Only two of the snail shells had activity, while some clam shells and crab exoskeletons had definite counts, and the counts of some oyster shells were high.

Most of the sponges were of the flat, encrusting type adhering to coral rocks. Sponges are arranged in Table 6 by natural groups in decreasing order of radioactivity. Although the data are not extensive, it is probable that the groups at the top of the list take up radioactivity more avidly than those at the bottom of the list. Mrs. Dunn observed that the sponges of relatively porous, open structure contained greater amounts of plankton and were more radioactive than the relatively dense sponges.

Comparison of the activity by stations in 1948 and 1949 was made by converting 1948 values from millimicrocuries per kilogram to d/m/g using a factor

Table 3. Average counts of wet tissue of algae and invertebrates, grouped by active and inactive localities at three atolls.

Name	Likiep		Bikini				Eniwetok				All stations	
			Inactive		Active *		Inactive		Active**			
	No.	d/m/g	No.	d/m/g	No.	d/m/g	No.	d/m/g	No.	d/m/g	No.	d/m/g
Tunicate	-	-	-	-	-	-	-	-	1	6,400	1	6,400
Star, asteroid	-	-	1	0	-	-	1	0	3	8,450	5	5,100
Anemone	-	-	-	-	-	-	-	-	1	2,600	1	2,600
Hydroids	2	0	1	100	1	52	1	3	2	7,200	7	2,100
Urchin, heart, Brissus	-	-	-	-	2	3,400	1	390	1	0	4	1,800
Oyster, Isognomon	1	0	2	0	-	-	4	0	3	2,700	10	820
Sponges	9	0	8	33	12	180	7	15	8	2,500	44	580
Gephyrian	1	0	1	7	-	-	-	-	1	1,600	3	520
Nereid worms	1	0	-	-	-	-	1	0	2	780	4	390
Slug	1	0	-	-	-	-	1	0	2	740	4	370
Algae	11	3	44	6	17	24	17	0	23	1,700	112	360
Oysters, other than Isognomon	-	-	6	2	1	39	-	-	7	530	14	270
Cucumber, other than Holothuria	3	0	3	8	-	-	1	0	3	570	10	220
Snail, Vasum	1	0	3	0	-	-	2	0	2	830	8	210
Cucumber, Holothuria atra & f.-r.	1	0	5	0	2	0	3	54	5	580	16	190
Urchin, oval, Echinometra mathaei	1	0	2	0	-	-	2	0	5	280	10	140
Snails, other than Conus, Cypraea, Nerita, & Vasum	3	0	12	2	3	250	9	24	6	340	33	93
Crab, hermit, Coenobita perlatus	-	-	5	0	-	-	3	0	2	450	10	90
Barnacles	2	0	-	-	-	-	-	-	1	270	3	88
Snails, Cypraea caputserpentis, & moneta	-	-	3	0	-	-	4	0	5	230	13	87
Shrimp	1	0	1	0	-	-	1	0	4	150	7	86
Urchins, other than Echinometra	1	0	6	0	-	-	3	0	5	100	15	33
Crab, Grapsus grapsus	1	0	6	0	1	0	2	2	3	120	13	28
Corals	3	0	6	0	3	0	10	66	8	6	30	24
Clam, giant, Tridacna & Hippipus	1	2	5	3	-	-	3	0	3	70	12	20
Crab, Eriphia laevimana	1	2	3	2	-	-	4	22	2	50	10	20
Snail, Nerita plicata & sp.	1	0	7	0	-	-	3	0	3	84	14	18
Octopus	-	-	-	-	-	-	1	0	1	21	2	10
Crab, Ocypode	-	-	5	2	-	-	2	0	2	36	9	9
Crab, hermit, other than Coenobitus	2	3	9	0	1	6	2	0	2	30	16	4
Star, brittle-, ophiuroid	2	3	3	2	-	-	4	0	2	15	11	4
Snail, Conus marmoratus, ceylonensis, ebraeus, flavidus	-	-	7	0	-	-	2	0	1	28	10	3
Crabs, other than Ocypode, Eriphia, & Grapsus	3	0	6	0	2	12	3	0	1	6	15	2
Clams, other than tridacnids	1	0	3	0	1	2	2	0	-	-	7	0
Sand dollar	-	-	2	0	-	-	-	-	-	-	2	0
Cricket	-	-	-	-	-	-	-	-	1	0	1	0
All	54	0.8	65	4.4	47	200	99	16	121	1200	486	150

*Dredging inside Rokar, Ion & Enyu, Areas 2795-7-9, July 29, a.m.
Dredging, Areas 1904, 2003-4, July 29, p.m. Anchor buoys, Area 2201, July 30
**Eberiru, Runit, Engebi

TABLE 4

Comparison for Eberiru, Engebi, and Runit, Eniwetok Atoll of activity of plankton-feeders with non-plankton-feeders.

Plankton-feeders

Clam, Tridacnids	18	Oyster Chama	810
" "	135	" Ostrea	1,600
" "	60	" Unidentified	18
Hydroids, Misc.	12,000	Sponges "	2,200
" "	2,000	" "	140
Oysters, Isognomon	160	" "	9,400
" "	10,000	" "	1,000
" "	2,100	" "	9
" Pinctada	160	" "	6,900
" "	680	" "	60
" "	400	Tunicate, compound	6,400
" "	0		

Non-plankton-feeders

Crabs, Ghost, Ocypode	58	Shrimp	170
" " "	10	Starfish	12,000
" Grapsus	120	"	12,000
" "	75	"	1,300
" "	160	Star-brittle, Ophiuroid	24
" Eriphia	120	" " "	0
" "	16	Snail, scorpion	470
" "	78	Snail, Vasum	41
" "	21	" "	1,600
" Misc.	6	" Cypraea	160
" "	18	" "	56
" "	200	" "	220
" "	6	" "	50
" "	280	" "	640
" "	1,500	Snail, sea, Nerita	150
" "	0	" " "	18
" Coenobita	900	" " "	78
" "	3	" " Purpura	8
" Dardanus	9	" " Pterocera	570
" Hermit, small	250	" " Trochus	12
" " "	52	" " Cerithium	980
" " "	0	" " Drupa	14
Cucumber, black, Holothuria	200	" " Conus	28
" " "	740	" " "	0
" " "	360	" " Strombus	0
" " "	480	Urchin, slate, Heterocentrotus	0
" , large brown, Actinopyga	21	" " "	0
" " " "	84	Urchin, Echinometra	0
" small tan	330	" "	0
" " "	680	" "	280
" " "	1,100	" "	900
" " "	2,000	" "	120
Shrimp	120	" Eucidaris	320
"	240	" Lytechinus	120
"	64	" small bald	63
		Urchin, heart Brissus	0

TABLE 5

Comparison of radioactivity expressed as d/m/g of entire organism attributable to soft parts as compared to hard parts (exoskeleton) of bivalves , crabs, and snails collected from Eberiru, Engebi, and Runit, Eniwetok Atoll.

Organism	No. of animals	soft	hard
Clams	3	45	34
Oysters	8	420	1300
Crabs	8	42	33
Snails	17	810	24

TABLE 6

Radioactivity of sponges by natural groups from all stations combined.

Class	Subclass	Order	Genus	d/m/g
Demospongiae	Keratosa		Spongia	6, 900
Demospongiae	Monaxonida	Hadromerina		1, 600
Demospongiae	Monaxonida	Poecilosclerina		860
Demospongiae	Tetractinellida	Carnosa		560
Demospongiae	Monaxonida	Halichondrina		310
Demospongiae	Monaxonida	Haplosclerina		170
Demospongiae	Tetractinellida	Myxospongida		50
Calcarea				44
Demospongiae	Tetractinellida	Choristida		9

2.2 (see Table 7). At Eniwetok there is a conspicuous reduction in the amounts of radioactivity at Rigili and Igurin, and a decline of Engebi from the position of the highest in activity of invertebrates in 1948 to third place in 1949. It will be noted also that counts of algae showed the position of Engebi to drop from second in 1948 to third in 1949. Perhaps the collections on Engebi in 1949 were not from the most active portions of that locality. The section of the present report dealing with the distribution of radioactivity on land shows great variability of intensity within relatively small areas near the target localities. If the same condition may be assumed to exist in the water, a slight change in position of the sampling station from one year to the next could effect noticeable change in the radioactivity of the invertebrates. At any rate the possibility of more rapid decay of material from Engebi than from other stations was negated by recounts in June, 1950, of from two to six of the 1948 samples from each of the three Eniwetok blast localities. No significant difference in the rate of decay over the 1-1/2-year period among the islands could be observed.

