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UWFL-79
Biology and Medicine

R F Palumbo

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

Ralph F. Palumbo

Laboratory of Radiation Biology
University of Washington
Seattle, Washington

Lauren R. Donaldson
Director

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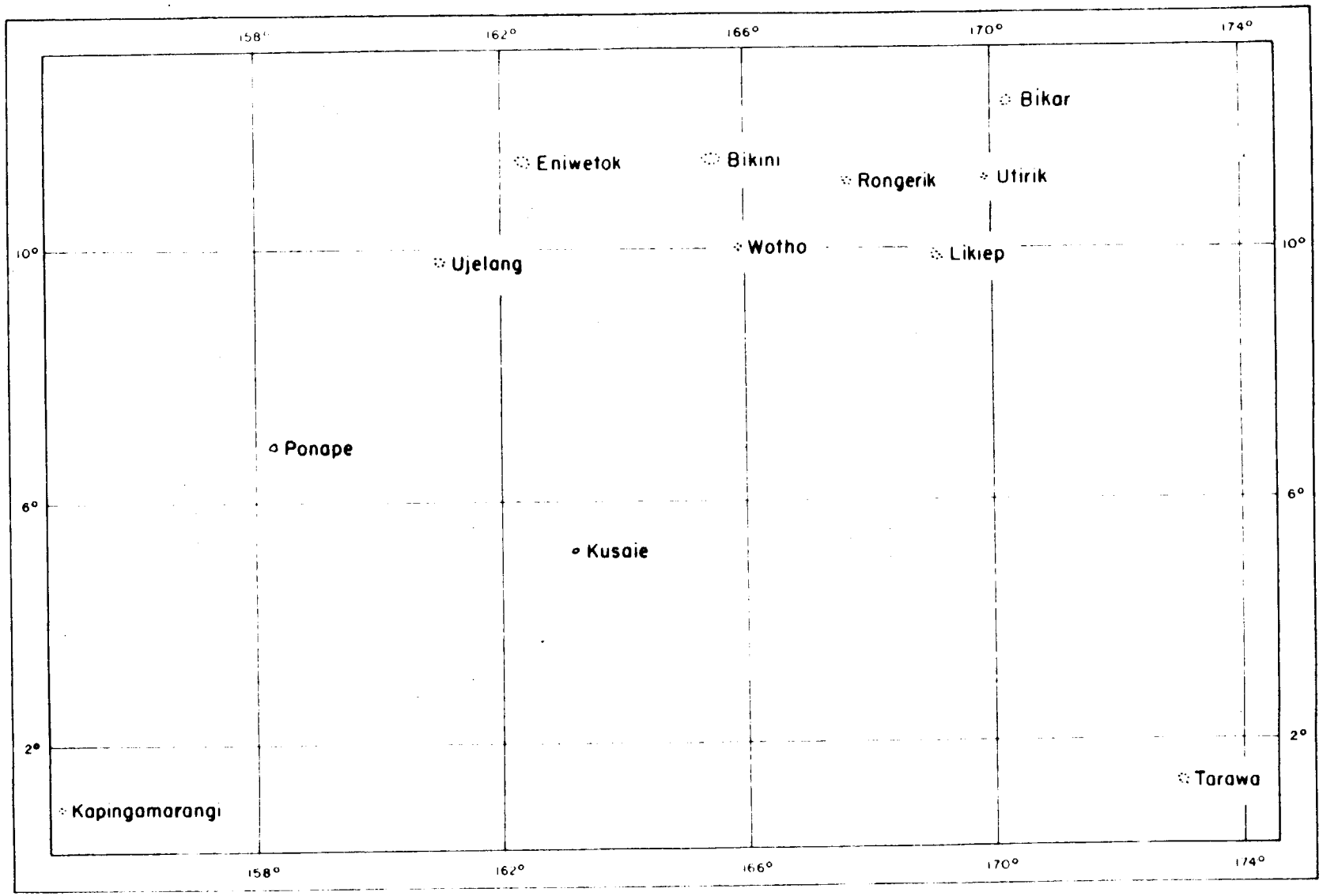

Fig. 1. Collecting stations in the central Pacific in the vicinity of the Eniwetok Test Site.

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 (1960).

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.

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

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

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. 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

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

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)

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

Table 3. Radioisotopes in fish, invertebrates and land plants from "off-site" locations July-August, 1958. Values are expressed as μμc/g wet weight plus or minus .95 counting error at time of collection.

