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RADIOACTIVITY IN THE BIOTA AT ISLANDS OF THE CENTRAL PACIFIC 1954 - 1958

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RADIOACTIVITY IN THE BIOTA AT ISLANDS OF THE CENTRAL PACIFIC, 1954 - 1958

Evaluations of the radioactive contamination of biological organisms in the vicinity of the Eniwetok Test Site have been made by the Laboratory of Radiation Biology since Operation Crossroads in 1946. In order to determine the geographical limits of the contamination, the area of the surveys was extended, in 1954, to include several islands away from the test site. The "off-site" collecting areas, shown in Figure 1, include locations in the Marshall, Caroline, and Gilbert Islands and were selected because of their direction and distance from Eniwetok as well as their accessibility. Surveys made at these islands in 1954, 1955, 1956, and 1958 showed that in 1956 and 1958 the radioactivity decreased with distance and direction from the test site and that at the islands within a 130-mile radius the radioactivity was approximately ten or more times that of the other islands. Tarawa, an atoll 800 miles to the southeast of the test site, contained very low levels of radioactivity.

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The results of studies by several laboratories on the radioactive contamination of areas adjacent to the test site and in the open ocean in 1954 to 1956 have been summarized by

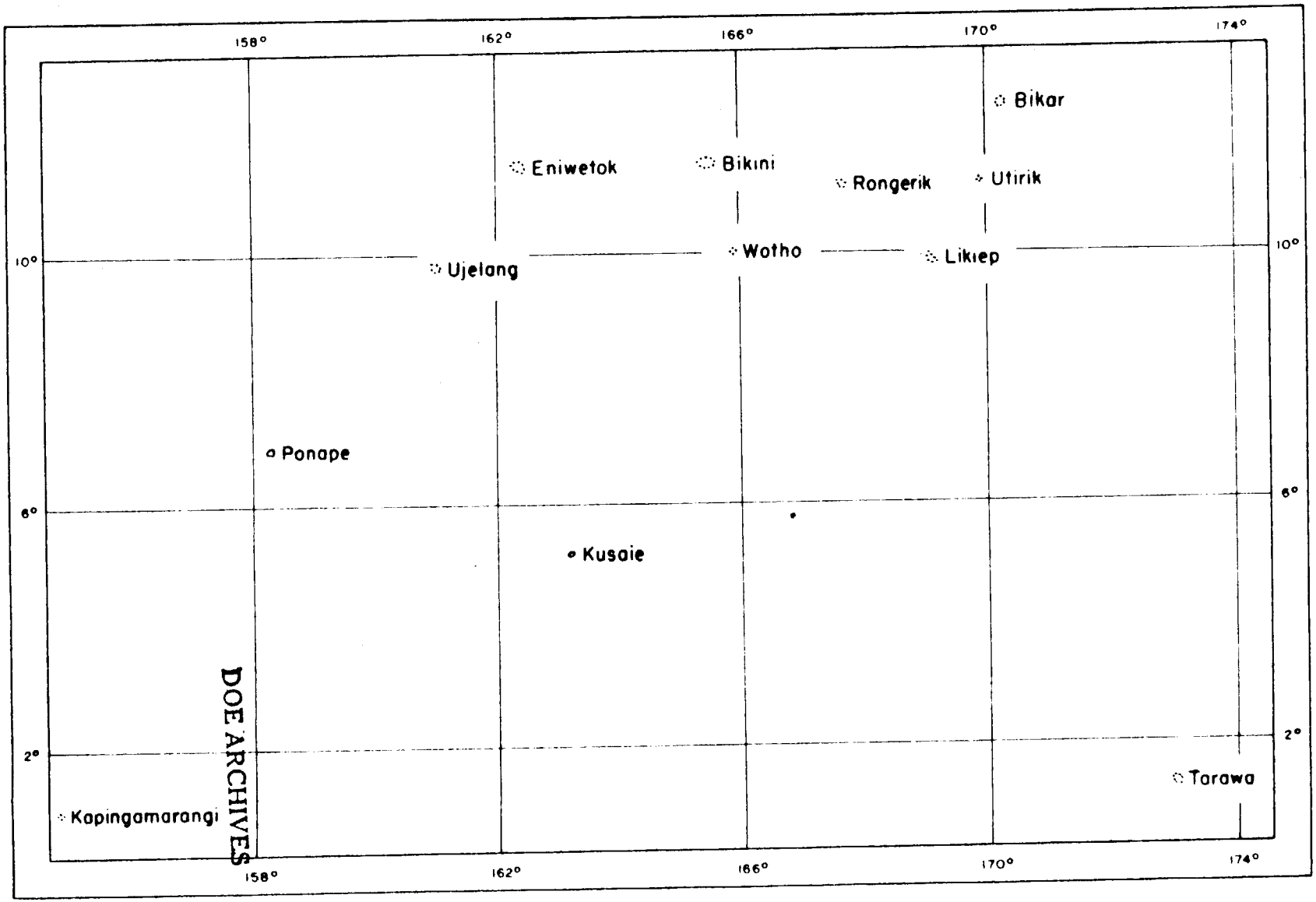

Fig. 1. Collecting stations in the central Pacific in the vicinity of the Eniwetok Test Site.

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Dunning (1957). Collections of marine organisms for radiobiological analyses also were made in the western Pacific following the Redwing (1956) and Hardtack (1958) test series. The 1956 collection was made by the George Vanderbilt Foundation at Saipan, Guam, Ulithi, Yap and Palau and was sent to the Hanford Atomic Products Operation laboratories for analysis. The results have been published by Thomas et al. (1958). Following Hardtack the George Vanderbilt Foundation made six collections (at three-month intervals) at Guam, Palau and the Gulf of Siam. These collections were sent to the Laboratory of Radiation Biology for analysis.

There was also another sampling program for radiobiological analyses made at the time of Hardtack. A series of collections of tuna from the western Pacific and Indian Oceans were made by the Japanese. One-half of the samples, which were obtained at the port of landing in Japan, were sent to the Laboratory of Radiation Biology for analysis. The analyses made by the National Institute of Health, Tokyo, have been reported by Kawabata (1960).

