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RADIOACTIVITY IN THE NIHOA AND ISLANDS OF THE CENTRAL PACIFIC
1954 & 1956

Kalpe P. Palumbo

Laboratory of Radiation Biology
University of Washington
Seattle, Washington

Lester R. Donaldson
Director

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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.

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

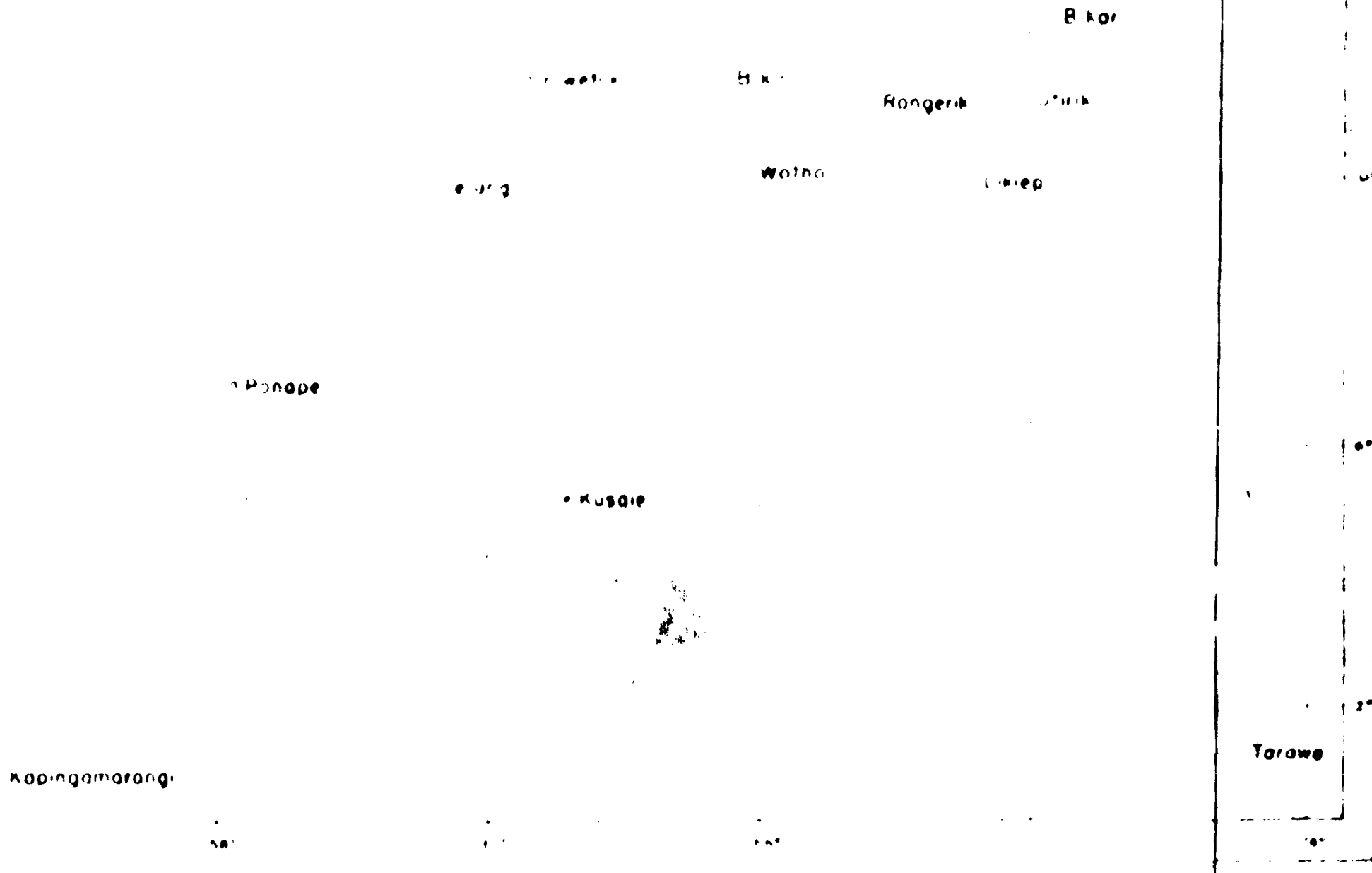


Fig. 1. Collecting stations in the central Pacific in the vicinity of the Eniwetok Test Site.

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 (1958).

The present report will be confined to the results of the studies made at the test site islands and the one test site island group. The period of study which encompasses three nuclear test series at the Bikini

Test Site. These were Castle 1954, Redwing - 1956, and Birdcatch - 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 K⁴⁰. (b) An internal window chamber continuously flushed with methane in a Geiger Counter Laboratory Nucleometer Mark 9, Model 3.

This system has a background of about 50 counts per minute and an efficiency of approximately 30 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 ($\mu\mu\text{C/g}$) 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

procedures 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 - 105 ⁹⁵	14.5
Ce ⁵⁷	9.6
Ce ¹⁴⁴ -Pr ¹⁴⁴	40
W ¹⁸⁵	9.6
Ru ¹⁰⁶ -Rh ¹⁰⁶	66.4

~~A quantitative analysis of a~~
collected in 1956 at Wotho Atoll was made in a single-channel, 30-position, automatic advance gamma spectrometer with a ten-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 Kawahata 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. 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" local western central Pacific Ocean, 1954-1958. Values are expressed as μ tissue at time of counting¹, plus or minus one standard deviation.

Location and date of collection	Algae, entire	Coconut		Fish		Sea cucumber muscle
		Nut	Milk	Muscle	Liver	
Off-site						
Bikini						
2-3-55	-	8.5 [±] 1.4	7.3 [±] 0.32	-	-	-
Kapingamarangi						
4-58	-	Background ²	1.9 ²	-	-	19 [±] 8.6
Kusaie						
7-5-56	26 [±] 11	-	8.2 ²	26 [±] 60	21 [±] 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 [±] 38	-
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

Table 2. (continued)

Location and date of collection	Algae, entire	COCONUTS		Fish		Sea cucumber muscle
		Meat	Milk	Muscle	Liver	
Rongorik 2-3-55	-	7.7 ^{±0}	6.8 ^{±0.64}	32 ^{±15}	1090 ^{±705}	-
Tarawa						
7-4-56	14 ²	3.8 ²	11 ²	10 ^{±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}
Palmyra						
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}	105 ^{±230}	-
7-19-58	66 ^{±22}	Background ²	1.3 ²	12 ^{±7.7}	33 ^{±14}	17 ^{±1.2}
Utirik						
8-17-54	1530 ^{±1290}	-	-	-	-	-
1-23-55	-	9.6 ^{±2.6}	9.6 ^{±2.4}	3.7 ^{±2.4}	40 ^{±57}	161 ^{±129}
7-16-58	-	9.6 ²	1.9 ²	18 ^{±22}	26 ^{±11}	4.5 ²
Notre						
7-21-56	206 ^{±137}	5.9 ²	-	290 ^{±47}	353 ^{±108}	-
7-22-56	26 ²	1.6 ²	1.3 ²	4.5 ^{±1.0}	8.2 ^{±1.3}	13 ^{±6.4}

1. Samples counted within 48 hours after collection
 2. Samples counted 15 months after collection
 3. Samples counted 15 months after collection

Table 2. (continued)

Location and date of collection	Algae, entire	Coconut		Fish		Sea cucumber muscle
		Meat	Milk	Muscle	Liver	
<u>Test Site</u>						
Bikini Island						
5-9 -54	-	-	-	10,300±1,300	24,500±32,300	-
6-22-54	155,000±140,000	-	-	936±1,100	62,700±47,300	85,900±15,600
11-2-55	741±518	-	-	221±19	1,140±1,010	312±94
9-22-56	5,450±1,600	94±62	34±6.8	106±7.7	450±395	-
8-28-58 ⁴	3,960 ²	-	-	-	4,730 ²	-

²One sample only

⁴(Enyu Island, Bikini Atoll)

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

Table 3. Radioisotopes in fish, invertebrates and land plants from 'off-site' locations July-August, 1958. Values are expressed as $\mu\text{C/g}$ wet weight plus or minus .95 counting error at time of collection.