Several points of interest merit discussion. Comparison of the invertebrates as a whole with algae shows more radioactivity in the algae than in the invertebrates at the Eniwetok Shot Islands, but not in the Bikini Target Area. Such sessile invertebrates as hydroids and encrusting sponges exceed the algae. In 1948 the algae and invertebrates were about equal in radioactivity at both Bikini and Eniwetok. In 1949 the invertebrates as a whole were less radioactive than the algae, probably because relatively more of the low-counting types of animals like crabs, clams, snails, and urchins were assayed in the latter year. However, higher counts were obtained from certain invertebrates such as starfish, hydroids, oysters, and sponges, than from any of the algae sampled. Indeed, the entrance and path within the organism of the relatively great amounts of radioactivity in certain of these invertebrates constitutes one of the most puzzling questions concerning the distribution of radioactivity among the living things at the atolls.

Low levels of radioactivity among the corals, which are sessile, plankton-feeding organisms, present an anomaly. Coral samples were almost exclusively of the hard, calcareous type. In preparing the samples, hard parts were not separated from protoplasmic portions, so that unless the hard parts were radioactive,

the sample count would be low even though activity were present in the soft p[illegible]
Presumably Ca^{45} does not occur sufficiently abundantly to become involved appreciably in the food cycle of corals.

SUMMARY

Radioactivity expressed in d/m/g wet tissue of invertebrates at the [illegible] stations was as follows: Bikini Target Area, dredging, 1080; Bikini target [illegible] 104; Eniwetok shores - Eberiru (near Aomon-Biijiri), 1500; Runit, 750; En[illegible] 490; Eniwetok dredging - off Eberiru, 140; off Bogon, 110. Less active stations at both atolls ranged down to 0.6. Considering all stations the most active sp[illegible] included asteroid starfish, 5,100; hydroids, 2,100; oysters, 820; and sponges. [illegible] Plankton-feeding invertebrates averaged significantly more activity than non-[illegible]ton-feeders.

TABLE 7

Comparison between 1948 and 1949 of radioactivity expressed as d/m/g wet tissue of invertebrates.

Atoll	Station	1948	1949
Bikini	Target Area	530	1,080
	Target buoys		104
	Bikini-Amen	59	
	Rokar	53	
	Rokar-dredge		68
	Bikini	48	3
	Bikini-dredge		30
	Amen	46	7
	Arji	37	
	Uku	37	
	Boro	33	1
	Namu	24	2
	Enyu	22	1
	Erik	11	6
Eniwetok	Engebi	6,600	490
	Eberiru		1,500
	Biijiri	3,100	
	Bogon	1,100	
	Rigili	770	2
	Runit	460	750
	Igurin	440	1
	Japtan	22	1

FISH

by

Arthur D. Welander

METHODS

The collections of fish, as in former years (see UWFL* Reports 7, 16, and 19) were made in shallow water on reefs inside the atoll during low tide periods. These shallow water collections were supplemented by deep water collections using traps and hook and line fishing, and by night fishing with a small dip net.

Shallow water collections, using the rotenone from derris root, were made on the lagoon side of Bikini, Enyu, Amen, Erik, Boro, and Namu Islands of Bikini Atoll; on the lagoon side of Igurin, Rigili, Japtan, Engebi, Runit and Eberiru Islands of Eniwetok Atoll; and the lagoon side of Likiep Island at Likiep Atoll.

Trap fishing was carried on with some success in the Target Area in 180 feet of water and less successfully in 20 to 30 feet of water near the reef between Bikini and Amen Islands, near Bokon Island, Bikini Atoll, and in some areas of Eniwetok Atoll. Trolling by means of feather or bone jigs produced a number of tuna, mackerel and barracuda from Ruji Pass, Bikini Atoll; and night fishing using a light produced a number of planktonic forms and planktonic feeders such as herring, silversides and halfbeaks. Table 1 and Figure 1** give a summary of the collecting data. The habitats fished and, to some extent, the methods used are similar to those used by the natives of the Marshall Islands.

GROUPS SAMPLED

The fish selected from the collections for determination of contained activity were in one of the following groups:

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*Applied Fisheries Laboratory, University of Washington.

damsel	jack	lizard fish
parrot	tuna	blennies
surgeon	mackerel	goatfish
grouper	wrasse	siganids
squirrel	snapper	halfbeaks
mullet	herring	butterfly fish
shark	silversides	filefish
barracuda	eel	flatfish

The first 10 or 15 of the above groups were given priority over all others for analysis and selections were made so that fish of a variety of feeding habits were represented at each sampling station. The fishes comprise those commonly available in the Marshall Islands and are, for the most part, used by the natives for food according to the information obtained at Likiep.

NUMBER OF SAMPLES AND KIND OF SAMPLE

A total of 727 samples were prepared from tissues taken from 369 fish. Selection of tissue samples were also standardized with five tissues (liver, viscera, bone, muscle, and skin) usually taken. The spleen and gonads were sampled when these organs were found to be of sufficient size to make an ashed sample, i.e., about one gram or larger.

The total activity per gram of an individual fish was calculated as the sum of the activity of all its tissues. This value was obtained in the following manner: (d/m/g of skin) x (ratio of the total tissue weight to total body weight) + (d/m/g of muscle) x (tissue to body ratio) + ditto for bone, for liver, and for all other tissues = d/m/g of fish. The body ratios, (see Table 1A) were obtained by weighing the tissues of fish from eight selected types. Fish other than those listed were placed under one of the types as follows: halfbeak, blenny, column 1; goatfish, lizard, snapper, mullet, column 2; damsel, butterfly fish, column 3; wrasse, column 4; flatfish, filefish, column 5; barracuda, tuna, jack, column 7.

**Ordinate is modified in all Figures to increase by multiples of ten.

TABLE 1

Average d/m/g in wet tissue of fish for each of the sampling stations.

Island	Area	Habitat and appr. depth	Date Collected	Date Counted	No. of Fish	No. of Samples	d/m/g Whole Fish	d/m/g Livers
				Bikini				
Enyu	2895U	Inside reef 5'	7/28	1/18	20	46	0.9	2.2
Bikini	2407V	Inside reef 5'	7/25	1/17-18	12	42	1.4	6.4
Boro	8799C	Inside reef 5'	8/2	1/20-2/14	22	34	1.4	1.8
Erik	0290N	Inside reef 5'	8/1	1/19-20	16	37	2.4	12.3
Namu	9514H	Inside reef 5'	8/3	2/14-15	23	37	5.2	22.6
Amen	1213R	Inside reef 5'	7/29	1/18-19	11	35	6.1	20.8
Ruji Pass		Deep channel	8/2	1/19	11	13	20.7	264.3
Bokon		Inside reef 30'	8/1	2/16	6	26	37.8	131.5
Target Area		Inside reef 180'	7/29	1/5-2/16	44	22	345.0	591.9
				Eniwetok				
Igurin		Inside reef 5'	8/9	1/6-1/12	14	48	0.6	0.0
Rigili		Inside reef 5'	8/10	1/16-17	31	49	1.0	0.0
Japtan		Inside reef 5'	8/8	1/6-2/20	14	60	2.0	2.5
Engebi		Outside " 5'	8/11	2/16-17	64	56	125.1	135.3
Runit		Inside 5'	8/15	2/18-20	17	47	144.2	156.8
Eberiru		Inside 5'	8/13	2/17-18	25	40	703.2	1408.6
				Likiep				
Likiep		Inside reef 5'	8/22	12/10/49 to 1/4/50	39	135	1.2	0.1