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The present report will be confined to the results of the studies made at the ten "off-site" islands and the one test site island shown in Figure 1, during a period which encompasses three nuclear testing programs at the Eniwetok

Test Site. These were Castle - 1954, Redwing - 1956, and Hardtack - 1958.

MATERIALS AND METHODS

The visits to the islands were made possible by the cooperation of Task Force 7.1 and the Trust Territory of the United States. Two to five-man teams were flown to the islands to collect samples which were refrigerated, returned to the Eniwetok Marine Biological Laboratory, dissected, weighed, dried, packaged and then sent to the Laboratory of Radiation Biology, Seattle, Washington, for further processing and analysis. The samples were prepared on 1.5-inch stainless steel planchets and counted for gross beta radioactivity in either one of two counting systems operated in the Geiger-Muller region: (a) One and one-half-inch end-window "pancake" type Anton tube in a 3-inch lead Anton shield connected to a Nuclear Chicago Model 181 scaler and equipped with an automatic sample changer. This system has a background of about 18 counts per minute and an efficiency of approximately 12 per cent based on K^{40}. (b) An internal counting chamber continuously flushed with methane in a Radiation Counter Laboratory Nucleometer Mark 9, Model 3.

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This system has a background of about 50 counts per minute and an efficiency of approximately 38 per cent based on P^{32}. The counts for biological samples were converted to disintegrations per minute per gram (d/m/g) of wet tissue and the counts for samples of island soil and beach sand were converted to d/m/g of dry material at time of counting by applying correction factors for sample weight, counter efficiency, and self-absorption.

The values for gross beta activity in the appendix tables are given in d/m/g plus or minus the 95 per cent counting error, which was obtained from nomographs based on the ratio of the counting rate and total time of counting of the sample to the counting rate and total time of counting of background (Kinsman, 1957). The values in the summary tables, Tables 2 and 3, however, have been calculated in terms of micromicrocuries per gram ($\mu\mu$c/g) of wet tissue.

