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RADIOLOGICAL SURVEY OF PLANTS, ANIMALS AND SOIL AT CHRISTMAS ISLANDS AND SEVEN ATOLLS IN THE MARSHALL ISLANDS

PROGRESS REPORT FOR 1974 - 1975

JANUARY 1977

UNIVERSITY OF WASHINGTON
COLLEGE OF FISHERIES
LABORATORY OF RADIATION ECOLOGY
SEATTLE, WASHINGTON 98195

PREPARED FOR THE U. S. ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION
NEVADA OPERATIONS OFFICE UNDER CONTRACT NO. EY-76-S-08-0269

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HEALTH AND SAFETY

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By

Victor A. Nelson

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INTRODUCTION

The Division of Operational Safety or DOS (now Safety Standards and Compliance) portion of the Laboratory of Radiation Ecology (LRE) Pacific Radiocology Program (formerly Johnston Atoll Program) began on 1 July 1974 and is continuing. The purpose of this program is to determine the kinds and amounts of radionuclides distributed in the foods, plants, animals, and soil of the Central Pacific, especially the Marshall Islands, and to furnish these data to SSS/ERDA and other appropriate agencies (Lawrence Livermore Laboratory, Nevada Operations Office ERDA) so that they may make an assessment of the dose of ionizing radiation received by the people living throughout the Central Pacific. Here we report the results of the analyses of samples collected on five field trips conducted from April 1974 to August 1975 and analyzed by 31 December 1976. A list of previous reports and letters containing data included in this report is given in Table 1.

SAMPLING PROGRAM

The field trips noted above are listed in Table 2. Atolls visited in the Marshall Islands are shown in Figure 1. Christmas Island in the Line Islands is about 2000 miles east of the Marshall Islands. All the trips, except the trip to Christmas Island, were joint surveys with personnel from Brookhaven National Laboratory. Representative biological and soil samples were collected with emphasis on food items common to the diet of the Marshallese people (i.e., fish, coconut, pandanus, breadfruit, coconut crabs, etc.) although non-edible portions of these items were also collected and analyzed. Soils were collected to provide data for estimating future distribution and quantities of radionuclides in the environment and biota.

The number of samples, after division into tissues or soil fractions, is shown in Table 2. Over half the samples were biota-plants, fish, clams, and coconut crabs, while just under half were surface (0-2.5cm) and profile (0-100+cm) soil samples. Approximately one-third of the samples came from Bikini Atoll, one-third from Rongelap Atoll, and one-third from Christmas Island, and Wotho, Utirik, Kwajalein, Ailinginae, and Rongerik atolls.

In addition to the samples our Laboratory collected, personnel from Brookhaven National Laboratory collected samples,made TLD measurements and took radiation survey readings with sodium iodide (NaI) scintillation detectors and a pressurized ion chamber. The results of the Brookhaven analyses and measurements will be combined with the LRE results in a series of joint reports to the open literature.

ANALYTICAL METHODS

Gamma-Ray Spectrometry

All of the samples were analyzed by gamma-ray spectrometry, either with a 3"x3" sodium iodide (thallium drifted) crystal and 200-channel pulse-height analyzers or with a germanium (lithium drifted) diode detector and 4096-channel, pulse-height analyzer. Soil samples were analyzed on the Ge (Li) system, and the biological samples were analyzed on both systems.

Table 1. List of Reports and Letters Containing Data Included in this Report.

1. 3 July 1974

   Letter report from A. H. Seymour to Tommy McCraw (DOS), cc to John Stewart (NVOO - ERDA). Results of the γ-spectrum analysis of 57 samples from Bikini and Rongelap in April, 1974.

2. 14 March 1975

   Letter of V. A. Nelson to William Robison (Lawrence Livermore Laboratory) cc to Tommy McCraw (DOS/ERDA), Roger Ray (NVOO/ERDA). Results of analyses of samples collected at Bikini Atoll in April and December, 1974.

   Thirteen tables: 41 γ-spectrom analyses; 34 strontium-90; 34 plutonium; and 5 iron-55.

   For Bikini dose assessment study by LLL.

3. 11 July 1975

   Letter of V. A. Nelson to Robert Conard (Brookhaven National Laboratory). Results of the analyses of 36 blood samples collected at Utirik and Rongelap Atoll in April 1974.

   Iron-55 and iron on all 36 samples.

4. 31 July 1975

   Letter of V. A. Nelson to Paul Gudiksen (LLL) cc Roger Ray (NVOO/ERDA), Tommy McCraw (DOS/ERDA). Results of the gamma-spectrum analysis of 64 soil samples collected on Bikini Island in April and December, 1974.

   For Bikini dose assessment study by LLL

5. 26 September 1975

   Preliminary report, "Radiological Surveillance of Christmas Island, August, 1975," by A. H. Seymour.

   Sent to W. S. Brown, General Manager, Gilbert and Ellice Islands Development Authority and to Tommy McCraw (DOS/ERDA)

   Results of 30 γ-spectrum analyses of samples collected on Christmas Island in August, 1975.

6. 16 June 1976

   Oral presentation by V. A. Nelson to Tommy McCraw and Joe Deal (DOS/ERDA).

   Results of 404 γ-spectrum analyses; 302 ^{90}Sr analyses, and 26 Pu analyses completed on samples collected in the Marshall Islands in 1974 and April, 1975

   (31 tables of data were left at DOS)

7. 9 September 1976

   Letter from V. A. Nelson to John Stewart (NVOO/ERDA).

   Results of 254 γ-spectrum analyses and 159 Pu analyses of soil samples [illegible]

8. 15 September 1976

   Letter from V. A. Nelson to William Robison (LLL)

   Results of 54 γ-spectrum analyses, 51 strontium-90 analyses and 35 Pu analyses on samples collected at Bikini Atoll in December 1974 and April 1975.

   For Bikini dose assessment study by LLL.

9. Late 1976

   Paper by A. Nevissi, W. R. Schell and V. A. Nelson

   "Plutonium and Americium in Soils of Bikini Atoll," pp 691-701

   In Transuranium Nuclides in the Environment.

   IAEA STI/PUB/410 Vienna, Austria

Table 2. Field Trips Conducted by LRE From April, 1974, to August, 1975, as Part of the DOS Portion of the Pacific Radioecological Program.

Date	Atolls Sampled	Samples Processed[a]				Samples Analyzed			
		Plants	Soil	Marine	Coconut Crab	γ	^{55}Fe	^{90}Sr	Pu
April, 1974	Utirik, Rongelap, Bikini	0	40	28	30	~100	5	62	27
November, December, 1974	Utirik, Rongerik, Rongelap, Ailiniginae, Bikini	46	177	48	25)	~440	~65	~270	~160
April, 1975	Kwajalein, Bikini, Wotho	35	67	32	6)				
June, 1975[b]	Bikini	0	0	0	0	0	0	0	0
August, 1975	Christmas Island	21	8	25	3[c]	57	0	0	0
	TOTAL	102	292	135	63	~600	~70	~330	~200

a. The number given is the total after the samples have been divided into tissues.

b. One man from LRE was part of a 20-man survey team coordinated by Lawrence Livermore Laboratory. All samples collected were analyzed by LLL.

c. Hermit crab and a land crab.

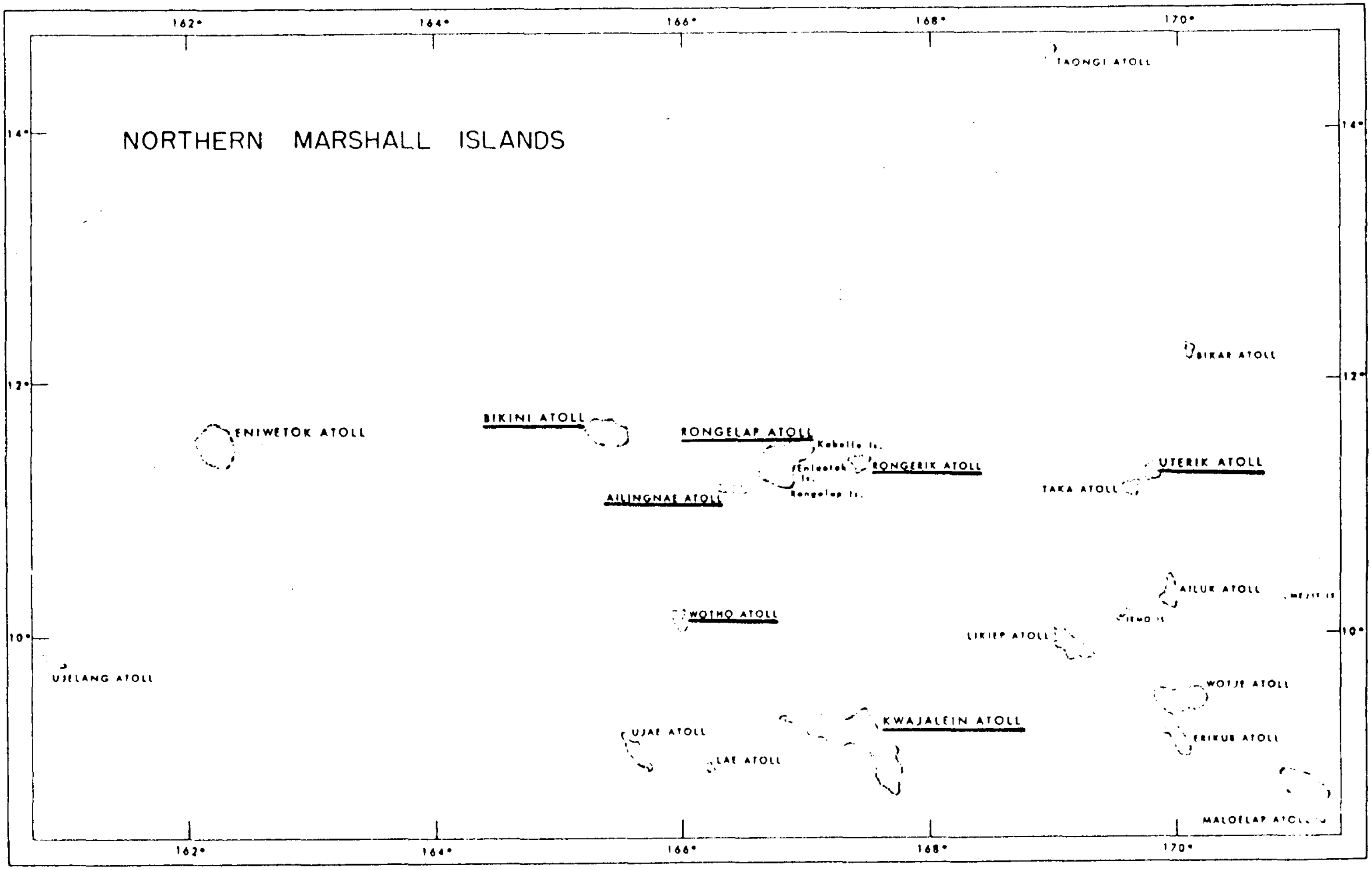

Figure 1. Sampling locations (underlined) in the northern Marshall Islands, 1974-1975.