Collection Date	Species	Tissue	K ⁴⁰	Zn ⁶⁵	Cs ¹³⁷	Co ⁵⁷	Mn ⁵⁴	Ra ²²⁶ -Rn ²²²	Rn ²²² -Po ²¹⁰	Pb ²¹⁰ -Bi ²¹⁰	Po ²¹⁰
6-30-58	Mixed	Whole	9.5 ± 2.3	16 ± 0.86	--	0.73 ± 0.15	--	--	--	--	--
7-1-58	Yellowfin tuna	Mixed	4.2 ± 0.44	0.60 ± 0.31	--	2.0 ± 0.064	--	0.55 ± 0.34	--	--	--
7-11-58	Groupers	Liver, muscle	9.1 ± 1.5	--	--	--	--	--	--	--	--
		Muscle	5.5 ± 0.82	--	--	--	--	--	--	--	--
7-16-58	Mixed	Whole	5.0 ± 0.68	4.5 ± 0.55	--	--	--	1.7 ± 0.41	--	--	--
7-19-58	Squirrelfish	Liver, muscle	6.8 ± 0.77	2.2 ± 0.42	0.17 ± 0.045	--	--	--	--	--	--
7-28-58	Yellowfin tuna	Mixed	3.5 ± 0.77	10 ± 2.3	--	--	--	--	40 ± 7.7	--	--
6-30-58	Cocoon crab	Abdomen	15 ± 2.2	60 ± 2.0	--	4.0 ± 0.30	--	--	--	--	0
	"	Carapace	10 ± 1.3	13 ± 1.0	1.4 ± 0.073	2.4 ± 0.15	37 ± 3.9	3.8 ± 0.86	--	--	18 ± 0.73 ¹
6-30-58	Cocoon	Milk	3.9 ± 0.30	--	--	--	--	--	--	--	--
	Pandanus	Fruit	11 ± 1.5	--	1.7 ± 0.091	1.4 ± 0.20	20 ± 5.9	--	--	--	0.0082 ± 0.0068
	Breadfruit	"	1.6 ± 0.19	--	0.27 ± 0.016	--	2.0 ± 0.034	--	--	--	0.0031 ± 0.0022
7-3-58	Cocoon	Milk	3.7 ± 0.39	--	0.077 ± 0.019	--	--	--	--	--	--
	Breadfruit	Fruit	3.0 ± 0.12	--	0.095 ± 0.0073	--	1.8 ± 0.17	--	--	--	0
7-11-58	"	"	19 ± 1.1	--	1.0 ± 0.069	--	21 ± 1.6	--	--	--	0
7-16-58	"	"	15 ± 0.35	--	1.3 ± 0.037	0.12 ± 0.035	2.0 ± 0.64	--	--	--	0.086 ± 0.0059
7-19-58	Cocoon	Milk	2.8 ± 0.43	--	0.26 ± 0.10	--	6.8 ± 0.23	--	--	--	0
	"	Meat	3.0 ± 0.34	--	0.35 ± 0.025	--	1.9 ± 0.64	--	--	--	0
	Breadfruit	Fruit	2.6 ± 0.64	--	0.50 ± 0.045	0 ± 0.073	10 ± 1.4	--	--	--	0.010 ± 0.0050
7-24-58	"	"	3.3 ± 0.21	--	0.12 ± 0.013	--	0.72 ± 0.32	--	--	--	0
7-25-58	"	"	5.5 ± 0.27	--	0.39 ± 0.015	--	--	--	--	--	0

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basis

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Rapingamarangi, Tarawa, Ponape and Kusale 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 1.3 to 19 $\mu\text{C/g}$ 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 $\mu\text{C/g}$, whereas samples collected at the same time at Ponape Island averaged 78 $\mu\text{C/g}$. 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.

The samples collected in January-February, 1956, 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.

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; $^{181,185}\text{W}$ 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 Kapinngamarangi and Utirik, $\text{Ce}^{141,144}$ - 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. P^{32} 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 $\mu\text{c/g}$ at time of counting); at time of collection the level of Zr^{95} - Nb^{95} would have been 40 $\mu\text{c/g}$. K^{40} was present in all samples analyzed. In some

samples from Wotho, Tarawa, Ponape, and Kapingamarangi, K^{40} contributed the major portion of the radioactivity. Other samples collected at the same time contained ^{131}I , 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 $\mu\text{C/g}$ 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.

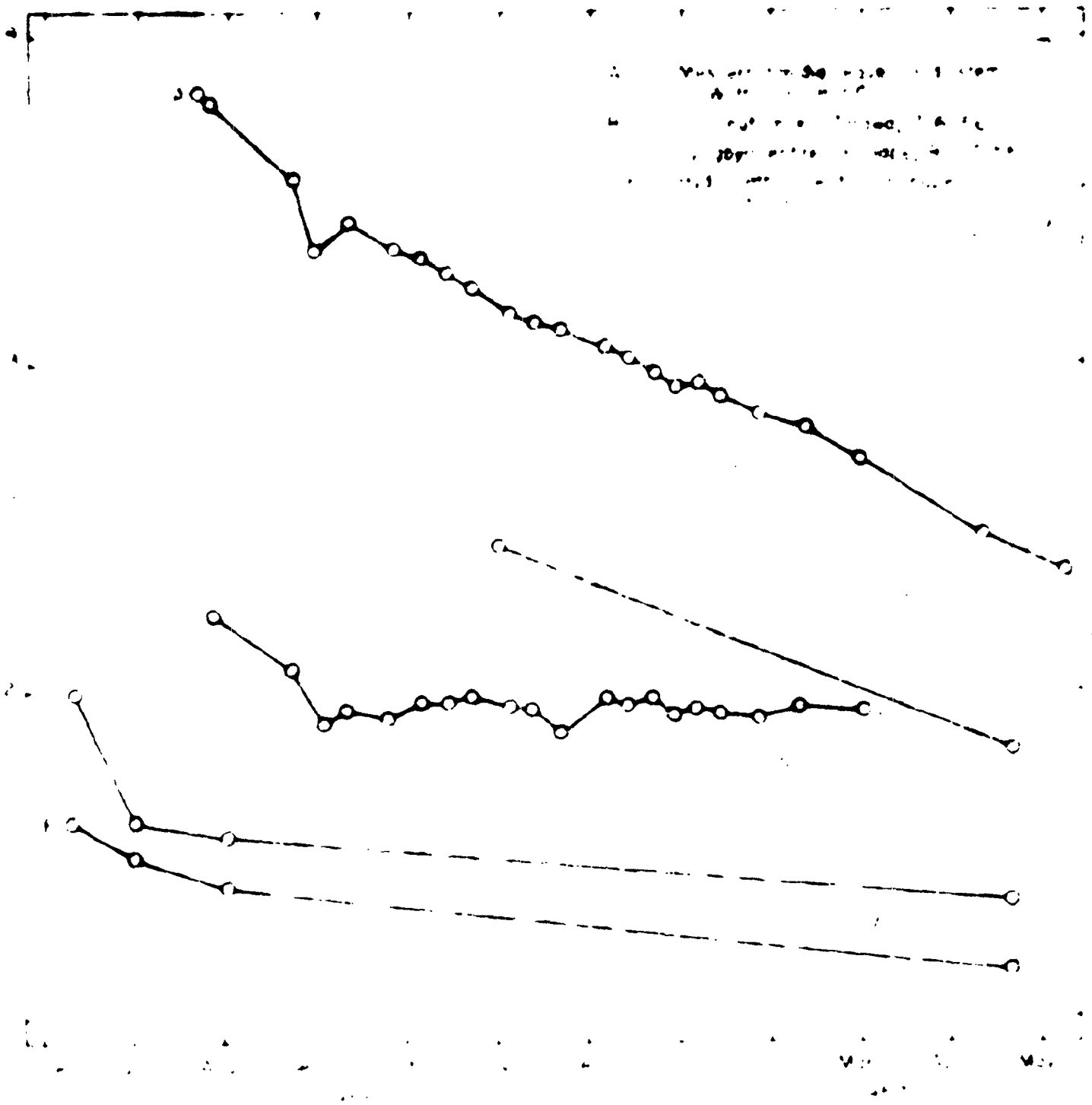


Fig. 2. Beta decay curves of samples collected in 1956.

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.
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 ^{181}W , ^{195}W , ^{65}Zn and ^{137}Cs were present in relatively high amounts in some samples. ^{90}Sr was found usually in very low amounts.

Appendix Table A. Gross beta radioactivity of the biological samples collected at Bikar Atoll, February 3, 1955, expressed in d/m/g of wet tissue at time of analysis*. The 0.9% counting error is included.