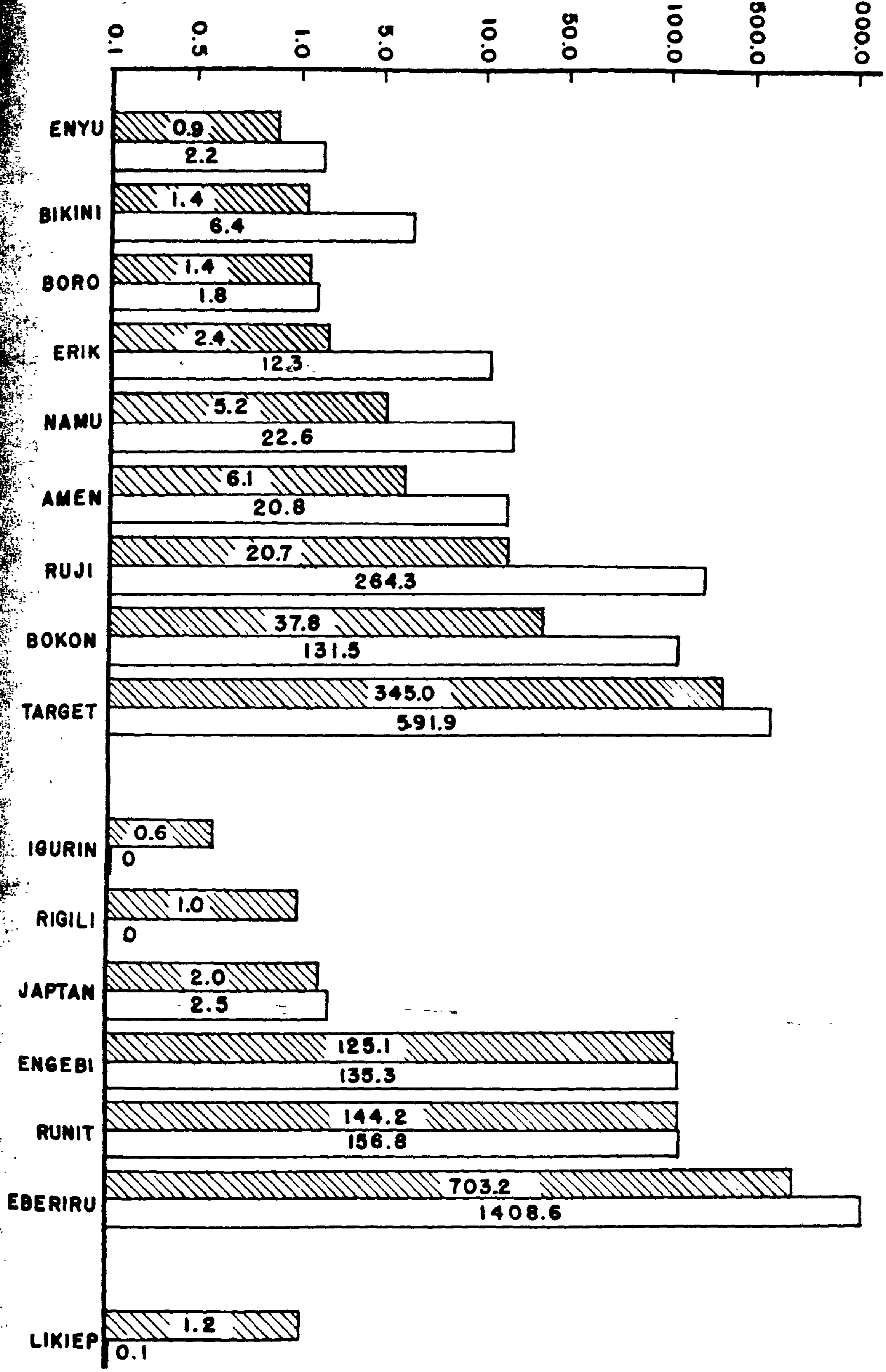

Figure 1. Histograms of d/m/g in wet tissue of fish (shaded) and of liver tissue (open) by sampling stations.

ANALYSIS BY AREA

The data were analyzed with the purpose of estimating radioactivity by areas, by species, by tissue, and by feeding habits. Analysis by area was based on the average activity of all fish sampled from one collecting area. Table 1 summarizes these data by comparing d/m/g of wet tissue of fish and of fish liver with each collecting area and also gives collection date, counting date, and habitat or depth of water from which collected. The average d/m/g per fish was higher at Eniwetok Atoll (142) than at Bikini (33) or Likiep Atolls (1.2). A similar relationship is seen in the activity of the livers (see Figure 1).

The most active areas of Bikini Atoll, listed in descending order, were the Target Area, off Bokon Island, Ruji Pass, Amen, and Namu Islands. The d/m/g in liver tissue show a similar picture, but with Ruji second to the Target Area. The activity of the three most active areas - Runi Pass, off Bokon Island, and the Target Area - were based upon counts of samples from larger than average fish caught in fairly deep water (30 feet or more); whereas the fish from other areas were taken from the shallow waters of the reef. There is no way we can separate these factors of size and depth of water inasmuch as the larger fish are taken in deeper waters. In the case of Ruji Pass the results are surprising because this is the first indication of activity spreading in any considerable magnitude (compared with the neighboring shallow waters) in this area. The pattern, as revealed by the activity in the fish generally, indicates fairly extensive contamination especially to the northwest and east of the Target Area and apparently to the southwest through the deep water channels emptying the atoll water. Our data are, of course, fallible in that we do not have enough large fish from the deep waters of other parts of the atoll although several unsuccessful attempts were made to obtain these by fish traps. Also, considering the variations in activity that occur in fish from the same area, possibly we do not have representative samples from each area.

The correlation between radioactivity and deep water and /or larger fish was seen in the 1947 resurvey (UWFL-7, Figure 11) in which collections of large fish from deep water around coral heads averaged higher than those from shallow waters of smaller fish. This pattern was not evident in the 1948 resurvey

TABLE 14

Ratio of tissue weight to total body weight for eight selected types of Bikini fish.

Fish	1. Eel	2. Brown spotted grouper	3. Convict surgeon	4. Parrot fish	5. Siganid	6. Squirrel	7. 2-line mackerel	8. Shark (est.)
<u>Tissue</u>								
Skin	.108	.064	.065	.110	.026	.173	.034	.100
Muscle	.686	.662	.567	.591	.616	.450	.788	.500
Bone	.099	.224	.175	.220	.170	.288	.118	.150
Liver	.013	.008	.014	.014	.010	.008	.005	.100
Viscera	.084	.020	.157	.050	.163	.064	.030	.100
Gills	.009	.021	.022	.015	.013	.017	.025	.050
Total	.999	.999	1.000	1.000	.998	1.000	1.000	1.000

(UWFL-16) because of insufficient collections from deep water of large fish.

The distribution of fish with activity at Eniwetok was striking. The fish collected from islands closest to the targets, i.e., Engebi, Runit and Eberiru, had high counts, but those collected from the three other islands sampled (Igurin, Rigili and Japtan) had little or no activity. Eberiru fish had the greatest amount of activity with Runit and Engebi showing similar amounts in both liver and whole fish. The comparatively inactive areas of Igurin, Rigili and Japtan were similar to Likiep and some islands of Bikini Atoll in activity in whole fish, but were not always comparable in liver activity.

ANALYSIS BY SPECIES

Table 2 and Figure 2 summarize the data according to the families of fishes and active and inactive areas of Bikini, Eniwetok and Likiep Atolls. The average d/m/g for all of these areas indicates that the parrot fishes (Scarideae) have absorbed the greatest amount of activity per fish sampled followed by the damsel fish (Pomacentridae), surgeon fish (Acanthuridae), wrasse (Labridae) and herring (Clupeidae).

The pattern of activity in the Eniwetok active areas, where we have a fairly good representation, indicates that the damsel fish absorbed the greatest amount of activity with parrot fish, surgeon fish, wrasse, squirrel (Holocentridae) and herring following in decreasing order of magnitude. The pattern of activity in the so-called inactive areas of Bikini, Eniwetok, and Likiep Atolls is variable for the most part, with the snappers (Lutianidae) having the greatest amount of radioactive materials. The picture in these areas of low activity is confused by the possibility of natural radioactivity as well as radioactivity that may be traceable to the atom bombs.

Comparing the data with that obtained in 1948 (UWFL-16, p. 19, Figure 3) we find some differences and some similarities. Generally speaking, the damsel, parrot, surgeon, wrasse, and snappers have comparatively high activities in both years, and the eel, shark, grouper, squirrel, and mullet are comparatively low. Discrepancies are to be found in the halfbeaks, goatfish, blennies, and lizard fishes. These differences are due to sampling, i.e., lack of blennies, eels, and lizard fishes from active areas, and to lack of sufficient numbers for reliable

TABLE 2

Disintegrations per minute per gram of wet tissue of fish averaged by families for the different inactive and active areas.

Family	Common Name	Active Bikini	No. Spec.	Inactive Bikini	No. Spec.	Active Eniwetok	No. Spec.	Inactive Eniwetok	No. Spec.	Likiep	No. Spec.	Average for all	No. Spec.
Pomacentridae	Damsel Fish	-	-	1.3	12	368.8	15	1.0	8	0.8	6	103.2	33
Scaridae	Parrot	-	-	0.9	6	261.6	6	1.0	5	-	-	215.8	17
Acanthuridae	Surgeon	-	-	2.0	6	213.8	4	0.7	8	8.0	2	48.3	20
Serranidae	Grouper	6.9	2	1.5	12	9.3	8	1.4	10	1.0	5	3.0	37
Holocentridae	Squirrel	2.7	1	1.0	3	43.8	5	1.3	5	1.4	6	8.0	20
Labridae	Wrasse	-	-	1.0	23	51.8	7	0	9	3.1	8	24.0	47
Mullidae	Goatfish	6.6	1	2.2	4	4.5	7	0.3	3	1.9	1	3.3	16
Lutianidae	Snappers	13.1	2	5.2	1	-	-	3.7	1	-	-	8.7	4
Muraenidae	Eels	-	-	0.9	4	-	-	0.1	2	3.4	2	1.4	8
Blennidae	Blennies	-	-	0.1	8	-	-	0	2	-	-	0	10
Clupeidae	Herring	-	-	-	-	24.0	7	0	2	0	2	21.7	11
Chaetodontidae	Butterfly	13.6	1	-	-	-	-	-	-	7.6	2	9.6	3
Carcharhinidae	Shark	-	-	0.9	1	-	-	-	-	-	-	0.9	1
Hemirhamphidae	Halfbeaks	-	-	0.9	1	7.5	1	-	-	1.1	2	2.7	4
Carangidae	Jacks	-	-	-	-	-	-	0.6	1	-	-	0.6	1
Synodontidae	Lizard Fish	-	-	0	1	-	-	2.6	4	1.8	1	1.9	6
Atherinidae	Silversides	-	-	-	-	5.0	3	-	-	0	1	3.8	4
Mugilidae	Mullet	-	-	-	-	5.2	1	-	-	-	-	5.2	1
Monacanthidae	Filefish	-	-	0	1	-	-	-	-	-	-	0	1
Averages for Areas		9.0	7	1.2	83	138.1	64	0.9	60	2.3	38	40.4	244