All samples were oven-dried, ground and a portion compressed in polyvinyl chloride (PVC) pipe 2 inches in diameter and either ½" or 1" inch deep that was used as a sample holder for radionuclide measurement. Fifty grams of tissue or 68 grams of soil could be compressed into the 2" x 1" container. The density of the biological and soil samples was 1.0 and 1.35, respectively. These samples were then analyzed for gamma-emitting radionuclides.

The gamma-emitting radionuclides in the samples counted on the NaI crystal were determined by a method of least squares. The radionuclides values in the samples counted on the Ge (Li) detector were calculated by hand or with a computer by adding the counts in five channels under a peak in the spectrum, subtracting the appropriate background counts, and applying correction factors to convert counts to picocuries (pCi). A set of previously reported reference spectra for the different geometries and radionuclides were used. All values were corrected for decay to the date of collection.

Iron-55, Strontium-90 and Plutonium Analyses

Solvent extraction, electrodeposition, and X-ray spectrometry were used for ^{55}Fe determinations. To measure ^{90}Sr content, ^{90}Y was chemically separated from ^{90}Sr, collected on a filter paper and counted with a low-level beta counting system. Plutonium was extracted by ion exchange, electroplated on platinum discs, and analyzed by alpha spectrometry with systems using surface barrier alpha detectors and pulse-height analyzers. Chemical yield was determined by use of ^{242}Pu as a tracer.

Error Limits

For a single sample, the error given for all radionuclides listed, except ^{90}Sr, ^{55}Fe and $^{239,240}Pu$, are two-sigma, propagated, counting errors. The error values for ^{90}Sr, ^{55}Fe, and Pu includes the two-sigma counting error and an analytical error. The error term for more than one sample is one standard deviation and disregards counting error.

Limits of Detection

Many factors influence the limit of detection, including the type of detector and analyzer, the presence of other radionuclides, the duration of the counting period, the size and density of the sample, and the geometry relationship of the sample and detector. Hence, the limits of detection varied considerably for various radionuclides and types of samples, but can be summarized by stating that the detection limits were approximately as follows:

By gamma detection

^{40}K	2.1 pCi/g or less
^{238}U	0.41 " "
^{102m}Rh, ^{125}Sb, ^{137}Cs, ^{152}Eu, ^{155}Eu, ^{207}Bi, ^{235}U, ^{241}Am	0.12 pCi/g or less

By beta detection

^{90}Sr	0.2 pCi/g or less

By X-ray detection

^{55}Fe	0.04 pCi/g or less

By alpha detection

$^{239,240}Pu$	0.02 pCi/g or less

RESULTS

Data are presented for the results of the analyses of the samples collected by LRE in the Marshall Islands in 1974 and 1975 and on Christmas Island in 1975. Appendix Tables 1 through 37 give the data for single samples. Tables 3 through 6 and Figures 3 through 7 in the text present summarized data usually in the form of the mean ± 1 standard deviation for several samples. The data will first be presented atoll by atoll and will then be summarized by comparisons between atolls by selected sample types. All data are given as picocuries per gram of dry weight, except where expressly noted.

Christmas Island

The sites at which samples were collected in August, 1975, are shown in Figure 2. Samples were analyzed for gamma-emitting radionuclides only. Seventeen naturally occurring or fallout radionuclides were detected in the samples analyzed, but only naturally occurring ^{40}K and ^{238}U, and the fallout radionuclide ^{137}Cs were present in more than 20% of the samples. Values for these three radionuclides are given in Appendix Tables 1 (plants), 2 (fish and invertebrates) and 3 (soil). Usually ^{40}K was the most abundant radionuclide in a sample and of the eleven fallout radionuclides detected only ^{137}Cs was present in concentrations greater than 1 pCi/g. Levels of ^{137}Cs above 1 pCi/g occurred only in Scaevola leaves (5.7 pCi/g) and unidentified leaves (32 pCi/g) from plants collected near the airfield wash-sump and in bone (1.6 pCi/g) from bonefish taken off London. The airfield wash-sump was used during the Dominic test series in 1962 to receive the wash-down water from aircraft used to collect air samples from the radioactive clouds produced by the detonations.

The results of these analyses indicate, as noted by Seymour (1975), that "only trace quantities of fallout radionuclides are present at Christmas Island and the amounts are significantly less than the naturally occurring radionuclides."

Kwajalein and Wotho Atolls

Samples from Kwajalein and Wotho atolls were collected incidental to a trip to Bikini Atoll in April 1975. Results of the analyses of these samples of plants, soil and coconut crabs for gamma-emitting radionuclides, ^{90}Sr and $^{239,240}Pu$ are given in Appendix Tables 4 (Wotho), 5 (Kwajalein) and 6 (Kwajalein coconut crabs). Naturally occurring ^{40}K is the most abundant radionuclide present in the plant samples. Concentrations of ^{40}K in pCi/g (dry) weight ranged from 2.4 in breadfruit leaves from Wotho to 40 in coconut milk from Rigej Island in Kwajalein Atoll. Cesium-137 was the predominant fallout radionuclide. Most plant tissues had between 0.5 and 2.5 pCi of ^{137}Cs per gram of dry weight. The seeds and rind of a papaya fruit from Wotho Island had 12 and 15 pCi of $^{137}Cs/g$. Strontium-90 levels were less than 1 pCi/g and $^{239,240}Pu$ values ranged from 0.03 to less than 0.002 pCi/g in plants from both atolls. Soil levels were slightly higher with a maximum of 0.16 pCi/g

TABLE 3. Mean concentration of ^{137}Cs, ^{90}Sr, ^{241}Am, and $^{239,240}Pu$ in the top 10 cm of soil from the soil profiles on Bikini Island.

Profile	Mean Radionuclide Concentration in pCi/g, dry ± SD [a]			
	^{137}Cs	^{90}Sr	^{241}Am	$^{239,240}Pu$
1	36 ± 6.2	19 ± 2.5	0.7 ± 0.2	0.5 ± 0.1
2	23 ± 2.5	15 ± 6.4	0.6 ± 0.2	0.8 ± 0.1
3	250 ± 120	250 ±110	9.9 ± 4.8	5.9 ± 3.8
9	53 ± 28	60 ± 11	2.4 ± 1.3	4.3 ± 2.1
10	230 ± 22	440 ± 38	11 ± 1.7	26 ± 5.8
11	9.6± 5.2	12 ± 3.8	0.2 ± 0.1	0.4 ± 0.2
12	120 ± 20	210 ± 67	7.6 ± 1.9	18 ± 5.8
A	46 ± 30	61 ± 14	1.7 ± 1.3	4.0 ± 3.3
C	14 ± 18	46 ± 34	0.9 ± .9	0.9 ± 1.7
D	80 ± 51	150 ± 31	11 ± 5.3	11 ± 15
E	57 ± 6.8	99 ± 15	3 ± 0.6	6.7 ± 1.3
G	45 ± 13	38 ± 1.9	2.7 ± 0.1	3.8 ± 2.0
I	168 ± 31	110 ± 41	7.9 ± 1.6	na
L	150 ± 11	280 ± 67	19 ± 4.8	38 ± 8
N	42 ± 25	35 ± 20	4.4 ± 3.0	8 ± 8

a. The error term is one sample standard deviation of the values for the three incremental samples - 0 to 2.5, 2.5 to 5, and 5 to 10 cm - used to compute the mean. The value for the increment from 5 to 10 cm was weighted twice as heavily as the other two incremental values.