The samples collected in 1958 were analyzed for gamma-emitting isotopes with a 3 x 3-inch sodium iodide crystal connected to a Radiation Counter Laboratory 256-channel analyzer. The radioisotopes present in the samples were identified by their gamma energies and for some of the samples the amount of each radioisotope was determined by a subtractive

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procedure similar to that described by Lowman et al. (1957). The counts per minute (c/m) for each radioisotope were converted to disintegrations per minute (d/m) by applying the correction factors listed in Table 1. The size of the sample affects the geometry, and the correction factors listed do not include error due to the differences in geometry between the biological samples and the radioisotope standards used to calibrate the efficiency of the counting system. This error ranged from 10 per cent for the smallest biological samples to 60 per cent for the largest samples.

The appropriate decay-correction factor was applied also to correct the values to the date of collection.

Table 1. Correction factors used to convert gamma counts to disintegrations

Radioisotope	Correction factor
K^{40}	409
Cs^{137}	16.5
Zn^{65}	54
Zn^{95}-Nb^{95}	14.5
Co^{57}	8.6
Ce^{144}-Pr^{144}	40
W^{185}	9.6
Ru^{106}-Rh^{106}	66.4

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A semiquantitative analysis of a Messerschmidia sample collected in 1956 at Wotho Atoll was made in a single-channel, 50-position, automatic advance gamma spectrometer with a two-inch well-type sodium iodide crystal.

For some of the 1958 samples the amount of Sr^{90} was determined by the precipitation plus ion-exchange method of Kawabata and Held (1958).

Radioactive beta decay data were obtained for some of the 1956 samples.

The common names of the organisms are used in the text and tables. The scientific names are given in Appendix Table M.

RESULTS

Gross Beta Radioactivity

The individual gross beta values plus or minus the 95 per cent counting error from ten collection sites during the interval 1954 to 1958 are given in Appendix Tables A to K. DOE AR A value identified as background signifies that the counting error was as great or greater than the net count, i.e., the count after background was subtracted. The data from the appendix tables for algae, coconut meat and milk, fish muscle and liver, and sea cucumber muscle are summarized in Table 2.

Table 2. Average gross beta values of samples from Bikini and "off-site" locations in the western central Pacific Ocean, 1954-1958. Values are expressed as μμc/g of wet tissue at time of counting[1], plus or minus one standard deviation.

Location and date of collection	Algae, entire	Coconut		Fish		Sea cucumber muscle
		Meat	Milk	Muscle	Liver	
Off-site						
Bikar						
2-3-55	-	8.6±1.4	7.3±0.32	-	-	-
Kapingamarangi						
7-4-58	-	Background[2]	1.9[2]	-	-	19±8.6
Kusaie						
7-5-56	26±11	-	8.2[2]	86±60	61 ± 37	-
7-3-58	16±7.3	2.1[2]	2.5[2]	2.0[2]	Background[2]	10±5.0
Likiep						
1-22-55	135±76	6.8±3.5	6.4±1.9	3.7±2.4	9.5± 11	175±90
Ponape						
12-16-54	33±16	8.2±2.3	2.3±0	24±15	181±206	-
5-13-56	83±97	-	-	21±24	32±6.4	4.2[2]
7-13-56	23±9.1	3.4±0.26	2.4[2]	-	-	-
9-26-56	78±61	11±1.1	2.2[2]	18±1.9	158± 30	-
7-24-58	56±46	Background[2]	-	5.5±2.0	3.4±1.1	-

[1] Samples counted 2-8 weeks after collection
[2] One sample only

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Table 2. (continued)

Location and date of collection	Algae, entire	Coconut		Fish		Sea cucumber muscle
		Meat	Milk	Muscle	Liver	
Rongerik						
2-3 -55	-	7.7±0	6.8±0.64	32±15	1090±705	-
Tarawa						
7-5 -56	14[2]	3.8[2]	11[2]	19±6.8	11±3.6	
7-11-58	1.3±1.4[3]	2.6±2.1[3]	1.5±1.7[3]	3.2±1.8	0.86±1.4	3.4±1.9
Ujelang						
2-3 -55	168±135	6.4±1.1	5.9±0.59	-	-	-
7-18-56	88± 14	4.4±0	3.4±2.1	6.4±1.6	145±230	-
7-19-58	66± 22	Background[2]	1.3[2]	12±7.7	33±14	17±1.2
Utirik						
5-17-54	1530±1290	-	-	-	-	-
1-23-55	-	9.6±2.6	9.6±3.4	3.7±2.4	40±57	161±129
7-16-58	-	5.0[2]	1.9[2]	18±22	26±11	4.5[2]
Wotho						
6-18-56	986±117	5.9[2]	-	290±47	353±100	-
6-30-58	26[2]	1.4[2]	1.2[1]	4.5±1.0	8.2±1.3	13±6.4