<u>Species</u>	<u>Tissue</u>	<u>d/m/g</u>	
<u>Land Plants</u>	<u>Coccoloba</u>	Meat	
		20 ± 1.5	
		15 ± 2.7	
	Milk	21 ± 3.7	
		15 ± .98	
		16 ± .56	
<u>Scaevola</u>	Leaf	16 ± 1.0	
		272 ± 20	
<u>Birds</u>	<u>Fairy tern</u>	Muscle	35 ± 4.0
		Liver	130 ± 6.5
		Lung	212 ± 21
		Kidney	91 ± 6.4
		Uleum	55 ± 7.4
		Bone	114 ± 30
		Skin	6 ± 7.5
	<u>Noddy tern</u>	Muscle	45 ± 3.3
		Liver	314 ± 4.8
		Lung	182 ± 6.8
		Kidney	370 ± 17
		Uleum	81 ± 7.6
		Bone	117 ± 17
		Skin	319 ± 14
		Egg shell	224 ± 6.4
		Egg yolk	36 ± 4.4
		Unhatched chick, gut	31 ± 5.7
		Unhatched chick, skin and feathers	30 ± 7.4
<u>Rats</u>	<u>Field rat</u>	Muscle	33 ± 4.6
		Kidney	83 ± 13
		Bone	63 ± 42
		Skin	126 ± 5.1

* Samples were collected seven months after Operation Castle; the plants were counted 3/3/55 and the birds were counted 3/9 to 4/15/55.

Appendix Table B. Gross beta radioactivity of the biological samples collected at Kapingarangangi Atoll, July 24, 1958; expressed in $\mu\text{Ci/g}$ of wet tissue at time of analysis*. The 0.95 counting error is included.

Species	Tissue	$\mu\text{Ci/g}$
<u>Land Plants</u>		
Breadfruit	Fruit	10 \pm 4.1
Coconut	Meat	Bgd.
	Milk	4.1 \pm .82
<u>Invertebrates</u>		
Clam (<u>Tridacna</u> <u>crocea</u>)	Muscle	9.4 \pm 1.7
		Bgd.
	Kidney	110 \pm 15
		120 \pm 17
	Visceral mass	4.9 \pm 2.8
		6.1 \pm 3.1
Coconut crab	Carapace	Bgd.
	Abdomen	12 \pm 4.3
Hermit crab	Carapace	49 \pm 18
		50 \pm 18
		37 \pm 19
		77 \pm 21
	Abdomen	Bgd.
		4.6 \pm 3.6
		5.0 \pm 4.0
	4.6 \pm 3.6	
Sea cucumber	Muscle	55 \pm 6.9
		26 \pm 4.1
	Integument	25 \pm 6.7
		21 \pm 3.9
	Gonad	40 \pm 6.5
		13 \pm 2.4
	Gut and contents	19 \pm 9.6
	11 \pm 9.0	
<u>Fish</u>		
Mixed reef fish	Entire	9.1 \pm 4.2
		7.0 \pm 3.8

* Samples were collected during Operation Hardtack and were counted 9/18-27/58; the fish samples were counted 10/19/59.

Appendix Table C. Gross beta radioactivity of the biological samples collected at Fusaie Island, 1956-1958, expressed in d/m/g of wet tissue at time of analysis. The 0.95 counting error is included.

<u>Species</u>	<u>Tissue</u>	1956 [*] Collection d/m/g	1958 ^{**} Collection d/m/g
<u>Marine Plants</u>			
<u>Asparagopsis</u>	Entire		16 ± 3.3
<u>Caulerpa</u>	"		44 ± 5.0
<u>Halimeda</u>	"	46 ± 4.4	42 ± 17
<u>Turbinaria</u>	"	42 ± 3.6 43 ± 4.1	
<u>Land Plants</u>			
<u>Banana</u>	Fruit		1.1 ± .58
	Meat	20 ± 2.2	
<u>Breadfruit</u>	Fruit		13 ± 5.4
	Meat	35 ± 4.4	
<u>Coconut</u>	Meat		4.6 ± 1.5
	Milk	15 ± 2.1	46 ± 13
<u>Lime</u>	Fruit		5.8 ± 2.4
	Meat	8.6 ± .67 6.5 ± .60	
	Seeds	30 ± 8.7	
	skin	16 ± 2.5 21 ± 2.7	
<u>Mango</u>	Fruit		11 ± 3.5
<u>Mountain apple</u>	Fruit	8.6 ± 1.3	
	fruit	7.2 ± .74	
<u>Orange</u>	Fruit		3.8 ± 2.1
	Meat	11 ± 1.7 9.2 ± 1.2	

* 1956 samples were collected 7/5/56 during Operation Redwing and were counted 7/23/56 to 9/12/56.
 ** 1958 samples were collected 7/1/58 during Operation Hardtack and were counted 7/23/58 to 9/2/58.

Appendix Table C. (continued)

Species	Tissue ^f	1958* Collection d/m/g	1959** Collection d/m/g
<u>Land Plants (continued)</u>			
Papaya	Fruit	4.6 ± .55	2.7 ± 1.9
	Fruit	5.7 ± .31	
	Seeds		7.3 ± 3.2
Pineapple	Fruit	11 ± 1.3	11 ± 2.2
		11 ± 1.5	
<u>Convolv</u>	Leaves		67 ± 7.4
Soursop	Fruit		4.8 ± 2.6
Screw pine	Fruit		11 ± 5.3
Sugar cane	Stem		Bgd.
West potato	Meat		Bgd.
Taro	Meat		34 ± 7.6
<u>Invertebrates</u>			
Ghost crab	Entire		14 ± 6.0
Hermit crab	Carapace	Bgd.	Bgd. ± 20
	Abdomen		15 ± 1.6
Sea cucumber	Muscle		38 ± 8.6
			22 ± 6.0
			18 ± 5.9
			13 ± 5.4
			28 ± 4.7
			38 ± 5.6
			24 ± 4.2
			19 ± 4.0
			20 ± 6.5
			18 ± 5.6
	18 ± 3.4		
	16 ± 3.2		
	Gut and contents		Bgd.
			Fgd.
			Bgd.
			Bgd.
Sponge	Entire		64 ± 10
<u>Fish</u>			
Mixed fish	Muscle	19 ± 15	
		313 ± 14	
		207 ± 9.5	

Appendix Table (continued)

Species	Tissue	1976 Collection d/m/g	1988 Collection d/m/g
Mixed fish (contd)	Liver	212 ± 11 51 ± 2.3 43 ± 15	
Parrot fish	Muscle Liver		4.1 ± 3.7 Pgd.

Appendix Table D. Gross beta radioactivity of the biological samples collected at Likiep Atoll, January 22, 1955, expressed in $\mu\text{m/g}$ of wet tissue at time of analysis*. The 0.95 counting error is included

Species	Tissue	$\mu\text{m/g}$
<u>Marine Plants</u>		
<u>Necomefia</u>	Entire	129 \pm 16
<u>Padina</u>	"	462 \pm 25
<u>Rhipilia</u>	"	300 \pm 28
<u>Land Plants</u>		
Banana	Meat	26 \pm 3.4
Coconut	Meat	12 \pm 3.0
		9.8 \pm .24
		24 \pm 4.4
	Milk	12 \pm .86
		19 \pm 2.8
		12 \pm .69
Screw pine	Fruit	33 \pm 4.4
		23 \pm 4.6
Taro	Meat	13 \pm 4.3
		13 \pm 3.8
<u>Invertebrates</u>		
<u>Coral</u> <u>Aeropora</u> sp.	Entire	106 \pm 27
		94 \pm 20
		83 \pm 17
<u>Pungia</u> sp.		
sea cucumber	Muscle	524 \pm 19
		245 \pm 30
	Integument	63 \pm 13
		587 \pm 25
	Gonad	622 \pm 28
	Out and contents	78 \pm 10
	2,400 \pm 70	

* Samples were collected seven months after operation Castle and were counted 2/24/55 to 2/29/55.