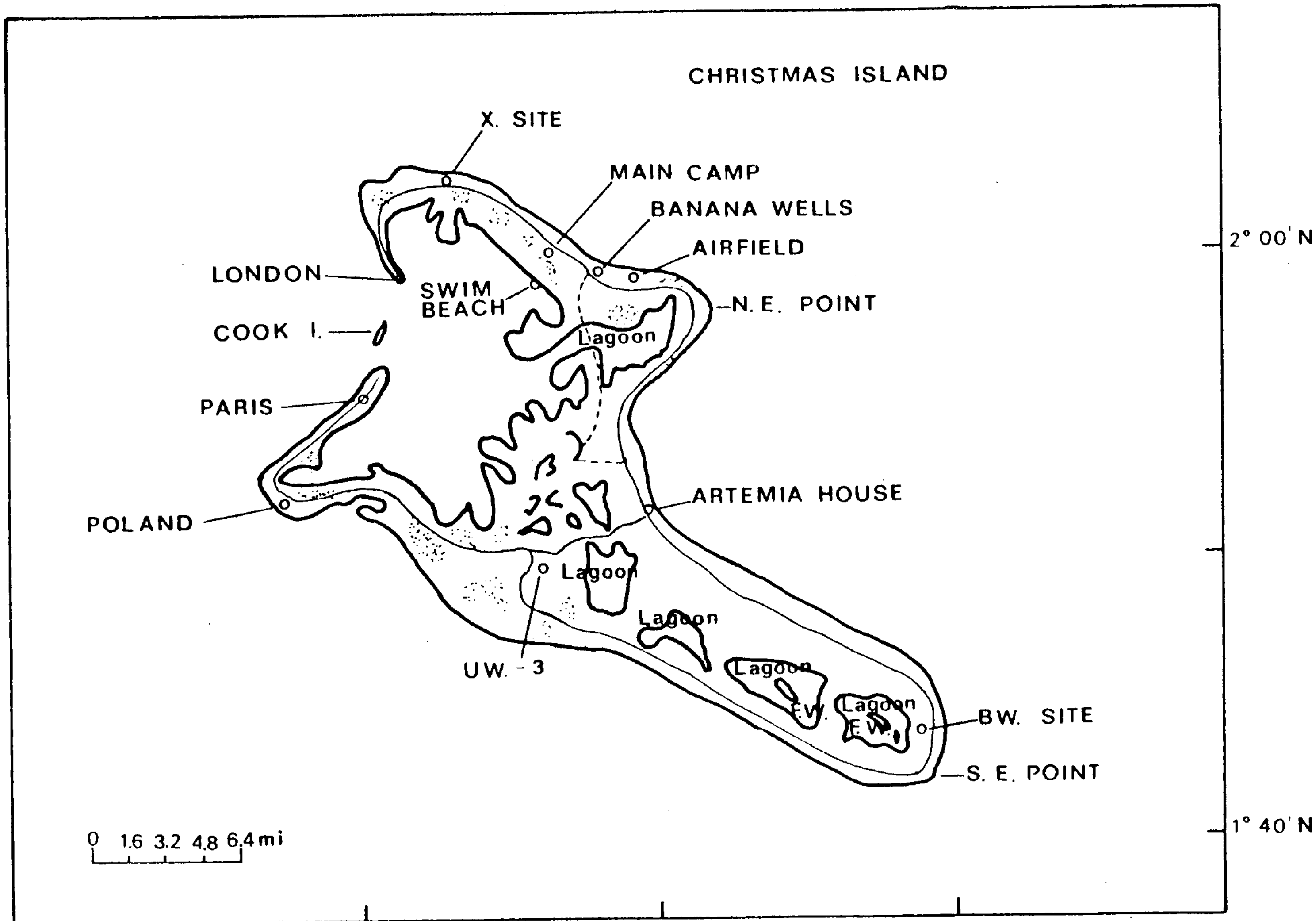

Figure 2. Christmas Island Sampling Stations, August 1975 (from Seymour, 1975)

in the surface soil samples from Wotho.

Ailiginae Atoll

Samples of soil, plants and fish were collected at Ailinginae Atoll in December, 1974. All samples were analyzed for gamma-emitting radionuclides and selected samples were analyzed for ^{90}Sr and ^{239,240}Pu. The results of these analyses are shown in Appendix Tables 7 (soil), 8 (plants), and 9 (fish).

Six fallout radionuclides, ^{60}Co, ^{137}Cs, ^{155}Eu, ^{241}Am, Pu, and ^{90}Sr, were easily measured in the soil samples from Ailinginae. Maximum values for all of these radionuclides were found in surface soil sample #1 from Ucchuwanen. These values in pCi/g of dry weight were as follows: ^{60}Co (0.9) ^{137}Cs (44), ^{155}Eu (2.6), ^{241}Am (3.6), ^{239,240}Pu (7.1) and ^{90}Sr (11). In this and other samples ^{137}Cs and ^{90}Sr were the most abundant radionuclides. Values for these two radionuclides were usually between 1 and 10 pCi/g and their ratio within a single sample was usually near 1. The mean value for ^{239,240}Pu in the five surface samples analyzed was 3.5 pCi/g.

In the plants from Ailinginae ^{40}K was the most abundant radionuclide averaging 12 pCi/g, while ^{137}Cs was the fallout radionuclide present in the highest concentration ranging from 2.9 to 15 pCi/g. Strontium-90 was the only other fallout radionuclide which was easily detectable in all the samples. Values for ^{90}Sr ranged from 1.6 to 7.1 pCi/g of dry weight and averaged 3.5 pCi/g, dry. Plutonium was not detectable in the single plant sample analyzed.

Five species of fish from Ailinginae were analyzed for gamma-emitting radionuclides and ^{90}Sr. Naturally occurring ^{40}K was measured in all the samples in concentrations ranging from 0.5 to 10 pCi/g of dry weight. Cesium-137 and ^{60}Co were the only fallout radionuclides detected in more than 50% of the samples and all values were less than 0.4 pCi/g. Strontium-90 values were less than the detection limits (0.1 to 0.8 pCi/g) for the method of analysis and sample size we used.

Two coconut crabs were collected at Ailinginae. Potassium-40 and ^{90}Sr levels were almost equal. In the muscle ^{137}Cs values were 12 pCi/g while ^{90}Sr values were less than 0.5 pCi. The exoskeleton had ^{90}Sr levels of 22 and 42 pCi/g. The two edible hepatopancreas samples had ^{137}Cs levels of 3.1 and 12 pCi/g, but ^{90}Sr values were 0.3 pCi/g.

Rongerik Atoll

Soil, plants, and fish were collected on and around Eniwetak Island, Rongerik Atoll, in November 1974. All samples were analyzed for gamma-emitting radionuclides and selected samples were analyzed for ^{90}Sr and/or Pu. Results of the analyses are given in Appendix Tables 6 (coconut crabs), 8 (plants), 9 (fish), 10 (soil) and 11 (soil).

Of the seven fallout radionuclides commonly found in the surface soil samples ^{137}Cs and ^{90}Sr were present in the highest concentrations. Cesium-137 values ranged from 1.9 to 55 pCi/g of dry soil, while ^{90}Sr values ranged from 7 to 35 pCi/g. Mean values for ^{137}Cs and ^{90}Sr were 19±16 and 18±11 pCi/g, respectively. The ^{137}Cs/^{90}Sr ratio for the surface samples in Appendix Table 9 was 0.9±0.3. Plutonium -239, 240, ^{241}Am and ^{155}Eu concentrations for these six samples averaged 3.9±2.5, 2.5±1.3, and 1.9±1 pCi/g, respectively. Cobalt -60 and ^{125}Sb values were less than 0.9 pCi/g (dry).

Pandanus and coconut samples contained, as is common for plants from the Marshall Islands, naturally occurring ^{40}K and fallout radionuclides ^{137}Cs and ^{90}Sr. Of the three *Pandanus* and three coconut tissues analyzed, the edible fruit of the *Pandanus* had the highest ^{137}Cs values, 15 to 31 pCi/g. Strontium-90 was highest in the leaves of the *Pandanus*. Plutonium levels were below the limits of detection.

Three species of fish were collected at Rongerik Atoll. Potassium-40 was the only radionuclide present in quantities above 0.6 pCi/g. Cobalt-60 and ^{137}Cs levels were less than 0.6 pCi and ^{90}Sr values were below the limits of detection.

The $^{137}Cs/^{40}K$ ratio in the three coconut crabs from Rongerik was 2.5±0.6. Cesium-137 values in the muscle and hepatopancreas averaged 29 and 10 pCi/g, (dry) except in one hepatopancreas sample which had a concentration of 4.3 pCi/g. In the exoskeleton ^{90}Sr levels averaged 44±5 pCi/g, while ^{137}Cs levels ranged from 2.5 to 3.5 pCi/g.

Utirik Atoll

In April and November, 1974, samples of soil, plants and marine organisms were collected at Utirik Island. These samples were analyzed for gamma-emitting radionuclides and some were also analyzed for ^{90}Sr and/or Pu. Results are shown in Appendix Tables 9 (fish), 12 (soil), 13 (plants), and 14 (clams).

Five surface soil samples collected in the interior of Utirik Island had radionuclide concentrations of less than one pCi/g except for ^{137}Cs and ^{90}Sr values which averaged 2.8±1.6 and 2.7±1.7 pCi/g, respectively.

The edible fruit from a *Pandanus* plant located near the center of Utirik Island had a ^{137}Cs level of 67 pCi/g. No other fallout radionuclides were above the limits of detection. Bananas from Utirik had low levels of fallout (0.5 pCi/g or less) in the edible portion of the fruit.

The marine organisms, fish and *Tridacna* clams, collected in the lagoon near Utirik Island had low levels (<1pCi/g) of the three fallout radionuclides (^{60}Co, ^{90}Sr and ^{137}Cs) measured. Naturally occurring ^{40}K values averaged about 8 pCi/g in the tissues of fish and clams.

Rongelap Atoll

Samples of soil, plants, fish, clams, and coconut crabs were collected on several islands of Rongelap Atoll in April and November/December, 1974. All samples were analyzed for gamma-emitting radionuclides and selected samples for ^{90}Sr and Pu. Results of these analyses are shown in Appendix Tables 6 (coconut crabs), 9 (fish), 13 (plants), 14 (*Tridacna* clams), and 15 through 21 (soil).

Coconut crabs were collected from six islands in Rongelap Atoll. Four were from the southern islands of Arbar and Busch (lowest radiation levels at Rongelap), five were from the northeastern islands of Mellu and Kabelle (medium radiation levels) and four were from the northern islands of Lukuen and Lomuilal (highest radiation levels). The mean ^{137}Cs and ^{90}Sr levels in the muscle tissue of the coconut crabs is shown in Figure 3. Levels of ^{90}Sr and ^{137}Cs are highest in coconut crabs collected on the northern and northeastern islands of Rongelap Atoll.