[1]Samples counted 2-8 weeks after collection

[2]One Sample only

[3]Samples counted 15 months after collection

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Table 2. (continued)

Location and date of collection	Algae, entire	Coconut		Fish		Sea cucumber muscle
		Meat	Milk	Muscle	Liver	
Test Site						
Bikini Island						
5-9 -54	-	-	-	1630±1730	24,500±32,300	-
6-22-54	155,000±140,000	-	-	936± 518	67,700±47,300	85,900±15,600
11-2-55	741±518	-	-	22± 19	1,140± 1,010	312±94
9-22-56	5,450± 1,600	94±62	34±6.8	106±7.7	3,450± 395	-
8-28-58[4]	3,960[2]	-	-	-	4,730[2]	-

[2]One sample only

[4](Enyu Island, Bikini Atoll)

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In this table the plus or minus values are based on standard deviation. For the purpose of comparing the radioactivity of samples at the test site with samples from the "off-site" islands, values for Bikini Island have been included in Table 2.

Radioisotopic Composition

The results of the semiquantitative analyses of gamma spectra of samples collected in 1956 and 1958 are given in Appendix Table L; results of quantitative analyses for some of the 1958 samples are given in Table 3. The latter table also includes the results of the Sr^{90} analyses. The samples were not analyzed immediately after collection; consequently the short-lived radioisotopes which might have been present at the time of collection are not included in the results.

DISCUSSION

The highest levels of gross beta radioactivity were found in samples of algae, fish liver and muscle, and sea cucumber muscle from Ujelang, Wotho, Utirik and Rongerik Atolls (Table 2), which are only one hundred to three hundred miles from the test site; however, the levels in coconut meat and milk were low, even at these atolls. The radioactivity of similar samples from the outlying atolls and islands of

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Sr^{90}
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0
18 ± 0.73[1]
--
0.0082 ± 0.0068
0.0031 ± 0.0022
--
0
0
0.086 ± 0.0059
0
0
0.018 ± 0.0050
0
0

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Kapingamarangi, Tarawa, Ponape, and Kusaie was only slightly above the background level of the counter. The naturally-occurring isotope K^{40} contributed most of the radioactivity, which, for the samples listed in Table 3, ranged from 1.8 to 19 μμc/g of wet tissue.

The levels of radioactivity in samples from one of the islands at the test site (Bikini) were considerably higher than in the "off-site" samples. For example, algae collected at Bikini Island in September 1956, two months after completion of the Redwing series, averaged 5,500 μμc/g, whereas samples collected at the same time at Ponape Island averaged 78 μμc/g. Similar comparisons with the fish, coconut and sea cucumber tissues showed that the major portion of the radioactivity was deposited at or close to the test sites at Eniwetok and Bikini Atolls.

Comparisons of the radioactivity of different tissues and of similar tissues at different times are limited by the number of samples. However, some general conclusions can be made. The algae and fish liver contained the highest levels of radioactivity and the coconut meat and milk were the least radioactive tissues at the majority of the stations. DOE ARCHIVES

The samples collected in January-February, 1955, at the atolls east of the test site contained relatively high amounts

of radioactivity, indicating that these islands, Bikar, Likiep and Rongerik (Appendix Tables A, D, F, and K), had become contaminated with the 1954 Bravo test fallout as had Rongelap Atoll. Of special note are the high levels of radioactivity in the island soil, fish liver and viscera and the low levels in the coconut samples collected at Rongerik. Later collections were not made at these islands and we do not know whether further contamination occurred there, as it did at islands to the south and west of the test site.