Appendix Table D. (continued)

Species	Tissue	d/m/g
<u>Fish</u>		
Blenny - red spotted	Entire	35 ± 9.2
		28 ± 6.9
- bluedash	Muscle	43 ± 10
	Liver	11 ± 4.3
	Viscera	48 ± 12
	Bone	69 ± 21
		21 ± 14
	Skin	15 ± 9.6
Butterfly fish	Entire	56 ± 27
	Muscle	12 ± 3.0
	Liver	15 ± 11
	Viscera	25 ± 6.9
	Bone	15 ± 8.7
	Skin	22 ± 8.1
Convict surgeon	Entire	78 ± 18
		59 ± 18
		56 ± 20
	Muscle	5.3 ± 4.1
	Liver	Bgd.
	Viscera	44 ± 8.5
	Bone	Bgd.
Skin	9.6 ± 4.6	
Damsel fish	Muscle	Bgd.
	Viscera	55 ± 9.6
	Bone	Bgd.
	Skin	19 ± 11
Grouper	Entire	22 ± 17
	"	52 ± 22
	"	Bgd.
Jack	Muscle	12 ± 8.1
	Viscera	46 ± 12
	Bone	40 ± 25
	Skin	59 ± 28
Wrasse	Entire	1. ± 3.9
		23 ± 1.3

Appendix Table E. Gross beta radioactivity of the biological samples collected at Ponape Island, 1954-1958, expressed in d/m/g of wet tissue at time of analysis. The 0.95 counting error is included.

Species	Tissue	1954* Collection d/m/g	1956** Collection d/m/g	Date	1958*** Collection d/m/g
<u>Marine Plants</u>					
<u>Halimeda</u>	Entire	71 ± 25	65 ± 7.4	5-13-56	20 ± 15
		130 ± 30	60 ± 7.0	"	
		89 ± 21	59 ± 13	7-13-56	
			83 ± 8.3	9-27-56	
		59 ± 8.0	"		
<u>Padina</u>	"		114 ± 9.0	5-13-56	230 ± 30
			171 ± 12	"	
<u>Caulerpa</u>	"		38 ± 5.1	"	
			57 ± 5.7	"	
<u>Hydroclathrus</u>	"		276 ± 16	"	
			673 ± 28	"	
<u>Turbinaria</u>	"		46 ± 4.3	1-13-56	
<u>Synsphaera</u>	"		307 ± 15	9-27-56	
			376 ± 15	"	
<u>Jania</u>	"		114 ± 14	"	
			91 ± 9.2	"	
<u>Seagrass</u>	Leaves	69 ± 8.2			110 ± 15
		27 ± 7.3			
		54 ± 12			

* 1954 samples were collected 12/16/54, 6 months after Operation Castle, and were counted 1/8-27/55.

** 1956 samples were collected 5/13/56 during Operation Redwing, and were counted 5/30-6/4/56.
 " " " " 7/12-13/56 " " " and were counted 6/8-9/9/56.
 " " " " 9/27/56 immediately following Operation Redwing, counted

10/27-11/19/56.

*** 1958 samples were collected 7/24-25/58, during operation Hardtack, and were counted 9/18-29/58.

Appendix Table 3. (continued)

Species	Tissue	1954 [*] Collection d/m/g	1956 ^{**} Collection d/m/g	Date	1958 ^{***} Collection d/m/g	
Land plants Coconut	Meat (green)	22 ± 2.7	7.1 ± 0.91	7-13-56	Bgd.	
		22 ± 2.6	7.9 ± 0.89	"		
		22 ± 2.7	22 ± 2.7	9-27-56		
		22 ± 2.6	22 ± 2.6	"		
	Meat (ripe)	15 ± 5.2	27 ± 3.3	"		
			23 ± 3.1	"		
	Milk	5 ± 0.53	4.9 ± 0.54	"		
		5 ± 0.54	5.2 ± 0.50	7-13-56		
	Breadfruit	Kin	41 ± 6.6	86 ± 4.7	"	
				67 ± 4.5	"	
Meat		20 ± 5.1	20 ± 4.4	"		
Seeds			25 ± 2.8	"		
			22 ± 2.4	"		
Entire		8.6 ± 3.5	"	8.6 ± 3.5		
Ways	Kin	50 ± 6.0				
		11 ± 5.3				
	Meat	9 ± 5.0				
		20 ± 4.9				
	Seeds	21 ± 6.0				
25 ± 6.0						

Appendix Table 2. (continued)

Species	Tissue	1954 [*] Collection d/m/g	1956 ^{**} Collection d/m/g	Date	1958 ^{***} Collection d/m/g	
<u>Land Plants (continued)</u>						
Arrowroot	Meat	35 ± 6.0				
		15 ± 5.2				
		17 ± 5.2				
	Leaves	23 ± 5.8				
	28 ± 6.6					
Tapioca	Meat		19 ± 2.6	7-13-56		
	Meat potato		9.2 ± 1.1	"		
Taro	Meat		9.8 ± 1.93	"		
			17 ± 1.1	"		
	Lime	Meat		11 ± 1.8	"	
		Skin		1.8 ± 1.2	"	
		Meat		12 ± 1.2	"	
			17 ± 1.1	"		
		Sands		118 ± 75	"	
Banana	Entire				6.4 ± 1.9	
	Skin		19 ± 3.3	"		
			17 ± 3.0	"		
			18 ± 2.6	"		
	Meat		19 ± 1.5	"		
		16 ± 1.6	"			
Sugar cane	Entire				13 ± 3.8	
	Meat		12 ± 3.3	"		
Pineapple	Entire		28 ± 4.0	"		
			10 ± 0.68	"	5.4 ± 1.9	
			13 ± 1.79	"		
Soursop	Entire				31 ± 5.4	

Appendix Table E. (continued)

Species	Tissue	1954 ² Collection d/m/g	1956 ²² Collection d/m/g	Date	1958 ²²² Collection d/w/g	
<u>Invertebrates</u>						
Sea cucumber	Tend	289 ± 12	17 ± 2.6	5-13-56	11 ± 3.3	
		119 ± 11			13 ± 3.6	
	Gut	83 ± 14	34 ± 7.2	"	12 ± 9.0	
		136 ± 19			Bgd. Bgd.	
	Integument and muscle			9.2 ± 3.7	"	
	Integument		40 ± 7.1 85 ± 9.8			26 ± 4.2 25 ± 3.2
Muscle					24 ± 4.0 23 ± 4.8 18 ± 4.3	
African snail	Liver		21 ± 4.4	"		
	Shell	71 ± 23				
Coral	Soft parts	190 ± 12				
	entire	206 ± 67				
		138 ± 52				
		74 ± 20				
Hermit crab	Muscle		Bgd.	7-12-56		
	Skeleton		Bgd.	"		
Clam	Muscle				8.6 ± 4.3	
	Kidney				74 ± 12	
	Visceral mass				10 ± 3.3	
Oyster	Muscle				44 ± 7.6	
					22 ± 6.1	

Appendix Table E. (continued)

Species	Tissue	1954 [*] Collection d/m/g	1956 ^{**} Collection d/m/g	Date	1958 ^{***} Collection d/m/g
Invertebrates (continued)					
Shore crab	Entire				14 ± 6.2
Fish					
Harracuda	Muscle		21 ± 2.6	5-13-56	
Yellowfin tuna	Muscle	102 ± 8.1			
		89 - 5.0	13 ± 2.8	"	16 ± 4.2
		88 ± 8.0	15 ± 2.7	"	13 ± 4.0
		92 ± 6.4			
		35 - 3.9			
		67 ± 5.6			
	Bone	132 ± 17			
		122 ± 16			8.6 ± 6.6
		82 ± 17			
		120 ± 16			
		71 ± 13			
		88 - 15			
	Liver	1460 ± 44			9.2 ± 4.6
		1020 ± 42			
		504 - 27			
		924 ± 38			
		231 ± 9.2			
		314 - 15			
	Skin				21 ± 6.1
	Gut				45 ± 7.4

Appendix Table E. (continued)

Species	Tissue	1954 [*] Collection d/m/g	1956 ^{**} Collection d/m/g	Date	1958 ^{***} Collection d/m/g
<u>Fish (continued)</u>					
Bonito	Muscle	75	± 6.6		
		20	± 5.8		
		36	± 5.0		
		29	± 5.0		
	Bone	68	± 23		
		51	± 12		
		100	± 14		
	Liver	48	± 13		
		143	± 7.1		
		118	± 8.0		
179		± 8.1			
		96	± 6.2		
Convict surgeon	Muscle	19	± 3.9		
	Bone	18	± 10		
	Liver	4.8	± 3.1		
	Gut	21	± 6.0		
	Skin	18	± 5.0		
Grouper	Muscle	19	± 4.4		
	Bone	55	± 18		
	Liver	140	± 19		
	Gut	69	± 8.2		
	Skin	27	± 8.1		
Goatfish	Muscle	14	± 5.6		
	Bone	37	± 15		
	Liver	46	± 13		
	Gut	45	± 5.8		
	Skin	18	± 6.9		