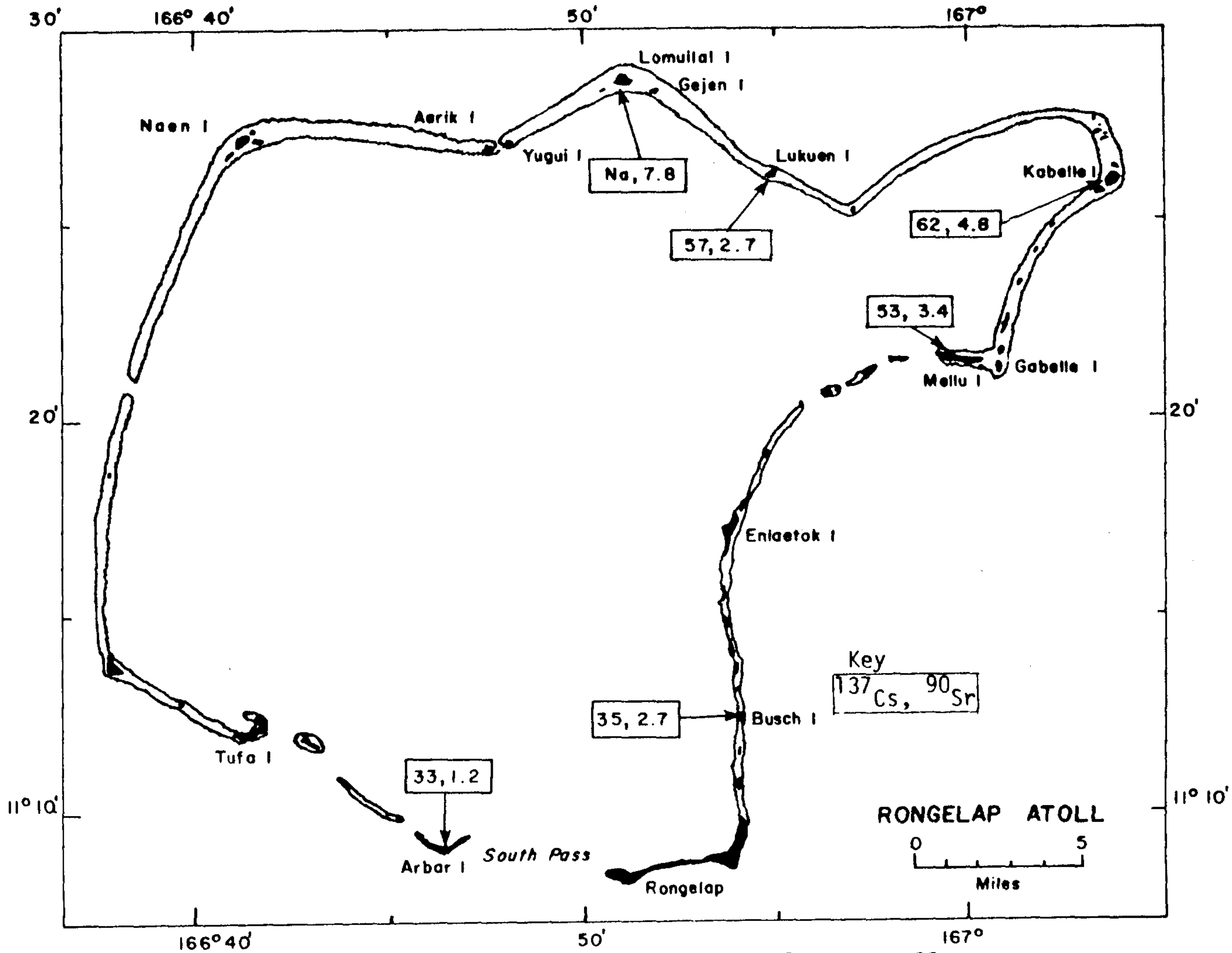

Figure 3. Mean concentration, in pCi/g, dry weight, of ^{137}Cs and ^{90}Sr in the muscle of coconut crabs from Rongelap Atoll, 1974.

Six species of fish were collected from three sites in the lagoon at Rongelap Atoll. Naturally occurring ^{40}K was the predominant radionuclide detected. Concentrations of ^{40}K averaged 10 pCi/g. Values of the three fallout radionuclides measured, ^{60}Co, ^{137}Cs, and ^{90}Sr were less than 1 pCi/g, except for the viscera of mullet which had ^{90}Sr levels of 1.1 and 2.7 pCi/g.

Tridacna clams from the lagoon off Rongelap and Kabelle Islands contained ^{60}Co as the only significant fallout radionuclide. Cobalt-60 levels were highest (11 pCi/g) in the kidney and low in the mantle and muscle. Potassium-40 in the tissues of these clams averaged 7.8±1.4 pCi/g.

Plants from Rongelap contained ^{137}Cs and ^{90}Sr in greater quantities than ^{40}K. The ^{40}K concentration in Pandanus leaves was 4.4±1.8 pCi/g while the ^{137}Cs and ^{90}Sr concentrations were 33±19 and 30±17 pCi/g (dry), respectively. Plants from the northern islands of Lukuen and Lomuilal had higher levels of ^{90}Sr and ^{137}Cs than did similar plants from Rongelap Island in the southern part of the atoll.

Soil samples were collected from six islands in Rongelap Atoll. Five gamma-emitting radionuclides, ^{60}Co, ^{125}Sb, ^{137}Cs, ^{155}Eu and ^{241}Am, were measured in most samples. Strontium-90 and $^{239,240}Pu$ were also easily measured in the samples analyzed for these radionuclides. Cesium-137 and ^{90}Sr were the most abundant of the above radionuclides as shown in Figure 4. Americum-241, $^{239,240}Pu$, and ^{155}Eu were the next most abundant radionuclides. They were commonly present in concentrations between 10 and 50 pCi/g while ^{60}Co and ^{125}Sb values were less than 10 pCi/g. At Rongelap Atoll, soil from the northern islands of Lomuilal, Lukuen and Gejen had the highest radionuclide values of the six islands sampled. The amounts of radionuclides in soil from Rongelap Island were about a factor of ten lower than amounts in soil from the northern islands.

Bikini Atoll

Samples were collected at Bikini Atoll in April and December 1974 and in April 1975 for analysis in our Laboratory. One coconut crab, Tridacna clams, nine species of fish, plants, and extensive soil profiles were taken for gamma-spectrum analysis. Selected samples were analyzed for ^{55}Fe, ^{90}Sr, or Pu. Results of these analyses are shown in Appendix Table 6 (coconut crabs), 14 (Tridacna clams), 22 and 23 (fish), 24 and 25 (plants), and 26 through 37 (soil).

1. Animals and plants

A single coconut crab captured on Bikini Island by an inhabitant of the island was purchased by us in 1974. In the muscle from this large crab the ^{137}Cs and ^{90}Sr values were 380 and 16 pCi/g of dry weight, respectively. Sixteen hundred pCi of ^{90}Sr per gram were found in the exoskeleton of this crab. Plutonium-239, 240 concentrations in the three tissues analyzed were about 0.02 pCi/g. Few coconut crabs remain on Bikini Island due to the destruction of the native vegetation during the rehabilitation of the island.

Tridacna clams from the lagoon near Bikini Island contained ^{60}Co in kidney tissue in amounts up to 322 pCi/g of dry weight. Cobalt-60 concentrations in the other tissues from this clam were less than 20 pCi/g. Values for other fallout radionuclides including ^{90}Sr and $^{239,240}Pu$ were less than