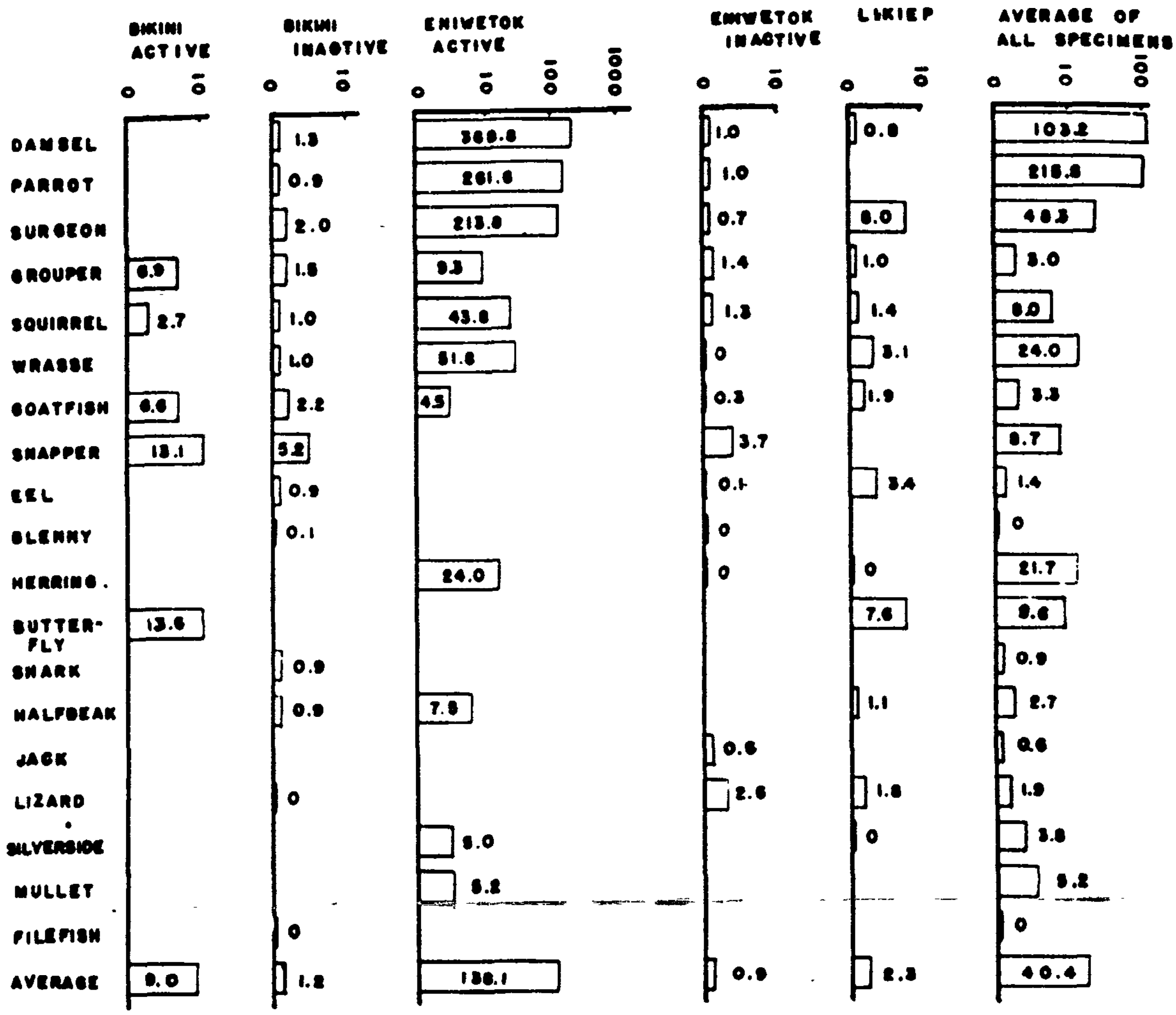

Figure 2. Histograms of d/m/g in wet tissue of fish in active and inactive areas

ges.

LYSIS BY TISSUES OR ORGANS

It was thought that an analysis of the tissues or organs could best be made ombining the data of the active areas of Eniwetok and Bikini (see Table 3 and re 3), but for comparative purposes the inactive areas have been added (see 4 and Figure 3). In the case of the active areas the viscera shows the test amount of activity, followed by liver, bone, skin, and muscle in order creasing amounts. Not enough samples of spleen or ovaries were taken to reliable information.

There is some evidence to indicate that natural radioactivity (such as is absorbed in muscle tissue, and perhaps in other tissues, of fish caught kiep and other comparatively inactive areas (see Table 4 and Figure 3). activity was revealed in all of the tissues sampled from these areas except case of liver tissues of fish from the inactive Eniwetok Islands. It is pected that the liver is a fairly good indicator of "extra-natural" radioactivity, point which might be worth further investigation.

ALYSIS BY FEEDING HABITS

The fish were divided into three groups according to feeding habits: rnivores, herbivores and omnivores, and plankton-feeders. In separating the into these categories the information obtained in 1947* was utilized. These are summarized in Tables 3 and 4 and in Figure 4.

Herbivorous and omnivorous types of feeders seemed to absorb the greatest ount of radioactivity in active areas. In disintegrations per minute per gram of ole fish, herbivores averaged 382, ~~carnivores, 41,~~ followed closely by planktonic ders with 26 d/m/g.

In averaging the individual tissues according to feeding habits it was found the herbivores were similar to the average for all tissues (see Figure 4) while carnivores, although somewhat similar, differed in the arrangement with bone owing the least activity and muscle having about twice as much as skin. Studies radioactivity in the tissues of planktonic feeders were made on only one fish cause of the small size of the specimens and can not be adequately compared.

*Bikini Scientific Resurvey, Technical Report, Armed Forces Special Weapons Projects. Vol. II, p. 30, 1947.

TABLE 3

Average d/m/g in wet tissue of fish collected near the active areas of Bikini and Eniwetok Atolls listed according to feeding habits.

Feeding Habit	Common Name	Liver d/m/g	Liver No.spec.	Viscera d/m/g	Viscera No.spec.	Bone d/m/g	Bone No.spec.	Muscle d/m/g	Muscle No.spec.	Skin d/m/g	Skin No.spec.	Total d/m/g	Total No.spec
Carnivores	Squirrel Fish	107.4	6	252.9	6	0	6	15.9	6	1.5	6	24.4	6
	Wrasse	196.2	6	1943.2	6	6.9	6	10.8	6	14.8	6	153.3	7
	Goatfish	177.3	9	25.6	8	2.1	8	4.8	8	3.8	8	6.2	8
	Grouper	79.6	22	108.3	10	1.0	10	5.7	10	1.5	10	7.5	10
	Snappers	631.5	45	99.0	2	2.7	2	8.1	2	6.3	2	13.2	2
	Barracudas	10.2	3										
	Tunas	3.9	2										
	Mackerels	35.4	2										
	Remoras	69.0	1										
Average of Carnivores		351.7	96	458.2	32	2.3	32	8.5	32	4.8	32	41.5	33
Omnivorous and Herbivorous	Damsel Fish	584.9	15	2335.5	15	20.7	15	4.2	15	11.8	15	386.6	15
	Parrot Fish	892.4	23	4825.8	5	269.1	5	12.9	5	29.8	5	572.4	6
	Surgeon Fish	218.2	15	1619.6	4	13.2	4	7.8	4	21.9	4	254.8	4
	Butterfly Fish	0	1	46.5	1	0	1	9.9	1	0	1	68.6	1
	Mullet	0	1	78.9	1	0	1	4.8	1	0	1	5.1	1
Average of Omnivores and Herbivores		592.2	55	2529.5	26	65.7	26	6.7	26	15.9	26	382.5	27
Planktonic	Herring											37.4	7
	Silversides											5.0	3
	Halfbeaks	41.7	1	21.6	1	5.6	1	4.8	1	10.5	1	7.6	1
Average of Plankton Feeders		41.7	1	21.6	1	5.6	1	4.8	1	10.5	1	25.8	11
Average of All		436.8	152	1363.6	59	30.3	59	7.6	59	9.8	59	168.7	71