Appendix Table E. (continued)

Species	Tissues	1954* Collection d/m/g	1956** Collection d/m/g	Date	1958*** Collection d/m/g	
<u>Fish (continued)</u>						
Marlin	Muscle		10 ± 2.7	5-13-56		
Mixed fish	Muscle		156 ± 14	"		
			48 ± 4.8	"		
			64 ± 7.0	"		
		Liver		84 ± 11	"	
				69 ± 7.8	"	
		56 ± 8.3	"			
Tuna	Muscle		36 ± 2.1	9-26-56		
			44 ± 2.2	"		
			39 ± 1.7	"		
		Liver		312 ± 7.6	"	
				425 ± 14	"	
	308 ± 11		"			
Mullet	Muscle				2 ± 3.2	
	Liver				5.6 ± 4.3	
Skipjack	Muscle				14 ± 4.2	
					12 ± 4.0	
	Skin Bone					6.3 ± 5.0
						22 ± 11

Appendix Table P. Gross beta radioactivity of the biological samples collected at Rongerik Atoll, February 3, 1955, expressed in d/m/g of wet tissue at time of analysis*. The 0.95 counting error is included.

Appendix

Species	Tissue	d/m/g	Species	
<u>Land Plants</u>				
Cocorut	Meat	17 ± 2.7	Fish (Convict)	
		17 ± 2.4		
	Milk	14 ± .90		
		16 ± .97		
Tomato	Fruit	259 ± 12		
	Leaf	1,050 ± 34		
	Stem	870 ± 41		
	Root	1,750 ± 65		
<u>Fish</u>				
Blenny	Muscle	41 ± 7.8		Ground
		30 ± 5.4		
		44 ± 8.0		
	Liver	1,080 ± 68		
		1,280 ± 65		
		1,690 ± 207		
	Viscera	15,200 ± 278		
		9,150 ± 171		
		7,730 ± 162		
	Bone	251 ± 32		
		148 ± 17		
		208 ± 2		
	Skin	81 ± 9.4		
		67 ± 6.5		
94 ± 8.5				
<u>Convict surgeon</u>				
Muscle	41 ± 5.4	Mulle		
	37 ± 6.3			
	70 ± 5.4			
	48 ± 4.6			
	3,200 ± 88			
	2,800 ± 86			
2,770 ± 77				
1,230 ± 60				

* Samples were collected seven months after Operation Castle and

Appendix Table F. (continued)

Species	Tissue	d/m/g
Fish (continued)		
Convict surgeon	Viscera	10,600 ± 240
		2,690 ± 69
		1,200 ± 54
		4,550 ± 106
	Bone	373 ± 25
		386 ± 28
		302 ± 22
		451 ± 30
	Skin	214 ± 15
		179 ± 10
		161 ± 10
		240 ± 14
	Coatfish	Muscle
133 ± 10		
Liver		2,320 ± 113
		2,770 ± 147
Viscera		5,880 ± 146
		3,590 ± 100
Bone		657 ± 52
		914 ± 56
Skin		408 ± 29
		613 ± 37
Grouper	Muscle	70 ± 6.7
		42 ± 8.0
	Liver	2,270 ± 90
		1,100 ± 41
	Viscera	420 ± 23
		1,950 ± 82
	Bone	163 ± 36
		186 ± 20
Skin	203 ± 12	
	145 ± 17	
Mullet	Muscle	83 ± 13
		114 ± 9.2
		87 ± 5.8
		122 ± 7.4

Appendix Table P. (continued)

<u>Species</u>	<u>Tissue</u>	<u>d/m/g</u>
<u>Fish (continued)</u>		
Mullet	Liver	966 ± 50
		884 ± 46
	Viscera	3,270 ± 65
		1,790 ± 28
		670 ± 32
		815 ± 28
		6,150 ± 13
		5,330 ± 67
	Bone	330 ± 38
		185 ± 25
		280 ± 37
		326 ± 32
	Skin	240 ± 17
		290 ± 18
152 ± 21		
222 ± 22		
Parrot fish	Muscle	37 ± 5.4
	Liver	7,100 ± 137
	Viscera	6,670 ± 144
	Bone	110 ± 19
	Skin	108 ± 13
Wrasse	Entire	466 ± 11
	Muscle	87 ± 6.2
	Liver	4,180 ± 113
	Viscera	2,510 ± 71
	Bone	726 ± 52
	Skin	740 ± 34
<u>Birds</u>		
Fairy tern	Muscle	44 ± 5.6
	Liver	224 ± 11
	Lung	224 ± 11
	Kidney	172 ± 8.9
	Ileum	71 ± 8.0
	Bone	54 ± 13
	Skin	152 ± 10
Noddy tern	Muscle	42 ± 3.7
	Liver	184 ± 9.6

Appendix Table F. (continued)

<u>species</u>	<u>Tissue</u>	<u>d/m/g</u>
<u>Birds (continued)</u>		
Noddy tern	Lung	158 ± 6.8
	Kidney	186 ± 9.8
	Ileum	92 ± 6.8
	Bone	66 ± 21
	Skin	181 ± 12
	Egg Yolk	24 ± 3.0
	Egg Shell	Bgd.

Appendix Table G. Gross beta radioactivity of the biological samples collected at Tarawa Atoll, 1956-1958, expressed in d/m/g of wet tissue at time of analysis. The 0.95 counting error is included.

Species	Tissue	1956 [*] Collection d/m/g	1958 ^{**} Collection d/m/g
<u>Marine Plants</u>			
<u>Caulerpa</u>	entire		Bgd. Bgd.
<u>Enteromorpha</u>	"	30 ± 7.4	
<u>Padina</u>	"		5.5 ± 2.7 5.5 ± 2.4
<u>Land Plants</u>			
Banana	Meat	22 ± 2.6	
	Skin	14 ± 2.1 17 ± 1.9	
Breadfruit	Fruit		6.0 ± 4.6 Bgd.
Coconut	Meat	8.3 ± 2.0	7.4 ± 6.7 6.9 ± 5.3 7.4 ± 5.1 12 ± 9.3
			Bgd.
			Bgd.
			Bgd.
	Milk	24 ± 1.3	3.5 ± 1.0 2.6 ± 1.2 10 ± 1.5 3.6 ± .72
			Bgd.
			Bgd.
Lime	Meat	11 ± 1.1 8.6 ± 2.4	
	Seed	15 ± 6.1	
	Skin	8.9 ± 3.6 18 ± 3.9	
<u>Messerschmidia</u>	Leaf		5.8 ± 2.7 6.3 ± 2.8

* 1956 samples were collected 7/6/56 during Operation Redwing and were counted 7/26-9/12/56.
 ** 1958 samples were collected 7/11/58 during Operation Hardtack and were counted 9/5-8/58; the plant samples were counted 10/9/59.

Appendix Table G. (continued)

Species	Tissue	1956 [†] Collection d/m/g	1958 ^{**} Collection d/m/g
<u>Land Plants (continued)</u>			
Papaya	Fruit		2.7 ± 1.9 2.9 ± 1.9
	Meat	9.8 ± 1.1	
	Skin	10 ± 1.3	
		10 ± 1.3	
<u>Scaevola</u>	Leaf		5.9 ± 2.9 6.9 ± 3.6
Squash	Fruit		3.6 ± 1.3 3.6 ± 1.3
<u>Invertebrates</u>			
Clam (<u>Arca</u> sp.)	Shell		4.7 ± 2.0
	Soft parts		8.3 ± 3.1
Ghost crab	Entire		6.9 ± 5.5 7.5 ± 6.0 7.2 ± 5.3
			Bgd.
			Bgd.
Shore crab	Entire		
Hermit crab	Muscle	Bgd.	
	Carapace	Bgd.	
<u>Squid</u>	Muscle		12 ± 4.3 5.7 ± 2.9
			4.4 ± 3.3
	Integument		8.4 ± 2.8 8.8 ± 3.0 6.8 ± 2.6
			6.5 ± 1.8
			5.5 ± 1.9
			7.2 ± 2.8
	Gonad		Bgd.
			Bgd.
			Bgd.
		Gut and contents	

Appendix Table 2. (continued)

Species	Tissue	1956 [*] Collection d/m/g	1958 ^{**} Collection d/m/g
<u>Fish</u>			
Mixed fish	Muscle	50 ± 8.0	
		24 ± 4.4	
		57 ± 3.6	
	Liver	31 ± 4.1	
		27 ± 4.5	
		13 ± 3.7	
Grouper	Muscle		10 ± 4.0
			8.9 ± 3.6
	Liver		Bgd. Bgd.
Herring	Entire	59 ± 4.7	
Snapper	Muscle		7.7 ± 3.6
	Liver		5.6 ± 4.3
Squirrelfish	Muscle		8.9 ± 3.6
	Liver		Bgd.
<u>Birds</u>			
Tern	Egg yolk	15 ± .28	
	Egg white	99 ± 4.3	
	Egg shell	10 ± 2.3	

Appendix Table H. Gross beta radioactivity of the biological samples collected at Ujae Atoll, 1955-1958, expressed in $\mu\text{m/g}$ of wet tissue at time of analysis. The 0.95 counting error is included.