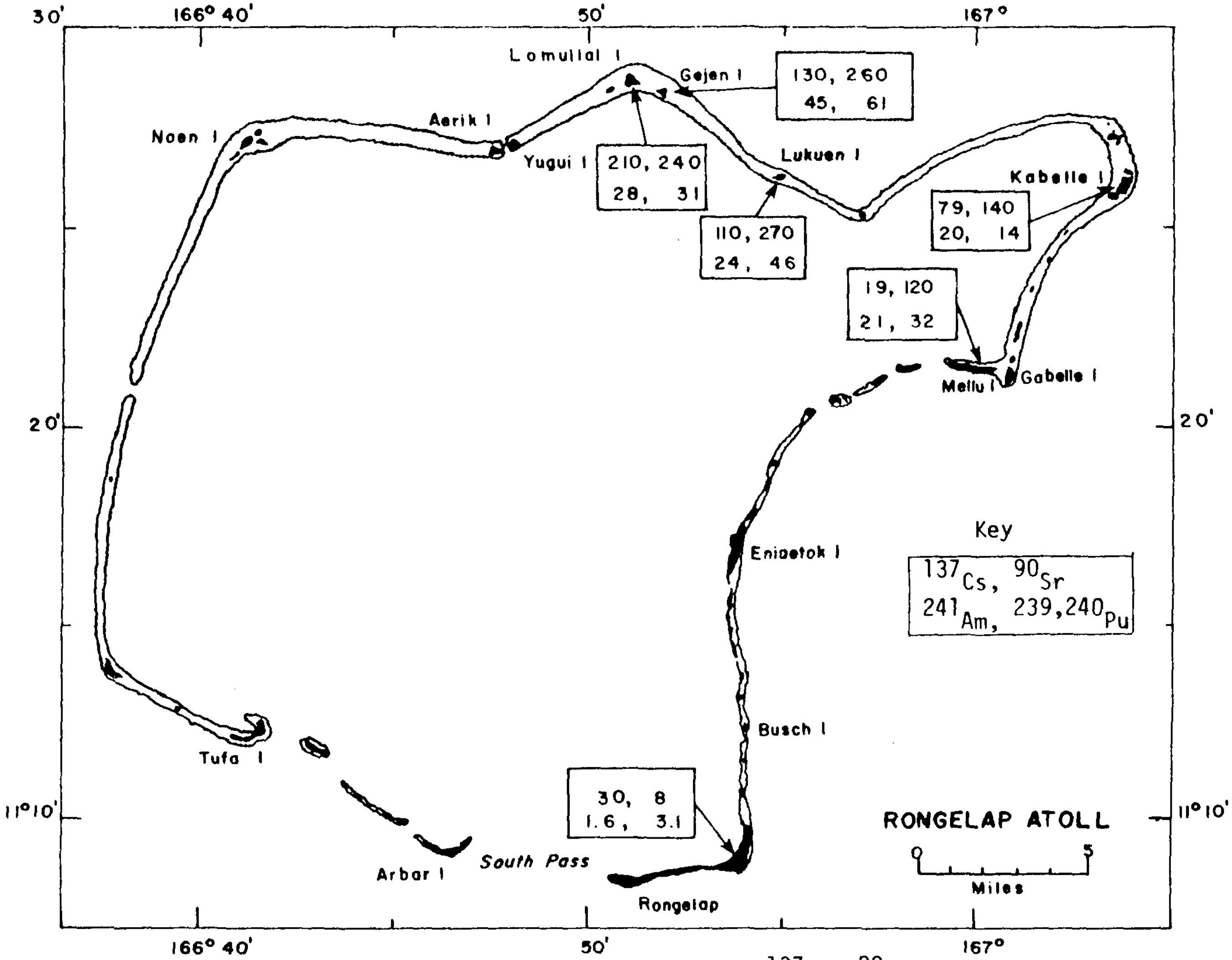

Figure 4. Mean concentration in pCi/g, dry weight of ^{137}Cs, ^{90}Sr, ^{241}Am, $^{239,240}Pu$ in surface (0-2.5cm) soil samples from Rongelap Atoll, December 1974.

0.3 pCi/g.

Nine species of fish were collected from four sites at Bikini Atoll. Of the fallout radionuclides commonly detected (^{55}Fe, ^{60}Co, ^{137}Cs, ^{90}Sr, and $^{239,240}Pu$) iron-55 was the most abundant with values up to 520 pCi/g of dry weight. Concentrations of ^{60}Co ranged up to 16 pCi/g of dry viscera from mullet collected near Bikini Island. Most of the other tissues contained less than 5 pCi of ^{60}Co per gram. Cesium-137 values were mostly below 1 pCi/g, however, the convict surgeon from Nam contained about 4.5 pCi of ^{137}Cs per gram. Most of the fish tissues analyzed also contained less than a pCi/g of ^{90}Sr and $^{239,240}Pu$. The highest values of ^{90}Sr (2.6 pCi/g) and $^{239,240}Pu$ (5.6 pCi/g) were measured in the viscera of mullet from Nam. Other than ^{55}Fe, naturally occurring ^{40}K was the most abundant radionuclide in the fish tissues analyzed. The average value of this radionuclide was 9 pCi/g versus 47, 2.6, and 0.65 pCi/g for ^{55}Fe, ^{60}Co and ^{137}Cs, respectively.

Although coconut, <u>Pandanus</u>, and breadfruit seedings have been planted on Bikini Island, only a few of the plants had begun to bear fruit in 1974 or 1975. Thus, most of the plant tissues sampled were leaves from these young plants. Results of the analyses of the plant samples are given in Appendix Tables 24 and 25. Cesium-137 was the most abundant radionuclide in most of the plant samples. Concentrations of ^{137}Cs in 15 samples of coconut fronds ranged from 58 to 649 pCi/g (dry) and averaged 154 pCi/g. The highest ^{137}Cs value was in the first <u>Pandanus</u> fruit produced on one of the new plants. Even though it was immature, the <u>Pandanus</u> fruit was picked and analyzed. The inedible portion of the fruit had a ^{137}Cs level of 3,670 pCi/g, while the edible portion had 3,520 pCi of ^{137}Cs and 255 pCi of ^{90}Sr. Of the plant tissues analyzed ^{90}Sr levels were highest (251 to 446 pCi/g) in the leaves of the new breadfruit plants.

Cesium-137 values in coconut leaves were usually greater than the ^{137}Cs value in surface soil from the same area. The highest ^{137}Cs values in plants were not, however, from the areas having the highest ^{137}Cs concentration in the soil. In fact one of the higher ^{137}Cs values was in coconut fronds from the area (Pit #11) which had the lowest ^{137}Cs value in the surface soil.

Plutonium-239,240 values were less than 1 pCi/g in the plant tissues sampled and were less than 0.05 pCi/g in the edible portions of the plants analyzed.

2. Soil

Both profile and surface soil samples were taken from Bikini, Enidrik and Nam Islands. Most of the samples were analyzed for gamma-emitting radionuclides, ^{90}Sr,* and plutonium,* while selected samples were analyzed for ^{55}Fe. Results of all analyses, except ^{55}Fe, are shown in Appendix Tables 26 through 32 (Bikini), 33 (Enidrik) and 34 through 36 (Nam). Results of the ^{55}Fe analyses are in Appendix Tables 27, 28 and 37. The locations of the soil profiles on Bikini Island are shown on Figure 5.

As found in past surveys on Bikini Atoll, most of the fallout

*Some of the analyses for ^{90}Sr and Pu were performed by McClellan Central Laboratory, Sacramento, California

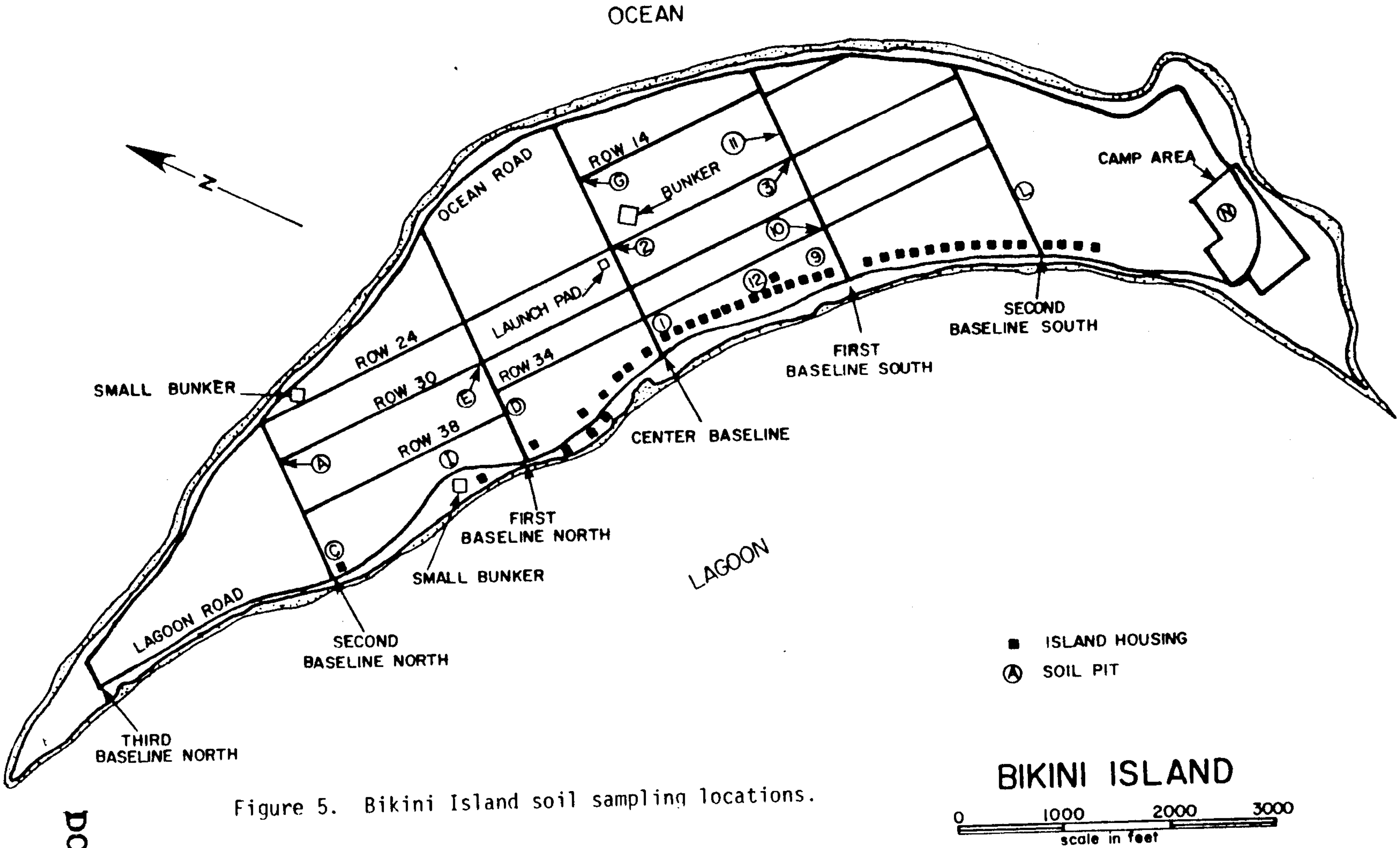

Figure 5. Bikini Island soil sampling locations.

radionuclides are in the top 15 cm of the soil; however, in some disturbed areas of Bikini Island (i.e., Profiles #1 and N) significant quantities of some radionuclides, especially ^{90}Sr, are found as much as one meter below the surface. The decline of ^{90}Sr (figure 6) concentration with depth is shown for a profile in disturbed (N) and relatively undisturbed (#9) areas on Bikini Island. In an undisturbed profile Pu, Am, and Eu values decrease the fastest and ^{90}Sr values decrease least rapidly with depth.

The mean concentrations of ^{137}Cs, ^{90}Sr, and ^{241}Am and $^{239,240}Pu$ in the top 10 cm of soil from the soil profiles on Bikini Island are given in Table 3. Values in this table are the means of the incremental samples - 0 to 2.5, 2.5 to 5, and 5 to 10 cm - from a profile with the 5 to 10 cm value weighted twice as heavy as the other values. Radionuclide levels are highest in the south-central part of the island (profiles 3, 10 and L) and in the area of the main garden (profile 12). Strontium-90 was the most abundant radionuclide followed in order of decreasing abundance by ^{137}Cs, $^{239,240}Pu$, ^{241}Am, ^{155}Eu, ^{60}Co and ^{125}Sb.