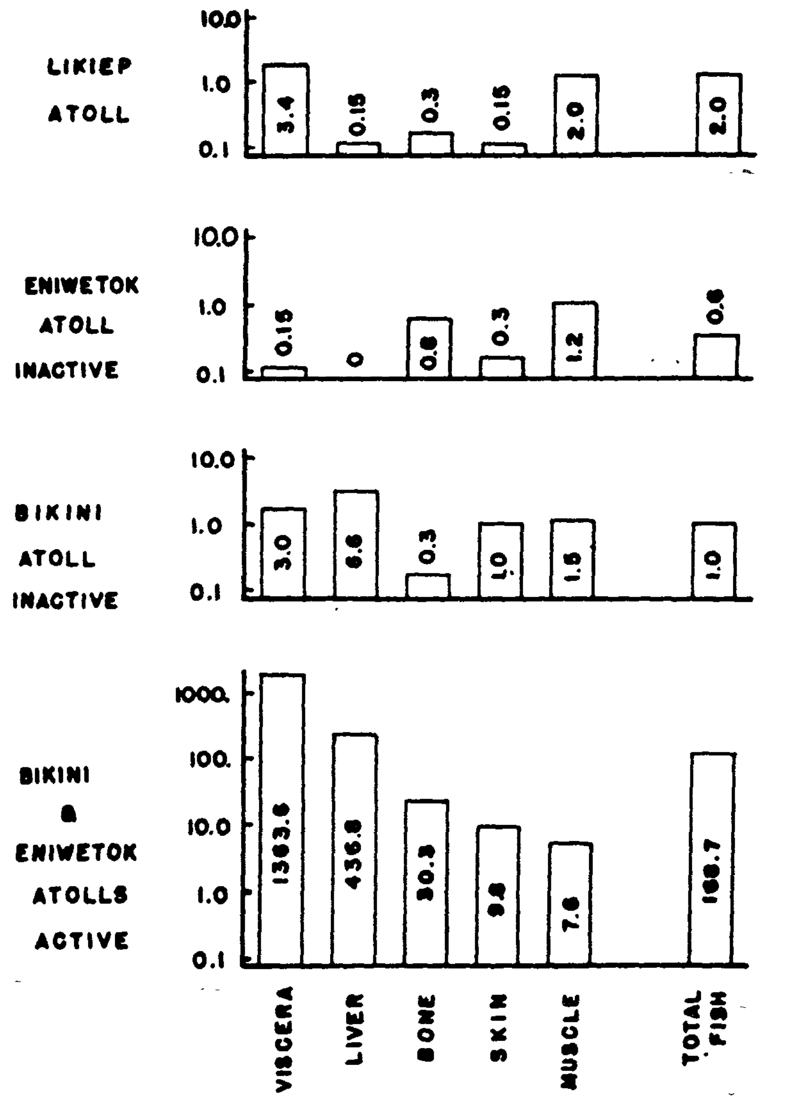

Figure 3. Histograms of d/m/g in wet tissue of fish by organs in active and inactive areas

TABLE 4

Average d/m/g of wet tissue of fish collected in the inactive areas of Bikini, Eniwetok and Likiep Atolls, 1949.

Feeding Habit	Common Name	Liver d/m/g	Liver No. spec.	Viscera d/m/g	Viscera No. spec.	Bone d/m/g	Bone No. spec.	Muscle d/m/g	Muscle No. spec.	Skin d/m/g	Skin No. spec.	Total d/m/g	Total No. spec.
Carnivores	Squirrel Fish	4.2	10	0.4	13	0.0	13	1.6	13	0.2	13	0.8	14
	Wrasse	3.0	13	0.0	13	0.0	13	0.4	13	3.2	13	1.2	40
	Goatfish	1.2	6	0.3	8	1.1	8	1.5	8	1.5	8	1.5	8
	Groupers	5.0	25	0.0	25	0.0	25	1.4	25	1.1	25	0.9	27
	Lizard Fish	0.0	2	0.0	2	0.0	2	2.0	2	0.0	2	2.0	6
	Eels	1.4	6	0.3	6	1.1	6	1.8	6	0.0	6	1.8	8
	Snappers	11.0	2	19.0	2	0.0	2	4.6	2	3.4	2	3.0	2
	Jacks	0.0	1	3.0	1	0.0	1	4.4	1	0.0	1	3.4	1
	Sharks	10.0	3	2.7	1	0.0	1	0.8	1	0.0	1	1.6	1
Average of Carnivores		4.0	68	0.8	71	0.2	71	1.4	71	1.3	71	1.2	107
Omnivorous and Herbivorous	Damsel Fish	4.8	25	1.8	27	1.4	27	1.1	27	0.2	27	1.4	37
	Parrot Fish	2.4	9	0.0	9	0.0	9	2.0	9	0.0	9	1.1	11
	Blennies	0.0	8	0.0	8	0.2	8	0.2	8	0.0	8	0.1	12
	Surgeon Fish	1.4	14	0.9	12	0.4	14	1.8	12	0.3	14	2.0	16
	Butterfly Fish	0.0	2	39.2	2	0.0	2	1.8	2	0.0	2	7.5	2
Average of Herbivores and Omnivores		2.8	58	2.4	58	0.8	60	1.3	58	0.2	60	1.4	78
Planktonic	Silversides											0.0	1
	Halfbeaks											0.4	3
	Herring											0.0	4
Average of Planktonic Feeders												0.1	8
Average of All		3.5	126	1.5	129	0.4	131	1.4	129	0.8	131	1.3	193

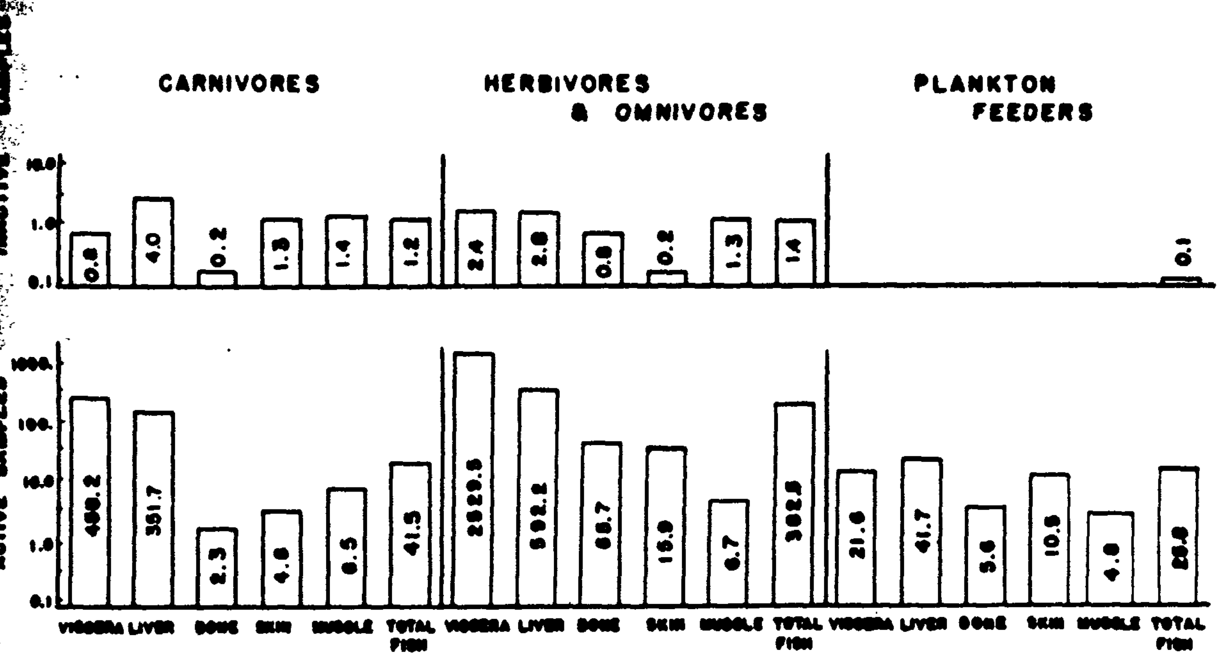

Figure 4. Histograms of d/m/g in wet tissue of fish by feeding habit and organs in active and inactive areas

TABLE 5

Comparison between 1948 and 1949 of radioactivity expressed as d/m/g wet tissue of fish.*

Atoll	Station	1948*	No. Spec.	1949	No. Spec.
Bikini	Bikini Island	14	29	1	12
	Bikini-Amen	11	19		
	Amen Island	21	17	6	11
	Uku Island	13	10		
	Namu Island	5	22	5	23
	Boro Island	5	10	1	22
	Erik Island	9	22	2	16
	Ruji Pass			21	11
	Arji Island	13	18		
	Enyu Island	10	10	1	20
	Rokar Island	16	12		
	Bokon Island (trap)			38	6
	Anchorage (near Bikini)	10	18		
	Target Area (trap)			345	44
	Average for comparable areas	11		2	
Eniwetok	Japtan Island	7	24	2	14
	Eniwetok Island	11	5		
	Igurin Island	15	15	1	14
	Rigili Island	13	28	1	31
	Bogon Island	77	22		
	Engebi Island	22	2	125	64
	Kirinian Island	79	1		
	Eberiru Island			703	25
	Biijiri Island	123	24		
	Runit Island	255	23	144	17
	Average for comparable areas	72		37	
Likiep	Likiep Island			1	39

* The 1948 data was converted from m c/kg using the formula 1 m c/kg = 2.2 d/m/g.