Birds were sampled only at Ujelang, Bikar and Rongerik in 1955 and at Tarawa in 1956. The 1955 samples contained relatively high levels of beta radioactivity, whereas those from Tarawa contained low levels. The white of a tern egg from Tarawa (Appendix Table G), however, contained more beta radioactivity (99 d/m/g) than any other tissue sampled, and fish, a principal food item of these birds, also contained significant amounts of radioactivity.

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Qualitative analyses of gamma spectra also give an indication of the quantity of the isotopes present. Analyses of this kind made shortly after the 1958 collections (Appendix Table L) show that Zr^{95}-Nb^{95} and $Ru^{103,106}$-$Rh^{103,106}$ were the predominant radioisotopes in the samples. Two exceptions were

noted: $W^{181,185}$ contributed the major portion of the radioactivity in Scaevola leaves from Kusaie and in Messerschmidia and Scaevola leaves from Ujelang (Lowman et al. 1959), and Zn^{65} was predominant in fish tissues from Ponape and Utirik. Co^{57} was present usually in lesser amounts, and Co^{58} and Co^{60} were found only in a sample of clam kidney from Ujelang and a fish liver sample from Utirik. Other radioisotopes were present only in a few samples. Cs^{137}, for example, was found in plants from Kapingamarangi and Utirik, $Ce^{141,144}$-Pr^{144} in a few samples from Kusaie, Ponape and Ujelang, and Mn^{54} in fish skin and gut from Ponape and clam kidney from Ujelang. Fe^{59} was detected once only, in a sample of skipjack muscle from Ponape.

The quantitative results of the gamma spectrum analyses shown in Table 3 are based on analyses made approximately eighteen months after the samples were collected; consequently the shorter-lived radioisotopes Zr^{95}-Nb^{95} (half life 65 days), Co^{58} (71 days) Ru^{103}-Rh^{103} (40 days) and Ce^{141} (32 days) had decayed to insignificant or non-detectable levels. In a 161-gram sample of yellow-fin tuna from Ponape, however, Zr^{95}-Nb^{95} were found in low amounts (0.12 μμc/g at time of counting); at time of collection the level of Zr^{95}-Nb^{95} would have been 40 μμc/g. K^{40} was present in all samples analyzed. In some

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samples from Wotho, Tarawa, Ponape, and Kapingamarangi, K^{40} contributed the major portion of the radioactivity. Other samples collected at the same time contained $W^{181,185}$, radioisotopes identified with the 1958 fallout. Some samples, such as coconut crab abdomen and whole fish from Wotho, contained Zn^{65}, whereas others, such as land plants, contained none. Some of the land plants contained measurable amounts of the long-lived fission products Cs^{137} and Sr^{90}. The highest level of Sr^{90} was found in a sample of coconut crab carapace from Wotho (18 μμc/g dry). The concentration of this isotope by the carapace of land crabs at Eniwetok has been reported by Held (1957).

The relatively rapid decay of beta radioactivity in some of the samples collected in 1956 at Tarawa, Ponape and Wotho (Fig. 2 A-E) indicates the presence of short-lived isotopes. A gamma spectrum analysis of one of the samples (leaves and stems of a Messerschmidia plant from Wotho) showed that Zr^{95}-Nb^{95} were the predominant radioisotopes in this sample. Thomas et al. (1958) found that these isotopes contributed approximately 84 per cent of the total radioactivity in a duplicate sample. The presence of short-lived isotopes in the 1956 samples indicated recent fallout at these islands.