Limited soil collections made on Enidrik Island show a slightly different pattern of radionuclide abundance (Appendix Table 33). Plutonium-239,240 was more abundant than ^{90}Sr at 2 of 4 sites, and ^{102m}Rh was more abundant at one site.

Radionuclides in soils from Nam were present in greater quantities (i.e. ^{90}Sr, 1,160 pCi/g; $^{239,240}Pu$, 637pCi/g; ^{241}Am, 470pCi/g, dry) than on Bikini Island, but the relative abundance of the radionuclides in soil from Nam was the same as in the soil from Bikini. Iron-55 values in soil from Nam are also higher than in Bikini soil.

A sample of noddy and sooty terns was also collected on Nam. The muscle of these birds contained the following radionuclides: ^{137}Cs, <0.1; ^{60}Co, 0.9; ^{90}Sr, 0.04; and ^{40}K, 8.5 pCi/g, dry weight. The eggs of these birds contained ^{137}Cs (0.1 pCi/g), ^{40}K (4.2 pCi/g), ^{60}Co (0.06 pCi/g) and ^{90}Sr (0.07 pCi/g).

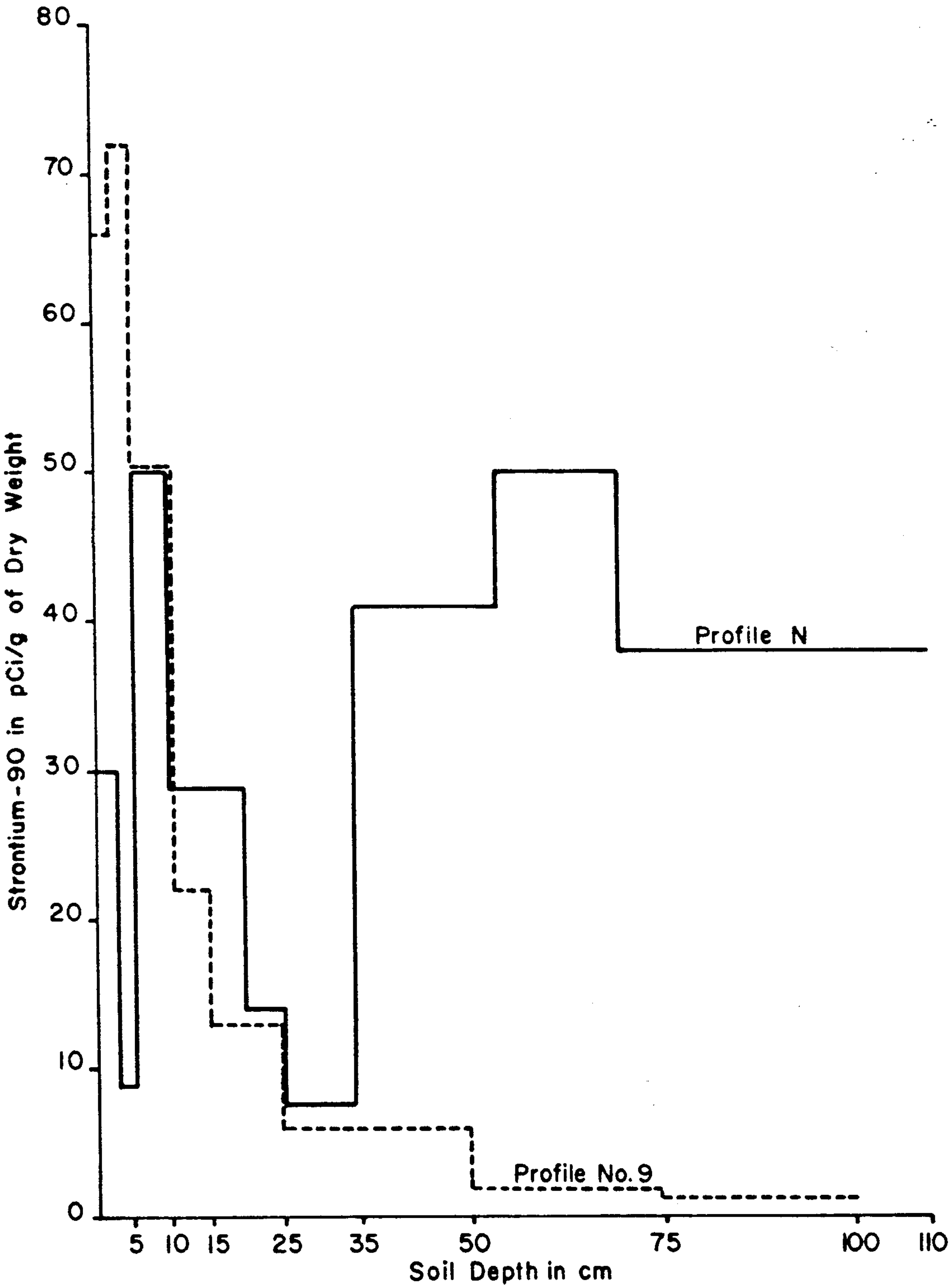

FIGURE 6. Distribution of ^{90}Sr with depth in profiles of disturbed (N) and undisturbed (9) soils from Bikini Island.

DISCUSSION AND CONCLUSIONS

Comparison of Radioactivity between Atolls

In order to compare the radioactivity found in biological and environmental samples from the seven atolls and Christmas Island, the results of the analyses of selected samples of soil, plants, and animals were summarized for each atoll. These data are shown in Tables 4 and 5 and in Figure 7.

The mean concentration of ^{137}Cs, ^{90}Sr, ^{241}Am and $^{239,240}Pu$ in surface soil (Table 4) varies significantly between atolls. Soils from Bikini and Rongelap atolls (excepting Rongelap Island and probably other southern islands which were not surveyed) have similar amounts and kinds of radionuclides. In these two areas amounts of ^{137}Cs and ^{90}Sr usually range from 20 to 300 pCi/g and amounts of ^{241}Am and $^{239,240}Pu$ range from 10 to 80 pCi/g. Soil from a second group of atolls, Rongerik and Ailinginae, plus Rongelap Island has radionuclide concentrations which are about an order of magnitude less than those noted above. Radioactivity amounts on Utirik, the easternmost atoll sampled in the Marshall Islands, are 5 to 10 times less than amounts on Rongerik and Ailinginae, but are still higher than amounts found in the single soil sample from Wotho Atoll. This atoll was south of the main pattern of fallout from Bravo which contaminated the other atolls. Kwajalein Atoll is further south and has even lower amounts of radioactivity. With slight variations, the differences between atolls exhibited by the soils can also be seen in *Pandanus* leaves, a representative plant sample (Figure 7) and in mullet, a representative fish (Table 5).

Christmas Island which was contaminated by a different series of tests than the Marshall Islands had lower amounts of fallout radionuclides than any atoll we surveyed in the Marshalls during 1974 and 1975. The naturally occurring radionuclides ^{40}K and ^{238}U were the predominant radionuclides in samples from Christmas Island.

Comparison of Radioactivity between Islands in Bikini Atoll

Differences in the radioactivity between areas of Bikini Atoll are most apparent in the soil data in Table 4. Soil from Nam Island next to Bravo Crater contains the highest amounts of ^{137}Cs, ^{90}Sr, ^{241}Am and $^{239,240}Pu$ of any soil we collected in 1974 and 1975. Samples of soil from Bikini Island contained about one-third the ^{90}Sr and ^{137}Cs, and one-tenth the ^{241}Am and $^{239,240}Pu$ found in soil from Nam. The $^{137}Cs/^{90}Sr$ and $^{241}Am/^{239,240}Pu$ ratios are similar in the soil from Nam and Bikini (between 1 and 2) indicating that the major source of radionuclides on these two islands was the same test and was probably the Bravo test of 1 March 1954.

Enidrik Island in the southern part of Bikini Atoll had less ^{90}Sr, ^{137}Cs and ^{241}Am in the surface soil than did Bikini Island, but Enidrik soil had about twice as much $^{239,240}Pu$. The ratios of these radionuclides in the soil from Enidrik were 0.25 for $^{137}Cs/^{90}Sr$ and $\sim$10 $^{241}Am/^{239,240}Pu$. These ratios are quite different from those found in soil from Nam or Bikini islands and indicate a different source for the fallout on Enidrik. The most likely source was the test series on the west end of Eneman Island, which lies about 1000 meters east of Enidrik.

Radioactivity in fish collected from the shallow areas around four islands of Bikini Atoll does not vary as markedly or as consistently as does the radioactivity in the soil. Mullet (Table 5) collected near Bikini Island had higher

Table 4. Mean concentration of ^{137}Cs, ^{90}Sr, ^{241}Am and $^{239,240}Pu$ in surface soil samples collected in 1974 and 1975 on Christmas Island in the Line Islands and on six atolls in the Marshall Islands[a].