In the inactive areas the activity in the tissues did not differ in the herbivores and carnivores to any great extent. Plankton-feeding fish showed little or no activity.

COMPARISON BETWEEN 1948 AND 1949 RESURVEYS

Table 5 is a comparison of the radioactivity expressed as d/m/g wet tissue of fish taken at Bikini and Eniwetok Atolls during the summers of 1948 and 1949. In sampling areas which are comparable for the two years (i. e., in which sufficient numbers of fish were collected in the same area in both years) there is a reduction in the amount of radioactivity. In averaging the data for the comparable areas of Bikini, Amen, Namu, Boro, Erik, and Enyu Islands of Bikini Atoll there is a reduction in radioactivity from 11 d/m/g in 1948 to 2 d/m/g in 1949 (about 82%). Similarly, averaging the data for the sampling areas of Japtan, Igurin, Rigili, and Runit Islands of Eniwetok Atoll there is a reduction from 72 d/m/g in 1948 to 37 d/m/g in 1949 (about 48%). The Engebi sample was not of sufficient size in 1948 to be included as a comparable area.

SUMMARY AND CONCLUSIONS

During the summer of 1949, 369 fish were collected at Bikini, Eniwetok, and Likiep Atolls in the Marshall Islands and their tissues analyzed for radioactive isotopes. The resulting data appeared to warrant the following conclusions:

1. The amount of radioactive isotopes absorbed by fish near the bomb sites at Eniwetok Atoll is about 120 times that of Likiep Atoll and inactive areas of Eniwetok and Bikini Atolls. The amount of radioactive isotopes absorbed in the Bikini Atoll active areas is about 27 times that of Likiep.

2. At Eniwetok the greatest amount of activity is concentrated in fish near the shot islands of Engebi-Aomon-Biijiri, and Runit. At Bikini the greatest amount of activity is found in samples from deep water~~, from large~~ fish, and from the Target Area.

3. The greatest amount of activity is absorbed by herbivorous and omnivorous fishes such as damsel fish (Pomacentridae), parrot fish (scaridae), and the like. These fish have about 10 times as much absorbed radioactive isotopes as such carnivorous species as groupers (Serranidae), squirrel fisn (Holocentridae), etc. Plankton-feeders, herring (Clupeidae) and silversides (Atherinidae) were similar to carnivores in amounts absorbed.

4. Collection from control areas and from bomb site areas indicate that natural-occurring radioactive isotopes in fish livers are relatively scarce (as compared to other fish tissues) while radioactive isotopes resulting from fission are relatively great.

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A DESCRIPTION OF TUMORS ON *IPOMOEA TUBA* FROM THE A-BOMB TEST SITES ON ENIWETOK ATOLL

(Appendix to Radiobiological Survey of Bikini, Eniwetok, and Likiep Atolls--July-August 1949)

by

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April 1953

Operated by the University of Washington under Contract No. AT(45-1)540 with the United States Atomic Energy Commission

CRIPTION OF TUMORS ON *IPOMOEA TUBA* FROM THE A-BOMB TEST SITES ON ENIWETOK ATOLL

Appendix to Radiobiological Survey of Bikini,
Eniwetok, and Likiep Atolls--July-August 1949

By Susann F. Biddulph and Orlin Biddulph

Tumors on plants of *Ipomoea tuba* were found on Engebi Island during the iobiological survey of July and August, 1949. At this time (17 months from test shot on Engebi Island) many of the *Ipomoea tuba* plants located in an 400 to 600 yards from the bomb crater showed tumorous growths of various es. The tumorous plants were found in disjunct areas of grass which had been fully covered by the dense growth of *Ipomoea* which surrounded them gure 1).

This species of *Ipomoea* is a vine with large heart-shaped leaves and a which grows prostrate on the ground to a length of some ten meters (Figure 2). The tumorous deformations on the plant varied from small warty out-growths the nodes on the basal portions of the stem (Figure 3) to huge, convoluted orous masses completely covering a stem which had been reduced to only a few timeters in height. The ability of the plants to recover from the deforma- n was indicated by the fact that the tumors were confined to the basal nodes the first case mentioned above, and that even in the most severe cases mal leaves were occasionally produced from tumorous masses (Figure 4).

Morphological and physiological abnormalities were found in other plants on some of the other islands surveyed. These were noted in the original port by both Biddulph and St. John (30) and included twisted stems and aves, reduced leaves, abnormal fruits, double flowers, color changes, etc. far as observed, *Ipomoea tuba* was the only plant to show tumorous growths.

Time and facilities did not permit a study of the tumors during the sur- y, but dried and preserved materials were brought back for study.

Since the problem of what causes abnormal plant growth and how it is intained is one of the most fundamental in biology, we have made a survey of literature on plant galls, or tumors, in an attempt to compare the tumors described in this study with some of those already known.

Plant galls or tumors may be caused by fungi, bacteria, viruses, nematodes, insects, chemical substances and genetic factors. They are as varied and numerous as the number of inciting agents would indicate.

The most intensely studied plant gall is known as Crown-Gall, which is incited by Agrobacterium tumefaciens. It has been observed on plants belonging to widely separated botanical families and it has been described on almost all organs of susceptible plants (10). The family Convolvulaceae, of which the genus Ipomoea, is a member is not found on this list, however. Crown gall bacteria are widely distributed and are apparently native in many soils where they lead an independent life or persist in old galls (16). It is uncertain whether the bacteria are intercellular or intracellular, but the bacteria must be introduced through a wound; and the size of the wound determines to some extent the size of the gall (9). Apparently the bacteria produce something which transforms normal tissue into tumor tissue. After this, the galls can continue to grow without the inciting principle, but the nature of the inciting principle and its mode of action are unknown. Crown-gall is not a systemic disease, however, and the relative size of the tumor apparently depends on the amount of transforming principle available at the time of the cellular alteration. There is a considerable histological variation in reaction to the crown-gall organism reported in the literature. In general, the tissues are more distorted than normal, and giant cells with many nuclei may be present (9). It has been reported by Braun (4) that cells which have undergone the transformation induced by the crown-gall organism can change back into normal cells and give rise to organs.

The host ranges of other gall-inducing bacteria are quite limited and are not applicable to this study (27).

Insects are probably the most common cause of galls in plants. In the case of a great many insects there is no mechanical injury, but in all cases is a stimulatory effect on cells in a meristematic or plastic condition As a result, there is cell enlargement or cell division or both, and the ted parts fail to differentiate into the characteristic tissues of the normal organ on which the gall is formed. The view is generally held that chemical tions of the larvae are primarily responsible for the proliferations (6) ugh Rahn (26) makes a novel suggestion that radiation from the larvae may some effect. There is a close analogy between the insect gall and the developf adventitious buds (7). On red currants, one of the mites produces a someswollen bud, or a dense growth of buds which do not develop normally (1). t galls are not systemic, although evidence of systemic disturbance due to a iplicity of insect bites has been presented in one case (25). Even in this nce, the effect did not extend for more than one or two internodes.

A number of workers have reported tumors on plants following the applicaof indoleacetic acid (5, 8, 31). When the histology of such tumors was died by Kraus, Brown and Hamner (21) it was found that the cells of the endois were especially responsive. Root histogens developed and later gave rise adventitious roots. Over the vascular bundles long proliferating strands of cular tissues developed from endodermal derivatives. These frequently enged sufficiently to rupture the tissues exterior to them. Cambium, ray parenma, and xylem proliferated greatly. The responses reported for other plants e been much the same. Some investigators claim that the galls produced by doleacetic acid and other organic acids are similar to those brought about by tual infection with the crown-gall organism (5, 22, 23). In all cases of tumors overgrowths produced by growth substances, there is a marked proliferation tissues which have already differentiated. The reports of adventitious shoots cabbage (12), in <u>Nicotiana</u> hybrids (14), and in <u>Geranium</u> (30) indicate that what normal recovery from growth substances is possible. The histological responses induced by 2, 4-D and 2, 4, 5-T are very similar to those of the growth substances, except that they are more marked in degree. In some there is stimulated cell proliferation and lateral root production, while other cases, there is greater cambial activity and the formation of thick xylem cells (29).