Species	Tissue	1955* collection $\mu\text{m/g}$	1956** Collection $\mu\text{m/g}$	1958*** Collection $\mu\text{m/g}$	
<u>Marine Plants</u>					
<u>Halimeda</u>	entire	160 \pm 15	173 \pm 12	180 \pm 24	
		215 \pm 17	215 \pm 14		
		117 \pm 11			
<u>Caulerpa</u>	entire	229 \pm 12		110 \pm 13	
<u>Microdictyon</u>	"	761 \pm 34			
<u>Liagora</u>	"	736 \pm 31			
<u>Land Plants</u>					
Arrowroot	Meat		6.8 \pm 1.7		
			6.5 \pm 1.6		
			6.9 \pm 1.1		
			8.6 \pm 1.3		
Breadfruit	Meat		7.2 \pm 3.5	6.6 \pm 1.4	
			15 - 4.8		
Bunchgrass	Tops	60 \pm 5.5			
		28 \pm 6.5			
Coconut	Meat	11 \pm 3.5	9.8 \pm 1.2	Egs.	
		17 \pm 3.9	9.8 - 1.1		
		14 \pm 2.8			
	Milk	Milk	14 \pm 3.0		2.8 \pm 7.6
			11 \pm .97	11 \pm 1.1	
			13 \pm .92	4.3 - 1.1	
			13 \pm 1.2		
		11 \pm .94			

* 1955 samples were collected 2/8/55, eight months after Operation Castle, and were counted 3/3/55 to 4/15/55.

** 1956 samples were collected 7/17-18/56, during Operation Redwing and were counted 8/23/56 to 9/6/56.

*** 1958 samples were collected 7/19/58, during Operation Hardtack and were counted 9/12-17/58.

Appendix Table H. (continued)

Species	Tissue	1955 ⁺ Collection 6/21/55	1956 ⁺⁺ Collection 4/21/56	1957 ⁺⁺⁺ Collection 1/27/57
<u>Land Plants (continued)</u>				
<u>Messerschmidia</u>	Leaf	69 ± 15		120 ± 11
		71 ± 8.9		
	Stem	50 ± 4.2		
		39 ± 11		
		58 ± 11		
Fruits	44 ± 6.0			
Papaya	Fruit		7.6 ± .46	4.5 ± 1.3
			5.0 ± .20	
<u>Sesuvia</u>	Leaf	63 ± 15		160 ± 15
		60 ± 6.5		
	Fruit	23 ± 3.3		
		21 ± 5.4		
Screw pine	Fruit Meat	20 ± 4.8	32 ± 4.2	19 ± 5.9
			33 ± 5.5	
	Epidermis	35 ± 6.3		
Taro	Tuber			7.0 ± 2.7
<u>Invertebrates</u>				
Clam (<u>Tridacna</u> <u>crocea</u>)	Mantle	60 ± 9.3		
		26 ± 5.0		
	Muscle			12 ± 4.6
				29 ± 5.0
				15 ± 5.0
				500 ± 53
Kidney	910 ± 46		120 ± 15	
			430 ± 42	

Table I. (continued)

	Class	1955 ^a Collection 1/2/3	1956 ^b Collection 1/2/3
Invertebrates (continued)			
Starfish (class Asteroidea)	Visceral mass	99 ± 6.3	61 ± 5.1
	Gill	102 ± 7.8	
Scudis-scorpia	Entire	207 ± 20	
sp.	"	196 ± 26	
<i>Stylocentria</i> sp.	"	147 ± 16	
<i>Stylocentria</i> sp.	"	416 ± 18	
<i>Stylocentria</i> sp.	"	278 ± 13	
Coconut crab	Carapace	150 ± 29	
		58 ± 21	
	Abdomen	4.5 ± 3.5	
		6.5 ± 3.8	
Ghost crab	Entire	30 ± 12	
Hermit crab	"	98 ± 13	
Sea cucumber	Muscle	39 ± 5.0	
		34 ± 5.2	
		38 ± 5.1	
	Integument	13 ± 1.7	
		11 ± 1.5	
		30 ± 3.5	

Appendix Table II. (continued)

	1955 ^a Collection	1958 ^b Collection
On		
On		
On		
Reddy Cove		
HW	88 ± 7.4 43 ± 4.3	
Li	593 ± 8.1 172 ± 3.2	
Lar	42 ± 18 347 ± 7.3	
HW	163 ± 9.1 170 ± 10	
	98 ± 6.6 170 ± 6.6	
	155 ± 29 155 ± 22	
Skin	377 ± 94 100 ± 10	

andix Table V. (continued)

Species	Tissue	1955 ^o Collection d/m/g	1956 ^{os} Collection d/m/g	1958 ^{ooo} Collection d/m/g
Herring	Muscle		110 ± 13	
Puffer	Liver		1220 ± 27	
Mixed	Muscle			7.3 ± 3.6
	Liver			82 ± 11
Sarge	Muscle			36 ± 5.9
	Liver			90 ± 12
Mixed	Muscle		11 ± 9.5	
	Liver		16 ± 6.4	
			14 ± 4.2	
			73 ± 8.9	
			162 ± 7.2	
			120 ± 5.5	

Table I. Gross beta radioactivity of the biological samples collected at Utirik Atoll 1954-1958, expressed in d/m/g of wet tissues at time of analysis. The 0.95 counting error is included.

Species	Tissue	1954 ^o Collection d/m/g	1955 ^{oo} Collection d/m/g	1958 ^{ooo} Collection d/m/g
<u>Seaside Plants</u>				
<u>Caulerpa</u>	Entire	575 ± 21		
		418 ± 18		
		1530 ± 44		
<u>Codium</u>	Entire	1200 ± 32		
	"	1250 ± 35		
	"	7880 ± 162		
	"	6070 ± 136		
<u>Lyngbya</u>	"	7120 ± 142		
		4500 ± 88		
		3100 ± 77		
<u>Land Plants</u>				
<u>Arrowroot</u>	Meat		44 ± 4.4	
<u>Breadfruit</u>	Meat		31 ± 4.2	
	Fruit		13 ± 2.6	
<u>Coconut</u>	Meat		18 ± 2.8	11 ± 2.0
			20 ± 2.6	
			18 ± 2.2	
	Milk		14 ± 1.0	4.2 ± .80
			29 ± 1.3	
		19 ± 1.1		

1 samples were collected 5-17-54 during Operation Castle and were counted 6-11-54
 2 samples were collected 1-23-55 seven months after Castle and were counted 2-21-55
 3 samples were collected 7-16-58 during Operation Hardtack and were counted 9-8-58.