Collection Site	Mean concentration in pCi/g, dry (n)[b] ^{137}Cs	^{90}Sr	^{241}Am	$^{239,240}Pu$
Christmas Island	<.08(8)	na[c]	ns[c]	na
Wotho Atoll				
Wotho Island	1.1± 0.1(1)	0.3± 0.1(1)	0.08± 0.06(1)	0.16± 0.06(1)
Utirik Atoll				
Utirik Island	2.8± 1.6(5)	2.7± 1.7(4)	0.27± 0.06(5)	0.77± 0.15(4)
Rongerik Atoll				
Eniwetak Island	19 ± 16(9)	18 ± 11(6)	3.4 ± 2.7(9)	3.9 ± 2.5(5)
Ailinginae Atoll				
Mogiri Island	8.4± 2.2(2)	5.6± 1.9(3)	1.5 ± 1.3(2)	3.1 ± 2.0(3)
Ucchuwanen "	24 ± 29(2)	7.6± 4.8(2)	2.0 ± 2.2(2)	4.0 ± 4.3(2)
Rongelap Atoll				
Rongelap Island	30 ± 13(6)	8 ± 1(1)	1.6 ± 1.0(6)	3.1 ± 3.5(5)
Mellu "	19 ± 0.7(2)	120 ± 36(2)	21 ± 4.2(2)	32 ± 5(2)
Kabelle "	79 ± 68(4)	140 ± 78(3)	20 ±10(4)	14 ±16(3)
Lukuen "	110 ± 61(6)	270 ±140(5)	24 ± 9(6)	46 ±12(3)
Gegen "	130 ± 88(3)	260 ±140(3)	45 ±17(3)	61 ±29(3)
Lomuilal "	210 ± 70(7)	240 ±130(7)	28 ±10(7)	31 ±16(2)
Bikini Atoll				
Bikini Island	110 ±100(15)	130 ±130(15)	6.1 ± 5.7(15)	11 ±12(14)
Nam "	270 ±350(5)	390 ±450(5)	65 ±73(5)	80 ±85(5)
Enedrik "	9.3± 8.2(4)	40 ± 46(4)	2.4 ± 1.9(4)	23 ± 6.9(4)

a. Only data from samples collected more than 50 m from the beach were used in this tabulation.

b. n is the number of samples used to compute the mean. Single sample (n=1) errors are two-sigma, propagated, counting errors, whereas the error for more than one (n>1) sample is one standard deviation of the mean.

c. na = not analyzed; ns = not significant.

Table 5

Predominant Radionuclides in Mullet Collected in the Marshall Islands, December 1974 and April 1975

			Radionuclide concentration in pCi/g, dry[a]					
Atoll	Island	Tissue	^{55}Fe	^{40}K	^{60}Co	^{137}Cs	^{90}Sr	$^{239,240}Pu$
Bikini	Eneu	Entire (37073)	na[b]	11 ±1.5	0.38±0.10	0.30±0.10	na	0.024±0.004
"	Nam	Evisc. whole (37085)	9.1±0.2	5.3±1.4	2.0 ±0.1	0.32±0.06	0.12±0.01	<0.002
"	"	Viscera (37086)[c]	100 ±0.6	4.4±1.5	4.2 ±0.2	0.43±0.10	2.6 ±0.2	5.6 ±0.6
"	Enidrik	Evisc. whole (37091)	6.9±0.2	7.9±1.9	0.82±0.14	0.14±0.07	<0.12	<0.002
"	"	Viscera (37092)	64 ±0.8	4.3±2.0	3.0 ±0.2	0.28±0.08	1.1 ±0.1	0.94 ±0.10
"	"	Evisc. whole (37093)	4.5±0.2	6.7±2.1	1.4 ±0.2	0.32±0.09	<0.15	0.007±0.002
"	"	Viscera (37094)	63 ±0.6	4.7±2.0	4.7 ±0.2	0.57±0.09	1.5 ±0.2	1.4 ±0.2
"	Bikini	Evisc. whole (30380)	10 ±0.2	6 ±0.9	3.5 ±0.1	0.12±0.06	0.18±0.07	<0.02
"	"	Viscera (30381)	33 ±0.4	4.2±1.6	16 ±0.8	0.73±0.22	na	na
"	"	Evisc. whole (30382)	11 ±0.2	7.9±1.3	1.9 ±0.1	0.72±0.08	<0.12	<0.05
"	"	Viscera (30383)	82 ±0.2	4.4±1.2	11 ±0.1	1.7 ±0.11	na	na
Rongelap	Lukuen	Evisc. whole (37143)	na	10 ±1.0	0.15±0.07	0.09±0.06	<0.13	0.034±0.004
"	"	Viscera (37142)	na	5.4±0.7	0.25±0.05	0.18±0.05	2.7 ±0.4	0.69 ±0.08
"	Kabelle	Evisc. whole (37225)	na	4.7±2.1	0.86±0.15	ns[b]	1.2 ±0.1	na
"	"	Viscera (37226)	na	5.8±1.0	ns	0.22±0.07	1.3 ±0.2	na
"	"	Evisc. whole (37227)	na	9.1±0.9	0.19±0.06	0.25±0.06	0.12±0.03	na
"	"	Viscera (37228)	na	9.5±2.8	0.73±0.22	0.82±0.20	0.35±0.12	na
Rongerik	Eniwetak	Evisc. whole (37231)	na	6.0±0.8	ns	ns	0.04±0.02	na
"	"	Viscera (37232)	na	9.4±1.4	ns	0.13±0.09	<0.005	na
Utirik	Utirik	Entire (30440)	na	5.2±1.5	ns	0.43±0.08	na	na

a. n is the number of samples used to compute the mean. Single sample (n=1) errors are two-sigma, propagated, counting errors, whereas the error for more than one (n>1) sample is one standard deviation of the mean.

b. na = not analyzed; ns = not significant.

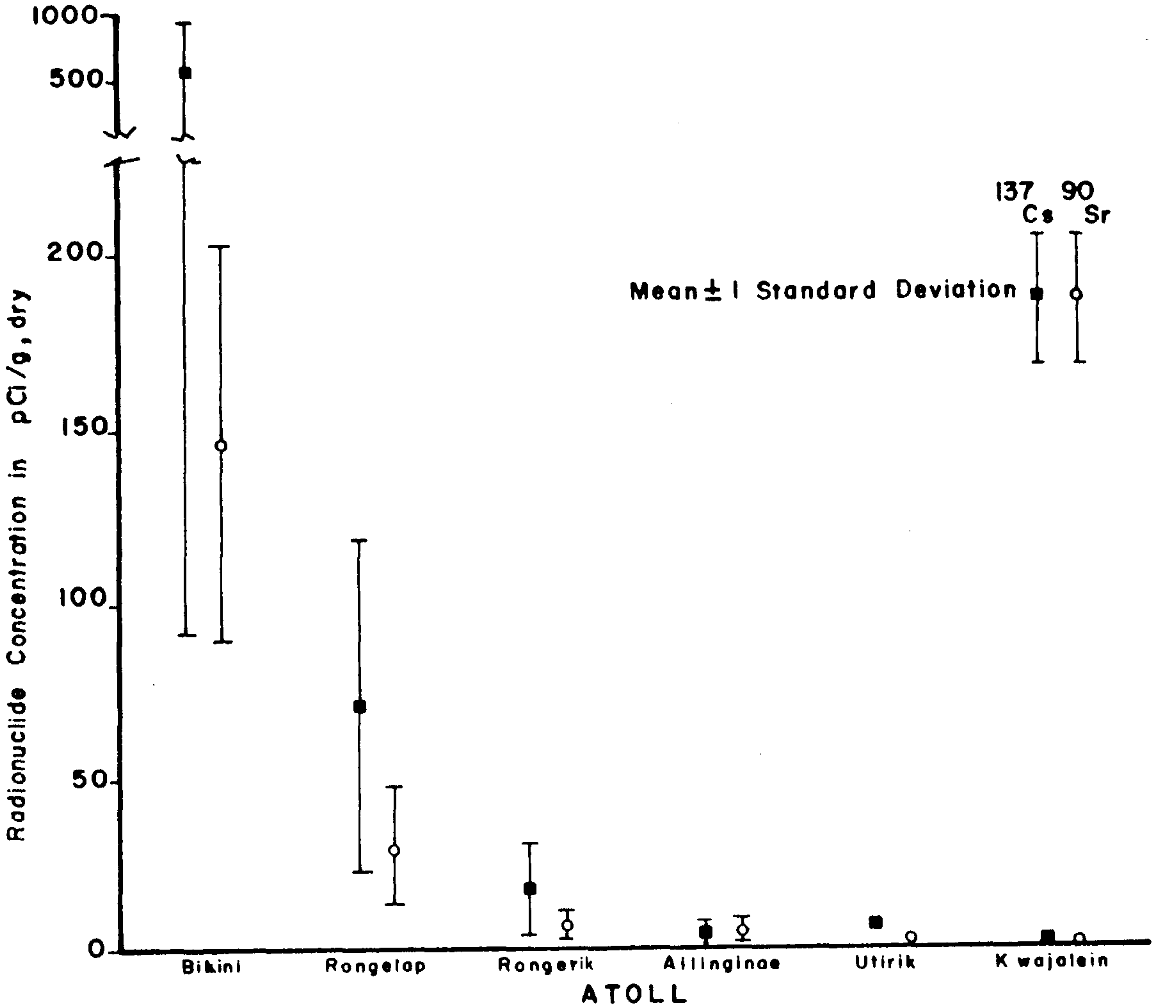

Figure 7. Mean concentration (±1 S.D.) of ^{137}Cs and ^{90}Sr in Pandanus leaves from six atolls in the Marshall Islands.

amounts of ^{60}Co and ^{137}Cs and lower amounts of ^{55}Fe than did mullet from Nam. However convict surgeon and mullet (Appendix Table 22) from Nam had higher amounts of ^{60}Co and ^{137}Cs than did convict surgeon fron Eneu Island the least contaminated area of Bikini Atoll. It is likely that the mullet range more widely within the lagoon than do the smaller convict surgeon, hence mullet captured in one area may have accumulated the radionuclides while in another area.

Comparison of Radioactivity between Islands in Rongelap Atoll

At Rongelap Atoll radionuclide concentrations in the soil increase as one moves northward along the east side of the atoll (Figure 5, Table 4). Of the islands sampled at Rongelap Atoll, soil from Rongelap Island has the least amount of radioactivity, while soil from the northern islands of Lukuen, Gejen, and Lomuilal has the most. Islands (Mellu, Kabelle) on the east side of the atoll have intermediate amounts of radionuclides in the surface soil. This soil distribution pattern corresponds with the fallout pattern determined shortly after the Bravo test at Bikini Atoll on 1 March 1954. On the second of March 1954 gamma dose rates were estimated to be 3.5 roentgens per hour (r/hr) at Rongelap Island, 19 r/hr on Kabelle Island, and 35 r/hr on Lomuilal Island in the northern part of the atoll (Held, 1965).