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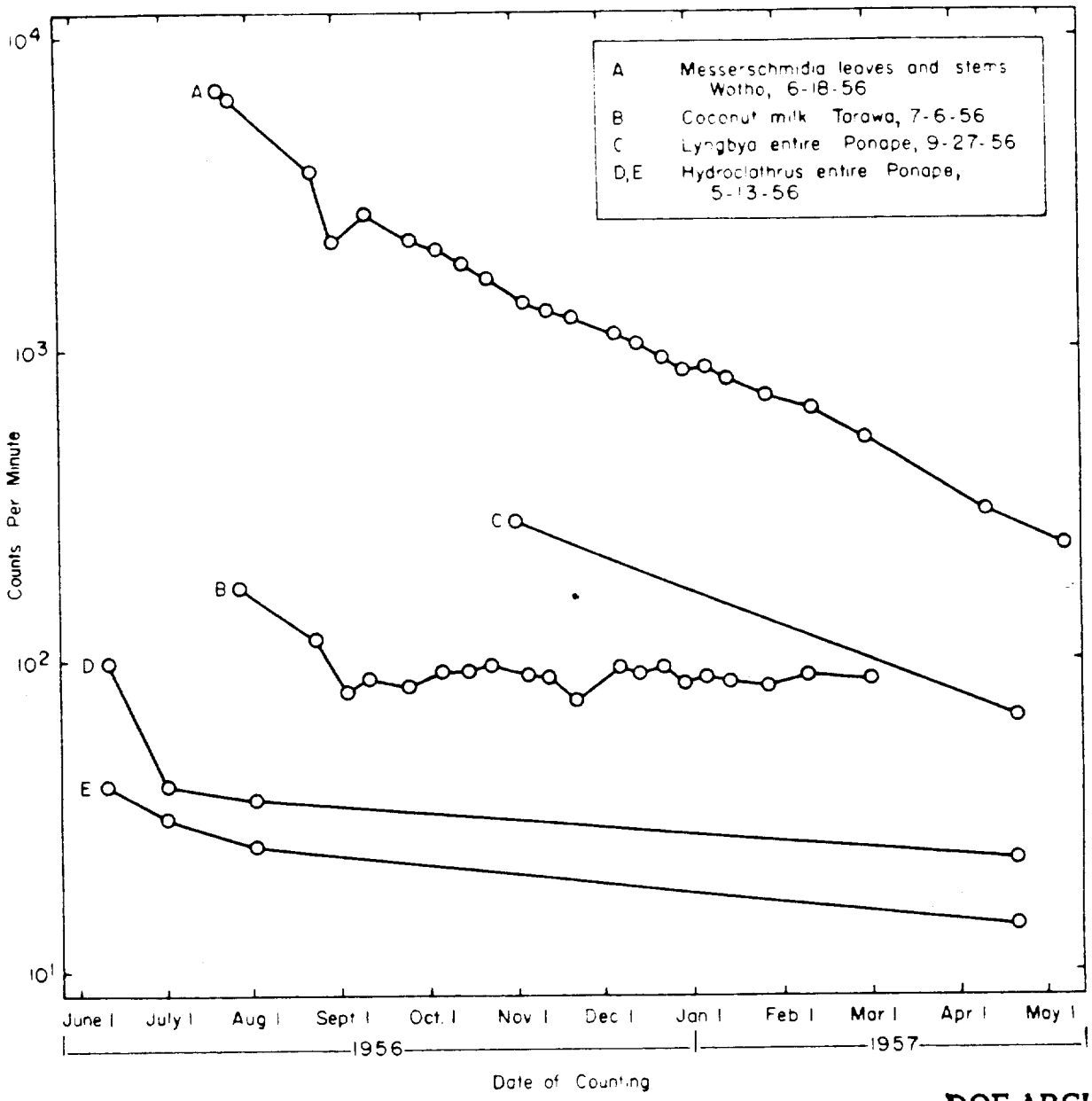

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Fig. 2. Beta decay curves of samples collected in 1956.

SUMMARY

1. Surveys were made in 1954 to 1958 to determine the geographical limits of the radioactive contamination from the tests in the central Pacific Ocean.

2. Collections of biological samples and soils were made at one test site island (Bikini) and ten "off-site" islands.

3. The gross beta radioactivity decreased with distance from the test site; in 1956 and 1958 islands within a 130-mile radius contained at least ten times as much radioactivity as the other islands.

4. The levels of radioactivity also were related to direction from the test site. In 1955 the islands to the east contained high levels of radioactivity. In 1956 and 1958 Tarawa, 800 miles southeast of the test site, contained very low levels whereas Kapingamarangi, approximately the same distance to the southwest, contained significantly higher amounts of radioactivity.

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5. Zr^{95}-Nb^{95} and $Ru^{103,106}$-$Rh^{103,106}$ were the predominant radioisotopes present in the majority of the samples.

Other isotopes, such as $W^{181,185}$, Zn^{65} and Cs^{137} were present in relatively high amounts in some samples. Sr^{90} was found usually in very low amounts.

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