Viruses in plants usually do not affect the meristematic regions. continued normal functioning of the meristem of the growing points and regions of most virus-affected plants indicates that if viruses are pres the meristem they rarely cause appreciable direct injury to this type of (2). An exception to this statement is the virus-produced tumor reported Kelly and Black (20). This tumor arose chiefly in the pericyclic region and stems and consisted of groups of distorted tracheids surrounded by meris tic cells and parenchyma interspersed with phloem.

Description of Tumors on Ipomoea tuba. -

The tumors varied from small wart-like tubercles at the nodes to larg contorted masses 5-6 centimeters in circumference (Figures 5_a and 5_b). The were yellowish-green in color, but the leaves produced on the newer growth were normal in color. As has already been stated, leaves sometimes arose the tumorous masses themselves, indicating at least partial recovery.

Histology. -

Whole tumors were brought to the laboratory in FAA. Pieces of the tissue were dehydrated and cleared in an alcohol-chloroform series and in "Tissuemat." They were sectioned serially at 15u and stained by Conant's Quadruple stain schedule. Sections of the stem of normal plants grown from seed in the greenhouse were fixed in FAA and either stained and sectioned as above or sectioned at 20u on a freezing microtome and stained with safranin fast green.

A cross-section of the normal mature stem of Ipomoea tuba just below the ...rue leaf shows a phellogen producing a thin-walled phellem several cells ...th on the periphery. Progressing toward the center of the stem from this ...ated the collenchyma, four or five cells in depth; considerable assimi... parenchyma containing lactiferous ducts and secretory cells; a uniseri... ...yer which may be an endodermis, but cannot be strictly identified as such ...it lacks Casparian strips and is not a starch sheath; a pericycle; external ... groups; the cambium, several cells in thickness; a ring of secondary ... traversed by pith rays; radial rows of primary xylem; and a central pith ...ining lactiferous ducts and strands of internal phloem (Figure 6). Both ...nal and external phloem contain well developed sieve tubes and companion ... The cortex and central parenchyma contain abundant starch and there are ... cluster crystals. Bands of fibers occur in the xylem of the older stem. ...ger portions of the stem are much the same as to tissues and organization, ...pt that there are no xylem fibers and no phellogen, the stem being covered ... uniseriate epidermis.

A longitudinal section of the normal primordium shows a uniseriate tunica ...ering the central, homogeneous corpus. Just back of the corpus region is ...area of cell elongation and pronounced procambial development. Phloem is dif...ult to distinguish in the longitudinal section, but xylem elements are easily ...ognized one to two mm. back of the apex. The origins of lactiferous ducts in ...th the central and cortical regions may be distinguished at about the same ...vel and many of the parenchyma cells contain large cluster crystals (Figure 7).

The tumors consist largely of parenchymatous tissue with relatively small ..., it would seem, inadequate amounts of xylem and phloem. The parenchyma cells ... about the same size as those occurring in the central pith of the normal ...lls. The xylem and phloem cells, on the other hand, are extremely small and ...re is apparently no cambial activity. The phloem varies from almost completely undifferentiated but elongated cells, which must serve as conducting tissue, to phloem with an apparent organization (in cross section) into sieve tubes and companion cells. However, no sieve plates were observed. The xylem elements are very much shortened with reticulate or spiral thickenings. The conducting tissues are rather regularly arranged in a cylinder around a central pith in each individual swelling of the multiple tumor. An internal phloem differentiates. The available material was not well fixed for cytological purposes, but the nuclei appeared normal. The parenchyma contains cluster crystals especially near the lactiferous ducts and starch grains are particularly abundant in the outermost layers of parenchyma. The lactiferous ducts are not well developed as in the normal stem and there appear to be no functioning secretory cells.

Aside from the proportionately small amount of conductive tissue, the tumors appear histologically surprisingly normal. There are no giant cells, the tissues maintain a regular arrangement, and there is no excessive proliferation of any one tissue. There is simply a general "ground mass" of parenchyma with relatively little xylem and phloem.

The striking histological feature of the tumors is the large number of growing points or primordia most of which fail to continue development. These primordia show a wide range from normality. In normal primordia, apical growth is retarded early and ensuing development and growth is due to intercalary activity in addition to some unlocalized cell division (15). In the tumor primordia, this intercalary growth seems to fail. The procambial strands differentiate into some semblance of a conductive tissue, but no new tissue seems to develop. The meristematic cells enlarge and become parenchymatous (Figures 8a and 8b). A phellogen must differentiate in some cases near the surface, but very often the tissue it produces is sloughed off. The surfaces of the primordia often appear to be suberized and some peripheral tissue sloughs off

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(Figure 9b).

It would seem that the tumors are formed because the processes of cell elongation and intercalary growth which would normally cause a stem to increase in length are somehow stopped. It is interesting to note in this connection that the growing points in the tumor tissue develop in a phyllotactic sequence (Figure 10).

A recent paper on radiation injury in barley from absorbed P^{32} is of particular interest here (24). It was found that when a meristematic region such as that of the root or stem tip was subjected to a constant, relatively high level of radiation from absorbed P^{32}, cell division ceased and the cells enlarged and took on an abnormally mature appearance.

Smith and Kersten (28) working with seedlings of Vicia faba grown from x-irradiated dry seeds found that there was little elongation in the root and that meristematic tissue such as cambium and pericycle actually degenerated.

In their study of ionizing radiations on the broad bean root, Gray and Scholes (13) found that after high dosages of x-irradiation (three-quarters of a mean lethal dose of x-rays) there was a slowing down of both mitosis and interkinesis in the meristematic region so that the rate of elongation was only about one-fourth normal. However, in the proximal half of the meristematic region cells continued to differentiate at roughly the normal rate but fresh cells were not formed in the distal half to maintain the constant total number of meristematic cells. The effect was "in the main one of mitotic inhibition combined with continued differentiation."

Other workers have observed injury to the meristematic regions in x-irradiated plants. Johnson (18) noted a change in the general aspect of the entire plant as a result of the greater development of lateral branches. This development of the laterals would indicate that the terminal meristem had been injured. In another article (19), she also states that a constant

effect of x-rays on seeds and seedlings of Helianthus annuus is the prod
of fasciation in stems, leaves and flowers.

At Brookhaven National Laboratory it is reported (3) that plants
to chronic irradiation in the "gamma field" are often severely stunted
Others show growth abnormalities such as the supernumerary buds in Trad

While it is well known that plants vary in their response to rad
we have found no previous record of radiation induced tumors such as th
described in this paper. However, as has been pointed out, a similar p
has been reported, i.e., a retarding of meristematic growth with contin
ferentiation; in the present case the phenomenon was carried to such a d
that large tumors resulted. The tumorous plants were limited on the te
to areas adjacent to the crater site where radioactivity was comparativ
A careful examination of stands of this species on several islands in
four atolls revealed no other cases of tumorous Ipomoea plants.

At the time the plants were collected a radiation survey of the
site was made by Seymour and Kellogg (30). At this time the survey me
corded 50,000 to 100,000 c/min. at the surface of the soil within the
question. A conservative estimation of the dosage received by the pla
then be somewhere between 0.1 and 10 rep/week* during August of 1949,
months after the actual bomb tests. Records of earlier levels of radi
and of the time when the plants first reestablished themselves are not

The tumors themselves were examined both by means of autoradiogr
by direct tissue count for radioactivity within them, but nothing more
traces of activity were present in the tissue mass. This is to be exp
the plant is a deep rooted one absorbing very little in the contaminat

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* Assuming Eav to be 1 mev.

layer. From the work of Jacobsen and Overstreet (17), it is known that fission products are absorbed onto roots but are not translocated in significant quantities to other parts of the plant. Therefore the external radiation which was received was predominatly beta radiation from the contaminated surface layer of the soil.

After careful consideration of all possible causal agents it seems highly probable that radiation is the cause of the tumorous growths on *Ipomoea*. However, it must be pointed out that we have not attempted to experimentally induce such tumors and that no radiation induced plant tumors have been previously reported in the literature to our knowledge. We feel justified, however, in concluding that the tumorous tissue herein described most nearly resembles radiation damaged tissue.

Acknowledgment. -

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Fig. 1—Ipomoea Tuba, Engebi Island. Area in which abnormal plants were found.

Fig. 2—Normal growth habit of Ipomoea tuba. Engebi Island.

Fig. 3—Tumorous growths at the basal nodes of the stem of Ipomoea tuba. Engebi Island.

Fig. 4—A tumorous Ipomoea plant, Engebi Island. There was very little elongation of the stem, but there is evidence of some recovery in the appearance of regenerated leaves.

Fig. 5a—Tumorous growths; about twice natural size.