Ratios of $^{137}Cs/^{90}Sr$ and $^{241}Am/^{239,240}Pu$ in soil from Rongelap Atoll are similar (1 to 2) to the ratios found in soil from Nam and Bikini Islands at Bikini Atoll again indicating the major source of these radionuclides was the Bravo test.

Radioactivity in the biota also varied with island. Coconut crabs (Appendix Table 6), fish (Appendix Table 9) and plants (Appendix Table 13) from the southern islands of Rongelap Atoll had less radioactivity than did similar samples from the northern island. However, the amounts of radioactivity in the biota did not differ as much as was noted for the surface soil. Cesium-137 and ^{90}Sr amounts in soil from the northern islands were 4 or more times the amounts found in soil from Rongelap Island, while the usual differences in ^{137}Cs and ^{90}Sr amounts in plants and coconut crabs from these two areas were factors of 2 to 4.

Differences in Radioactivity due to Sample Type

As noted for surveys since 1964 (Welander, et al.,1967; Held, 1971; Lynch et al., 1975), ^{90}Sr and ^{137}Cs are the primary radionuclides in biological and soil samples from the terrestrial environment. In addition ^{241}Am and $^{239,240}Pu$ are important in soil, especially from Bikini and Rongelap atolls, both because of the quantity of these radionuclides present in soil and because they are alpha-emitting radionuclides, which have a higher potential health hazard than most of the gamma-emitting radionuclides. Of the plants sampled, *Pandanus* leaves are the best indicator species for ^{137}Cs because they concentrate ^{137}Cs, are abundant and are easily sampled throughout the year. The fruit of the *Pandanus* contains greater amounts of ^{137}Cs than do the leaves, however, the fruit is available for only part of the year. *Pandanus* leaves may also be used as an indicator for ^{90}Sr, if coconut crabs are not available. The exo-skeleton of this crab contains the most ^{90}Sr of any sample type analyzed, however, coconut crabs are not present in all areas. When available coconut crabs are also good indicator organisms since they integrate ^{137}Cs as well as ^{90}Sr, from a wide area on an island, whereas the *Pandanus* integrate ^{137}Cs and ^{90}Sr from a relatively small area of an island.

In the marine environment the neutron-induced radionuclides, ^{55}Fe and ^{60}Co, were predominant together with naturally occurring ^{40}K. Tridacna clams remain the best indicator species for ^{60}Co, while ^{55}Fe is most abundant in the liver or viscera of fish, especially large pelagic fish.

Change in Radioactivity with Time

With the passage of time since the tests which produced most of the fallout on the atolls surveyed, the radionuclides initially deposited in the environment have been concentrated or diluted by many processes. Some of these natural processes are physical-decay rate, weathering of fallout particles, transport by rainwater, wind or wave-and some are biological-selective uptake or discrimination by the plants and animals which inhabit the contaminated areas. In addition man has redistributed radionuclides by his physical disturbance of the land during construction of houses and planting of food crops (i.e. Bikini, Eneu and Rongelap islands).

A summary of the change with time in the amount of ^{60}Co, ^{90}Sr, and ^{137}Cs in selected sample types from Bikini and Rongelap atolls is given in Tables 6 and 7. Since samples were not collected in the same locations or for the same purpose during the 20 year span covered in the tables, the data are not strictly comparable or useful in calculating ecological half-life in all cases. The small number of samples for some species and normal biological variability also contribute to the fluctuation in the amount of radioactivity measured. However, the general trends indicated by the majority of the data are still distinct.

In general, both the number and amounts of radionuclides have decreased in the soil and biota at both Bikini and Rongelap atolls. Several radionuclides ^{54}Mn, ^{57}Co, ^{65}Zn, ^{144}Ce, which were present at Bikini Atoll in 1964 (Welander, et al., 1967) were not detectable in 1974. Amounts of the dominant radionuclides at Rongelap in 1958-59 and at Bikini in 1964 (^{60}Co, ^{90}Sr and ^{137}Cs) were significantly less in 1974-75 although they were still abundant.

On Bikini Island the amount of ^{90}Sr or ^{137}Cs measured in coconut crabs in 1974 is 30 to 60 per cent of the amount measured in 1964. This rate is significantly greater than the decrease expected from decay alone, hence other processes must also be acting. One of the possible factors acting to reduce the availability of ^{90}Sr and ^{137}Cs to coconut crabs on Bikini Island was the physical mixing of the soil during the rehabilitation of the island. This disturbance and physical decay reduced the amount of radioactivity in the surface soil by almost an order of magnitude between 1964 and 1974. However, the rate of decrease of ^{90}Sr in coconut crabs from Rongelap Atoll (undisturbed between 1957 and 1974) is similar to that seen at Bikini Atoll, hence the soil mixing on Bikini may not have been an important factor in determining the rate of decline of ^{90}Sr in the coconut crab on Bikini.

SUMMARY

The DOS portion of LRE's Pacific Radioecology Program began on 1 July 1974. The purpose of the program is to determine the kinds and amounts of radionuclides in biological and environmental samples from the Central Pacific, especially the Marshall Islands. Five field trips were conducted for this program between April 1974 and August 1975. About 600 samples were collected and about 600 γ-spectrum, 70 iron-55, 300 strontium-90, and 200 plutonium analyses were performed.

Table 6

Mean concentration of ^{90}Sr and/or ^{137}Cs in plants, coconut crabs, and surface soil from Bikini Atoll, 1964-1975.

Sample type	Collection Location	Collection Date	Number of Samples	Radionuclide concentration pCi/g, dry	
				^{137}Cs	^{90}Sr
Pandanus, leaves	Bikini I.	1964	several	290	120
" "	"	1972	2	280	NA
" "	"	1974-5	4	510	150
Coconut, leaves	Bikini I.	1964	several	140	NA
" "	"	1972	8	430	NA
" "	"	1974-5	14	160	13
Coconut crab, muscle	Bikini I.	1964	1	940	55
" "	"	1969	6	760	50
" "	"	1974	1	380	16
Coconut crab, exoskeleton	Bikini I.	1964	1	190	2300
" "	"	1969	6	130	1400
" "	"	1974	1	70	1600
Soil, 0-1 inch	Bikini I.	1964	2	920	930
" "	"	1967	3	540	NA
" "	"	1969	3	1200	520
" "	"	1970	50	160	NA
" "	"	1972	9	80	NA
" "	"	1974-5	15	110	130
Soil, 0-1 inch	Nam I.	1964	2	200	NA
" "	"	1969	1	63	18
" "	"	1972	4	130	NA
" "	"	1974	5	270	390
				^{137}Cs	^{60}Co
Mullet, muscle	Nam I.	1964	b	6.4	98
" evisc. whole	"	1969	b	0.8	12
" evisc. whole	"	1972	b	0.7	9
" evisc. whole	"	1974	b	0.3	2
Noddy tern, muscle	Nam I.	1964	b		11
" "	Oroken	1969	b	0.5	4
" "	Nam I.	1974	b	<.1	0.9

a. These data were taken from the following reports:

Collection Date	Report
1964	Welander, et al., 1967
1967, 1969, 1970	Held, 1971
1972	Lynch et al., 1975
1974-5	This report

b. Composite sample of several individuals

Table 7

Mean concentration of ^{137}Cs and ^{90}Sr in Pandanus and ^{90}Sr in coconut crabs collected at Rongelap Atoll from 1957 - 1974.

Sample Type	Collection Area	Collection Date	Number of Samples	Mean Concentration[a] in pCi/g, dry ^{137}Cs	^{90}Sr
Pandanus leaves	Rongelap I	1958	9	114	25
"	"	1959	19	87	
"	"	1961	16	101	
"	"	1963	13	69	15
"	"	1971	3	15	
"	"	1974	1	13	11
"	Kabelle I	1958	4	360	46
"	"	1961	1	120	
"	"	1963	1	170	42
"	Lomuilal, Lukuen I	1974	2	43	40
Coconut crab, muscle	Rongelap I	1957-58	12		14
"	Arbar, Busch I	1974	4		2
"	Kabelle I	1955	1		120[b]
"	Kabelle I	1957-58	14		47
"	"	1974	3		4.8
Coconut crab, exo-skelton	Arbar I	1959	2		480
"	"	1974	2		64
"	Mellu I	1959	2		1100
"	"	1974	1		240
"	Kabelle I	1959	3		1600
"	"	1974	3		190

a. These data were taken from the following sources:

Collection Date	Source
1955	Donaldson, 1955
1958-1971	LRE, unpublished data
1974	This report

b. 27 pCi/g, wet, multiplied by a wet/dry ratio of 4.5.

Results of the analyses indicate that ^{90}Sr and ^{137}Cs are dominant in the terrestrial environment and, in addition, ^{241}Am and $^{239,240}Pu$ are also important in the soil from Bikini and Rongelap atolls. Cobalt-60 and ^{55}Fe are predominant in the marine environment together with naturally occurring ^{40}K.

Amounts of radioactivity vary between atolls and between islands within an atoll in relation to the distance from the test sites. Bikini atoll has the highest amounts of radioactivity, but the northern islands of Rongelap Atoll have only slightly lower amounts. Rongerik and Ailinginae atolls and the southern islands of Rongelap Atoll have similar amounts of radioactivity which are lower than Bikini by factors of 5 to 10 or more. Values at Utirik Atoll are lower still, but are higher than amounts at Wotho and Kwajalein atolls. Christmas Island in the Line Islands has the least amount of radioactivity of the areas surveyed for this report.

Radioactivity on Bikini and Rongelap atolls has declined significantly with time and should continue to do so due to physical and biological processes.

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