Sample and location	Collection date	Species	Tissue	K^{40}	Zn^{65}	Cs^{137}	Co^{57}	W^{185}	Ru^{106}-Rh^{106}	Zr^{95}-Nb^{95}	Sr^{90}
Fish											
Wotho	6-30-58	Mixed	Whole	9.5 ± 2.3	16 ± 0.86	--	0.73 ± 0.15	--	--	--	--
Kusaie	7-3 -58	Yellowfin tuna	Mixed	4.2 ± 0.44	0.68 ± 0.31	--	2.0 ± 0.064	--	0.55 ± 0.34	--	--
Tarawa	7-11-58	Grouper	Liver, muscle	9.1 ± 1.5	--	--	--	--	--	--	--
			Muscle	5.5 ± 0.82	--	--	--	--	--	--	--
Utirik	7-16-58	Mixed	Whole	5.0 ± 0.68	4.5 ± 0.55	--	--	--	1.7 ± 0.41	--	--
Ujelang	7-19-58	Squirrelfish	Liver, muscle	6.8 ± 0.77	2.2 ± 0.82	0.17 ± 0.045	--	--	--	--	--
Ponape	7-25-58	Yellowfin tuna	Mixed	3.5 ± 0.77	16 ± 2.3	--	--	--	--	40 ± 7.7	--
Invertebrates											
Wotho	6-30-58	Coconut crab	Abdomen	15 ± 2.2	68 ± 2.0	--	4.0 ± 0.38	--	--	--	0
		" "	Carapace	10 ± 1.3	13 ± 1.0	1.4 ± 0.073	2.4 ± 0.18	37 ± 3.9	3.8 ± 0.86	--	18 ± 0.73[1]
Land Plants											
Wotho	6-30-58	Coconut	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
Kusaie	7- 3-58	Coconut	Milk	3.7 ± 0.39	--	0.077 ± 0.019	--	--	--	--	--
		Breadfruit	Fruit	3.8 ± 0.12	--	0.095 ± 0.0073	--	1.8 ± 0.18	--	--	0
Tarawa	7-11-58	"	"	19 ± 1.1	--	1.0 ± 0.069	--	21 ± 1.6	--	--	0
Utirik	7-16-58	"	"	15 ± 0.35	--	1.3 ± 0.037	0.12 ± 0.035	2.0 ± 0.64	--	--	0.086 ± 0.0059
Ujelang	7-19-58	Coconut	Milk	2.8 ± 0.43	--	0.26 ± 0.10	--	6.8 ± 0.23	--	--	0
			Meat	3.0 ± 0.34	--	0.35 ± 0.025	--	3.9 ± 0.64	--	--	0
		Breadfruit	Fruit	2.6 ± 0.64	--	0.50 ± 0.045	0.29 ± 0.073	10 ± 1.4	--	--	0.018 ± 0.0050
Kapingamarangi	7-24-58	"	"	3.3 ± 0.21	--	0.12 ± 0.013	--	0.77 ± 0.32	--	--	0
Ponape	7-25-58	"	"	5.5 ± 0.27	--	0.39 ± 0.015	--	--	--	--	0

[1] Dry weight basis

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.

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.

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 $\mu\mu c/g$ at time of counting); at time of collection the level of Zr^{95}-Nb^{95} would have been 40 $\mu\mu c/g$. 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 $W^{181,185}$, 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.