Appendix Table I. (continued)

Species	Tissue	1954* Collection d/m/g	1955** Collection d/m/g	1958*** Collection d/m/g
<u>Land Plants (continued)</u>				
Papaya	Meat		69 ± 4.8	
	Seeds		102 ± 6.0	
	Entire			11 ± 2.7
Screw pine	Meat		12 ± 3.5	
	Epidermis		24 ± 4.1	
	Fruit			19 ± 4.8
Taro	Meat			4.8 ± 2.4
<u>Invertebrates</u>				
Clam (<u>Anadara antiquata</u>)	Shell			Bgd.
	Muscle			12 ± 4.6
	Kidney			45 ± 35
	Visceral mass			42 ± 5.6
Corals <u>Acropora</u> sp.	Entire		82 ± 21	
			79 ± 25	
			109 ± 16	
<u>Pungia</u> sp.	Entire		75 ± 20	
Ghost crab	"			67 ± 8.9
				99 ± 13
				52 ± 8.6

Table I. (continued)

Species	Tissue	1954 [*] Collection d/m/g	1955 ^{**} Collection d/m/g	1958 ^{***} Collection d/m/g
<u>Invertebrates (continued)</u>				
Hermit crab	Entire			180 ± 19
Sea cucumber [#]	Muscle	101 ± 6.0		10 ± 2.5
		662 ± 33		
		300 ± 15		
	Integument	180 ± 12		20 ± 3.6
		143 ± 13		18 ± 3.5
		104 ± 6.4		
	Gonad	161 ± 10		11 ± 8.6
		1640 ± 68 ^{##}		9.7 ± 2.2
	Gut and contents	376 ± 27 ^{##}		Egd.
		440 ± 22		Egd.
759 ± 35				
		588 ± 29		
Snail (<u>Turbo</u> sp.)	Entire			190 ± 20
<u>Fish</u>				
<u>Paraselfish</u>				
<u>Abudefduf</u>				
<u>biocellatus</u>	Muscle			7. ± 7.4
	Liver			7.3 ± 10
<u>Dascyllus</u>				
<u>aruanus</u>	Entire	57 ± 7.2		
		46 ± 6.2		
		64 ± 12		
		43 ± 6.0		
		60 ± 7.0		

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1958 species not determined
contained some sand particles

Appendix Table I. (continued)

Species	Tissue	1954 ^o Collection d/m/g	1955 ^{oo} Collection d/m/g	1958 ^{ooo} Collection d/m/g
<u>Fish (continued)</u>				
<u>Paracentrus</u>				
<u>americanus</u>				
	Muscle		7.1 ± 5.3	
	Liver		271 ± 203	
	Bone		16 ± 12	
	Skin		22 ± 18	
	Viscera		23 ± 13	
			28 ± 20	
			45 ± 45	
	Muscle			4.3 ± 3.6
	Liver			30 ± 6.7
<u>Grouper</u>				
<u>Spinophthalmus</u>				
<u>longatus</u>				
	Entire		56 ± 18	
			32 ± 15	
	Muscle		8.0 ± 3.0	
	Liver		169 ± 75	
	Bone		24 ± 19	
	Skin		19 ± 7.9	
	Viscera		69 ± 26	
Jack	Muscle		14 ± 4.4	
	Liver		Ed.	
	Bone		24 ± 19	
	Skin		32 ± 16	
	Viscera		108 ± 25	

Jack	Liver	1954	75
	Bone	1954	19
	Skin	1954	7.9
	Viscera	1954	28
	Muscle	1954	4.4
	Liver	1958	19
	Bone	1958	16
	Skin	1958	23
	Viscera	1958	23

Table I. (continued)

Species	Tissue	1954 [*] Collection d/n/g	1955 ^{***} Collection d/n/g	1958 ^{***} Collection d/n/g
<u>Fish (continued)</u>				
Wrasse	Liver		2.9	
	Bone		14	
	Skin		20	
	Viscera		30	

Table J. Gross beta radioactivity of the biological
 Utohe Atoll, 1956-1958, expressed in terms
 of analysis. The 0.95 counting error

Species	Tissue	1956 ^a Collection d/m/y	Count	Count error
<u>Marine Plants</u>				
<u>Caulerpa</u>	Entire	460 ± 15		
		97 ± 26		
<u>Halimeda</u>		73 ± 33	56 ± 18	
<u>Land Plants</u>				
Arrowroot	Meat	46 ± 2.9	21 ± 4.0	
		74 ± 4.7		
Breadfruit	Fruit	76 ± 3.2	89 ± 4.2	
		89 ± 4.2		
Coconut	Meat	13 ± 1.8	3.2 ± 2.0	
	Milk		2.7 ± 0.73	
<u>Messerschmidia</u>	Leaves and stems	20,000 ± 420		
<u>Morinda</u>	Fruit	66 ± 2.0		
		89 ± 2.5		
Screw pine	Fruit		130 ± 20	
	Meat	76 ± 5.2		
		86 ± 5.6		
	Skin	67 ± 4.4		
		67 ± 4.4		
<u>Fish</u>				
Mixed reef fish	Muscle	618 ± 28	8.9 ± 1.6	
		657 ± 19	12 ± 1.0	
	Liver	590 ± 15	20 ± 1.5	
		1020 ± 43	15 ± 1.1	
		720 ± 30		

samples were collected 6/10/56 during Operation Redwing and were counted 7/25
 30/56.
 samples were collected 6/30/58 during Operation Hardtack and were counted 8/1
 12/58.

Appendix Table J. (continued)

Species	Entire	1956* Collection d/m/g	1958** Collection d/m/g
<u>Invertebrates</u>			
Coconut crab	Carapace	Egd.	210 ± 31
			140 ± 28
			160 ± 30
			780 ± 83
	Muscle	Egd.	6.3 ± 4.0
	Liver	Egd.	
	Abdomen		41 ± 7.4
			56 ± 7.6
			38 ± 7.0
			210 ± 21
Sea cucumber	Muscle		13 ± 4.1
			41 ± 7.0
			31 ± 5.5
	Integument		50 ± 5.2
			130 ± 14
	Gonad	Egd.	
			10 ± 2.2
	Gut and contents		Egd.
			Egd.
			Egd.
Spider snail	Shell		73 ± 35
			120 ± 36
	Soft parts		63 ± 13
			21 ± 7.6
	Liver		19 ± 10
			53 ± 4.0

10 (continued)

<u>Species</u>	<u>Tissue</u>	<u>1956[*]</u> <u>Collection</u> <u>d/m/g</u>	<u>1958^{**}</u> <u>Collection</u> <u>d/m/g</u>
<u>Invertebrates (continued)</u>			
Hermit crab	Muscle	Bgd.	
	Skeleton	Bgd.	
	Liver	Bgd.	

Appendix Table K. Gross beta radioactivity of soil samples collected at various islands in the Central Pacific during 1954-1958, expressed in d/m/g of dry soil at time of analysis. The 0.95 counting error is included.

Island	Soil type	Date		d/m/g
		Collected	Counted	
Bikar	Island	2-3-55	4-8-55	16,100 ± 716
	Beach	"	"	208 ± 109
Kusaie	Island	7-5-56	10-9-56	Bgd.
Likiep	Island	1-22-55	4-8-55	785 ± 129
	Beach	"	"	Bgd.
Ponape	Island	12-16-54	1-7-55	295 ± 74
	"	7-13-56	8-8-56	Bgd.
Rongerik	Island	2-3-55	4-8-55	1,820 ± 164
	"	"	"	2,980 ± 185
Tarawa	Island	7-8-56	10-9-56	140 ± 92
	"	7-11-58	9-5-58	Bgd.
Ujelang	Island	2-8-55	4-8-55	165 ± 109
	Beach	"	"	162 ± 109
	Island	7-18-56	10-9-56	Bgd.
	"	7-19-58	10-19-58	Bgd.*
Utirik	Island	1-23-55	4-8-55	1,140 ± 185
	Beach	"	"	41 ± 118
Wotho	Island	6-15-56	10-9-56	250 ± 99

* Samples counted more than one year after collection.

Appendix Table L. Semi-quantitative evaluation of the gamma-emitting radioisotopes in biological samples collected in the Central Pacific area.