Fig. 5b—(1) End of stem showing tumors and regeneration of leaves at the tip. (x 2).

(2) Tumorous mass showing dead primordia in the center and numerous living growing tips on either side.

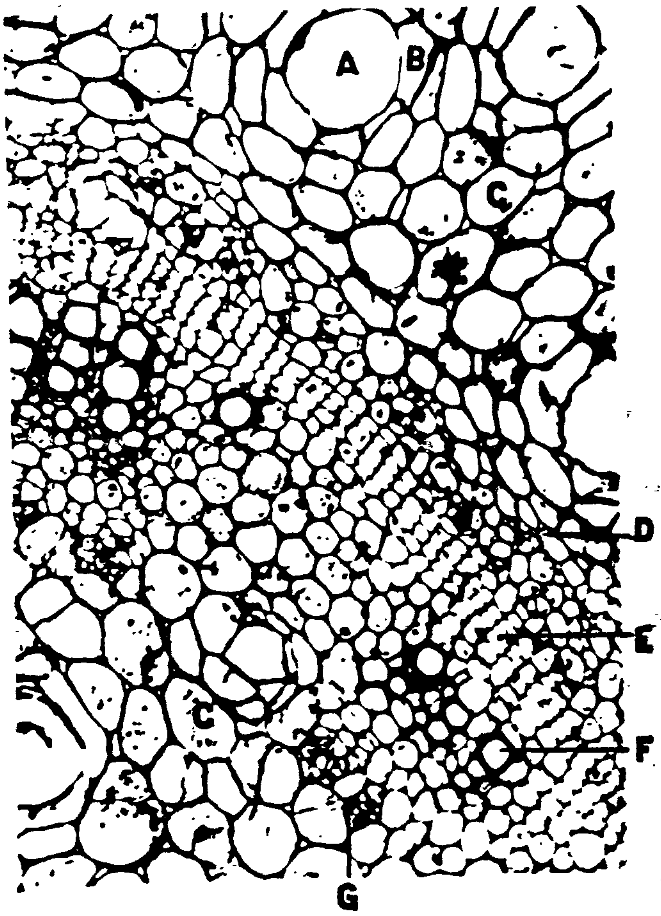

Fig. 6—Photomicrograph of segment of a cross section of the normal stem of Ipomoea tuba. (x 175). A, lacteriferous duct; B, secretory cell; C, parenchyma; D, external phloem; E, cambium; F, xylem; and G, internal phloem.

Fig. 7—Photomicrograph of normal growing tip. (x 145). A, young leaf; B, tunica; and C, corpus.

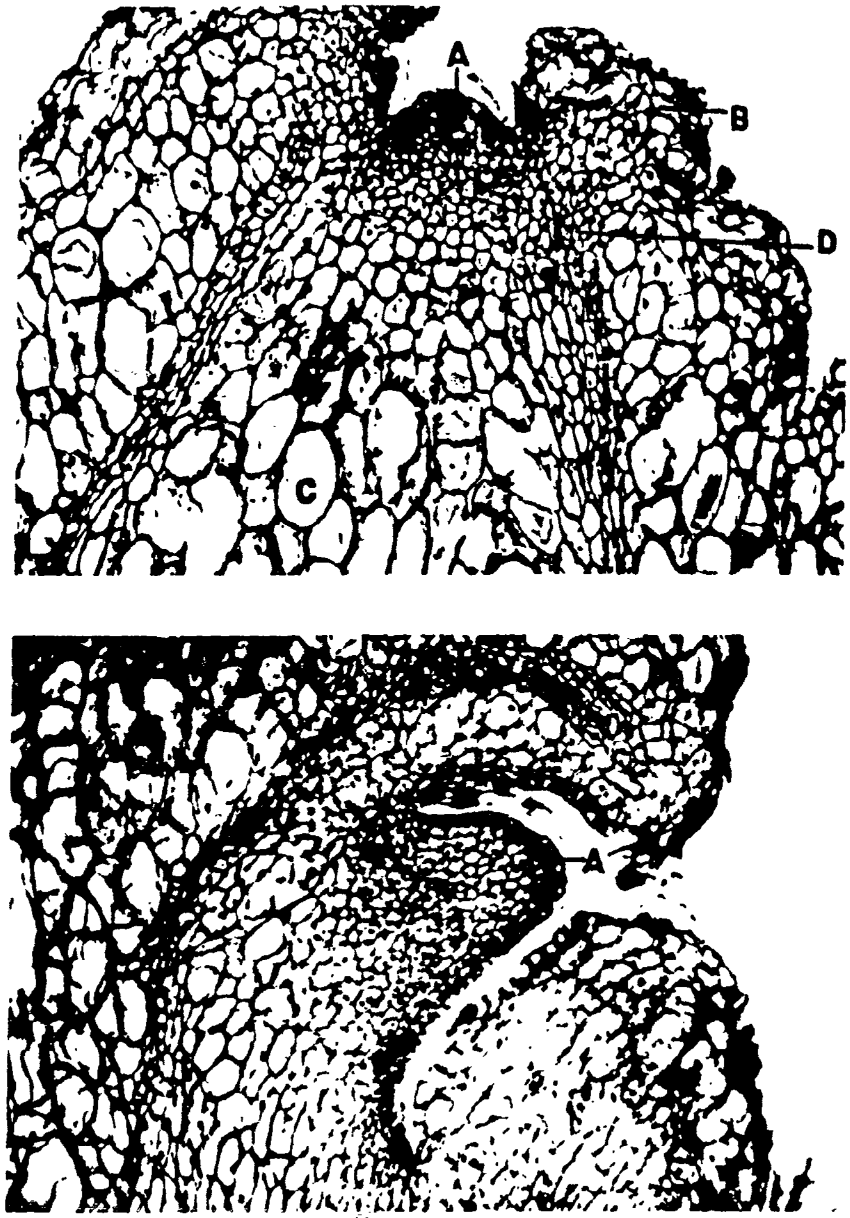

Fig. 8—Photomicrographs of abnormal primordia from tumors. (x 145). Primordia such as the two pictured here were among the more "normal" type found in the tumors. A, suberized surface cells; B, "young leaf"; C, parenchyma; and D, conducting tissue.

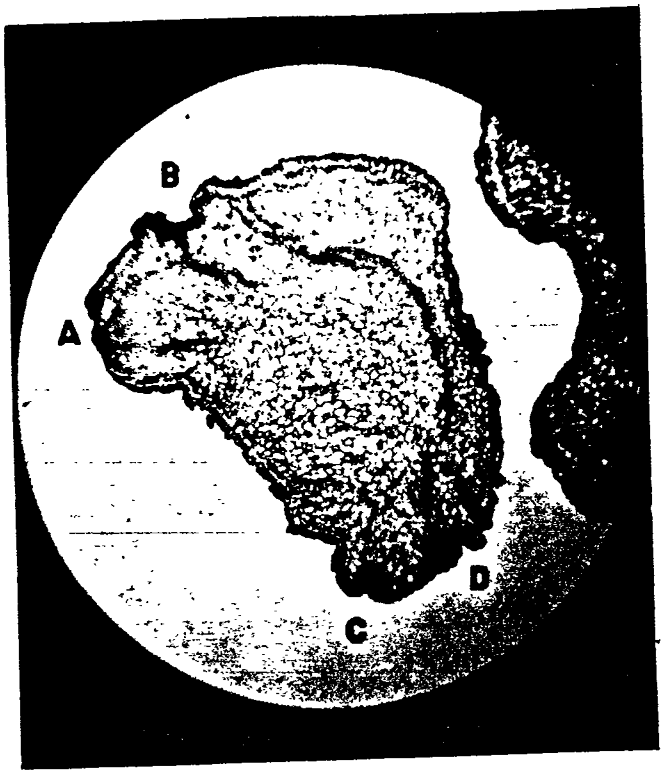

Fig. 9a—Photomicrograph of tumor section showing several primordia which had apparently ceased growth.

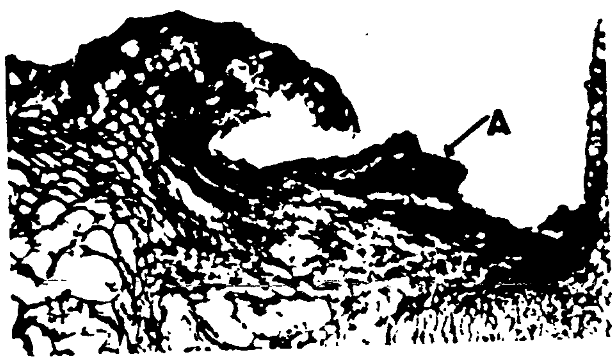

Fig. 9b—Photomicrograph of primordium at "B" above showing A, suberized surface which is being sloughed off. (x 145).

Fig. 10—Surfaces cut from tumors showing phyllotactic sequence of primordia.