Location, Collection date and Sample	Co ⁶⁰	Zn ⁶⁵	Co ⁵⁸	Zr ⁹⁵ Nb ⁹⁵	Cs ¹³⁷	Ru ^{103,106} Rh ^{103,106}	Co ^{114,114} Pr ¹¹⁴	Co ⁵⁷	W ^{181,185}	Mn ⁵⁴	Po ⁵⁹
KAPINGAMARANGI											
7-24-58											
Fish liver		++		+++		+++					++
Coconut meat				++++		+++					+
milk				++++		++					+
Breadfruit, fruit				++++	++	+++					
KUCALE											
7-24-58											
Yellowfin tuna											
muscle		+		++		+++					
skin		+		+++		+++					
Scaevola leaves				+++		+++	++		++++		
PONAPE											
7-25-58											
Mixed fish											
muscle				++++		+++					++
liver				++							+++
Skipjack											
muscle		+		++++		+++					+
skin				+++		+++					
bone				+++		+++				++	
Yellowfin tuna											
muscle				++++		+++					+++
white muscle				+++		++					+++

- + = very low or questionable
- ++ = present in low amounts
- +++ = present in higher amounts
- ++++ = predominates

Appendix Table I. (continued)

Location, Collection Date and Sample	Co 60	Co 58	Co 55	Co 137	Pu 103, 106 Re 103, 106	Co 111, 114 Pr 111	Co 57	W 181, 185	In St	Re 59
PONAPE (continued)										
Yellowfin tuna										
skin	+++									
bone	+++									
gut	+++									
Taro			+++		+++					++
Coconut meat			+++		+++					++
milk			+++	+	+++					
Breadfruit			+++		+++					++
Lime			++		+++					++
Banana			+++		+++					+
Pineapple			+++	+	+++	++				
Sea cucumber										
gonad	+		+							++
integument			+++		++					++
<u>Pinna</u>										
kidney	++		+++		+++					
visceral mass	++		++		+++					+
<u>Crapsus</u>										
entire			+++		+++					++
UJELANG										
7-19-58										
Surgeon fish,										
muscle			+++		+++	++				
Mixed fish muscle										
and liver	+++		+++		+++					+
Mixed fish, liver	+++		+++		+++					+

ix Table L. (continued)

Location, Collection date and Sample	Co 60	Zn 65	Cu 58	Zr ⁹⁵ Nb ⁹⁵	Cs 137	Ru 101,106 Rh 103,106	Co 141,144 Pr 144	Co 57	W 181,185	Pa 231	Po 210
UJELANG (continued)											
Coconut meat				++		++					+
milk				++		++					+
Breadfruit, fruit				+++		++++					+
Papaya fruit				+++		++++					++
Pandanus fruit				+++		++++					+
Taro root				+++		++++					+
Messerschmidia											
leaves				+++		+++	++				++++
Scaevola leaves				++		+++	++				++++
Caulerpa, entire				++		+++	++				
Tridacna clam											
muscle				++		+++					++
visceral mass				+++		++++					++
kidney				++		++++					++
UTIRIK											
7-16-58											
Fish liver				+++		++					
muscle				+++		++					
Coconut meat				++		+					
milk				+		++					

Appendix Table L. (continued)

Location, Collection date and Sample	Co ⁶⁰	Zn ⁶⁵	Cc ⁵⁸	Cs ¹³⁷	Sr ^{103,106} Rh ^{103,106}	Co ^{111,114} Pr ¹¹⁴	Co ⁵⁷	W ^{181,185}	Mn ⁵⁴	Fe ⁵⁹
UJELANG (continued)										
Pandanus fruit			++	++++	++					
Papaya fruit			++	++++						
Breadfruit, fruit			++++	+++	++++					
WJTHO										
6-18-5										
<u>Messerschmidia</u> leaves			++		++++					
6-30-58										
<u>Halimeda</u> , entire					+++					

Appendix Table V. Scientific names of the species.

Common name	Scientific name
I. BIRDS	
Fairy tern	<u>Sterna bergii</u> Chapman
Noddy tern	<u>Anous stolidus</u> L.
II. FISH	
Barracuda	<u>Scombrus japonica</u> <small>DuRoi and Valenciennes</small>
Blue dash blenny	<u>Istiblennius paulus</u> <small>Bryan and Herre</small>
Red spotted blenny	<u>Istiblennius edentulus</u> <small>Bloch and Schneider</small>
Bonito	<u>Katsuwonus pelamis</u> (Linnaeus)
Butterfly fish	<u>Chaetodon auriga</u> <small>Forsk.</small>
Convict surgeon	<u>Acanthurus triostegus</u> L.
Carpel fish	<u>Pomacentrus nigricans</u> <small>(acepede)</small>
" "	<u>Cacyllus aruanus</u> (Linnaeus)
" "	<u>Abudefduf biocellatus</u> <small>(Quoy and Gaimard)</small>
Flatfish	<u>Muraenichthys samoensis</u> (Gunther)
Groupers	<u>Epinephelus fuscoguttatus</u> (Forsk.)
" "	<u>E. merra</u> <small>Bloch</small>
" "	<u>E. elongatus</u> <small>Schultz</small>
Herring	<u>Sprattelloides delicatulus</u> (Bennett)
Jack	<u>Caranx sexfasciatus</u> <small>(Quoy and Gaimard)</small>
Marlin	<u>Tetrapterus</u> sp.
Mullet	<u>Neomyxus chaptalli</u> <small>Hydoux and Scouleyer</small>

Appendix Table continued

Common name	Scientific name
<u>LAND PLANTS (cont.)</u>	
Screw pine	<u>Pandanus tectorius</u> Par.
Soursop	<u>Annona muricata</u> L.
Squash	<u>Cucurbita</u> sp.
Sugar cane	<u>Saccharum officinarum</u> L.
Sweet potato	<u>Ipomoea batatas</u> (L.) Poir.
Tapioca	<u>Manihot utilissima</u> Pohl
Taro	<u>Cyrtosperma charissonia</u> (Schott) Merrill
Tomato	<u>Solanum lycopersicum</u> L.
<u>V. MARINE PLANTS</u>	
Algae	<u>Asparagopsis taxiformis</u>
"	
"	
"	
"	
"	
"	
"	
"	
"	

Appendix Table N. (continued)

Common name	Scientific name
FISH (continued)	
Parrot fish	<u>Scaurus</u> sp.
Puffer	<u>Tetraodon</u> sp.
Skipjack	<u>Euthynnus affinis yaito</u> (Kishinouye)
Snapper	<u>Lutianus</u> sp.
Squirrel fish	<u>Myripristis murdjan</u> (Forsk.)
" "	<u>Holocentrus microstomus</u> (Gunther)
Wrasse	<u>Halichoeres trimaculatus</u> (Quoy and Gaimard)
Yellow fin tuna	<u>Thunnus albacore macropterus</u> (Terminck and Schlegel)
III. INVERTEBRATES	
African snail	<u>Achatina fulica</u> Ferrussac
Clam	<u>Anadara</u> sp.
	<u>Arca</u> sp.
	<u>Pinna</u> sp.
	<u>Tridacna crocea</u> Lamarck
Coconut crab	<u>Birgus latro</u> L.
Corals	<u>Acropora</u> sp.
	<u>Fungia</u> sp.
	<u>Heliopora</u> sp.
	<u>Pocillopora</u> sp.
	<u>Porites</u> sp.
	<u>Styosmilia</u> sp.
Ghost crab	<u>Cypride ceratophthalma</u> (Fallas)
Hermit crab	<u>Coenobita perlatus</u> Edw. T.
	<u>Coenobita</u> sp.
Oyster	<u>Ostrea</u> sp. (?)

Appendix Table M. (continued)

Common name	Scientific name
INVERTEBRATES (continued)	
Sea cucumber	<u>Holothuria atra</u> Jaeger
Shore crab	<u>Grapsus grapsus</u> L.
Snail	<u>Turbo</u> sp.
Spider snail	<u>Lambis lambis</u> (L.)
Sponge	not identified
IV LAND PLANTS	
Arrowroot	<u>Tacca leontopetaloides</u> (L.) Ktze
Banana	<u>Musa sapientum</u> L.
Breadfruit	<u>Artocarpus altilis</u> (Park.) Fosb.
Bush papaya	<u>Scaevola</u> sp.; probably <u>S. sericea</u> (Vahl)
Bunch grass	<u>Lepturus repens</u> (Forster) R. Brown
Coconut	<u>Cocos nucifera</u> L.
Lime	<u>Citrus aurantifolia</u> (Christm.) Swingle
Mango	<u>Mangifera indica</u> L.
Messerschmidia	<u>Messerschmidia argentea</u> (L.) I. M. Johnston
Morinda	<u>Morinda citrifolia</u> L.
Mountain apple (?)	Not identified
Orange	<u>Citrus</u> sp.
Papaya	<u>Carica papaya</u> L.
Pineapple	<u>Ananas comosus</u> (L.) Merr.

Appendix Table V. (continued)

<u>Common name</u>	<u>Scientific name</u>
MARINE PLANTS (continued)	
Algae	<u>Padina commersonii</u> Lory
"	<u>Rhipilia</u> sp.
"	<u>Turbinaria ornata</u> (Turn.) J. Agardh
Sea grass	Not identified

VI. RATS

Field rat	<u>Rattus exulans</u> Peale
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