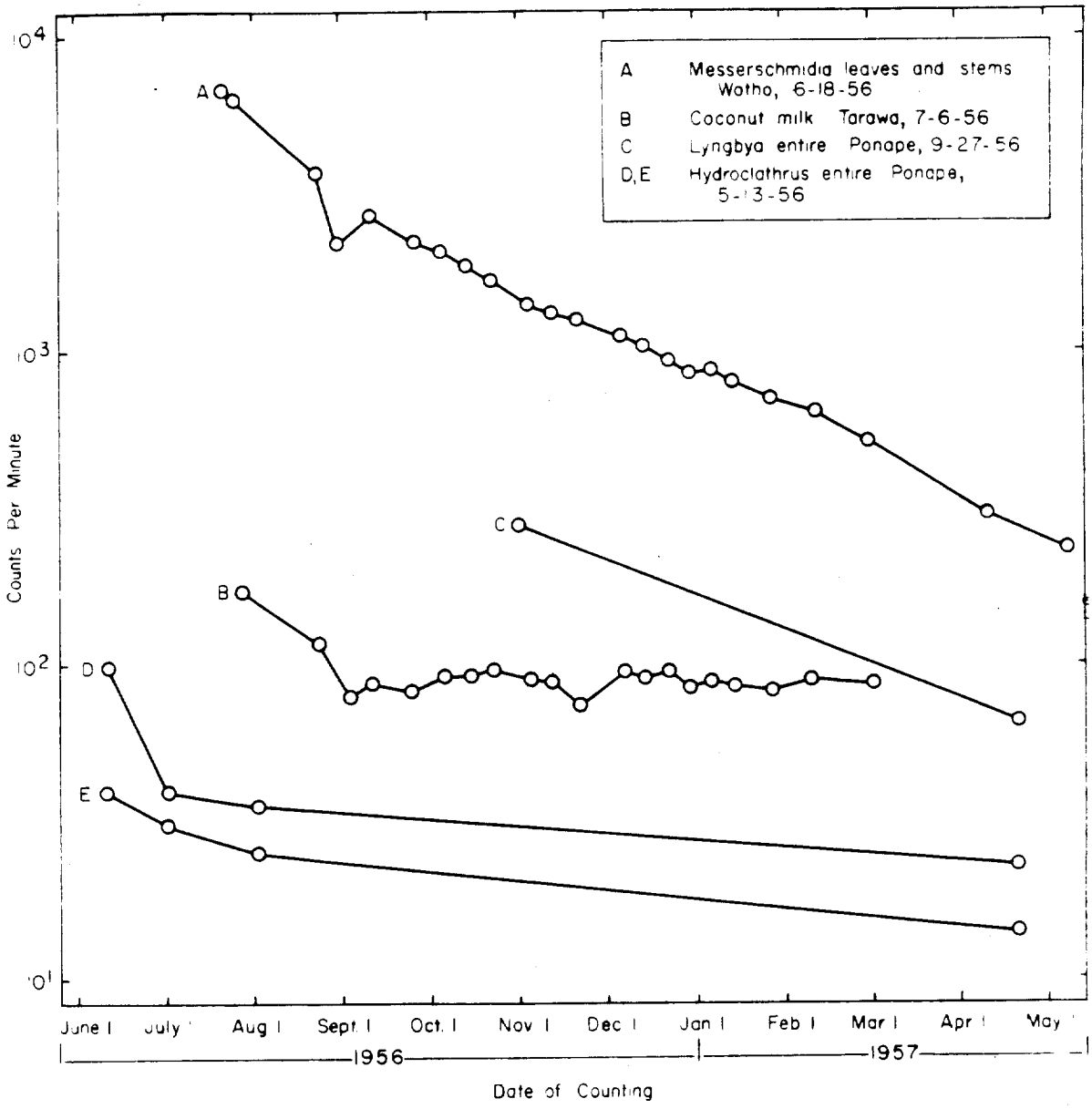

Fig. 2. Beta decay curves of samples collected in 1956.

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

APPENDIX

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 0.95 counting error is included.

Species	Tissue	d/m/g
Land Plants		
Coconut	Meat	20 ± 3.5
		15 ± 2.7
		21 ± 3.7
	Milk	15 ± .98
		16 ± .86
		16 ± 1.0
Scaevola	Leaf	272 ± 20
Birds		
Fairy tern	Muscle	38 ± 4.0
	Liver	130 ± 6.8
	Lung	212 ± 21
	Kidney	91 ± 6.8
	Ileum	85 ± 7.8
	Bone	114 ± 30
	Skin	76 ± 7.6
Noddy tern	Muscle	46 ± 3.3
	Liver	314 ± 4.8
	Lung	182 ± 6.8
	Kidney	379 ± 17
	Ileum	85 ± 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 ± 8.4
Rats		
Field rat	Muscle	33 ± 4.6
	Kidney	83 ± 13
	Bone	563 ± 42
	Skin	126 ± 8.1

* 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 Kapingamarangi Atoll, July 24, 1958; expressed in d/m/g of wet tissue at time of analysis*. The 0.95 counting error is included.

Species	Tissue	d/m/g
Land Plants		
Breadfruit	Fruit	10 ± 4.1
Coconut	Meat	Bgd.
	Milk	4.1 ± .82
Invertebrates		
Clam (*Tridacna crocea*)	Muscle	9.4 ± 1.7
		Bgd.
	Kidney	110 ± 15
		120 ± 17
	Visceral mass	4.9 ± 2.8
		6.1 ± 3.1
Coconut crab	Carapace	Bgd.
	Abdomen	12 ± 4.3
Hermit crab	Carapace	49 ± 18
		50 ± 18
		37 ± 19
		77 ± 21
	Abdomen	Bgd.
		4.6 ± 3.6
		5.0 ± 4.0
		4.6 ± 3.6
Sea cucumber	Muscle	55 ± 6.9
		28 ± 4.1
	Integument	25 ± 4.7
		21 ± 3.9
	Gonad	40 ± 6.5
		13 ± 2.4
	Gut and contents	19 ± 9.6
		11 ± 9.0
Fish		
Mixed reef fish	Entire	9.1 ± 4.2
		7.0 ± 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 Kusaie Island, 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
Marine Plants			
Asparagopsis	Entire		16 ± 3.3
Caulerpa	"		44 ± 5.0
Halimeda	"	86 ± 9.4	42 ± 17
Turbinaria	"	42 ± 3.6 43 ± 4.1	
Land Plants			
Banana	Fruit		1.1 ± .58
	Meat	29 ± 2.2	
Breadfruit	Fruit		13 ± 5.4
	Meat	35 ± 4.4	
Coconut	Meat		4.6 ± 1.8
	Milk	18 ± 2.1	56 ± 13
Lime	Fruit		5.8 ± 2.4
	Meat	8.6 ± .67 6.5 ± .60	
	Seeds	30 ± 8.7	
	Skin	16 ± 2.5 24 ± 2.7	
Mango	Fruit		11 ± 3.5
Mountain apple	Fruit	8.6 ± 1.3	
	Fruit	7.2 ± .74	
Orange	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 7/25/56 to 9/12/56.

** 1958 samples were collected 7/3/58 during Operation Hardtack and were counted 8/28/58 to 9/2/58.

Appendix Table C. (continued)

Species	Tissue	1956* Collection d/m/g	1958** Collection d/m/g
Land Plants (continued)			
Papaya	Fruit	4.6 ± .58	2.7 ± 1.9
	Fruit	5.7 ± .31	
	Seeds		7.3 ± 3.2
Pineapple	Fruit	11 ± 1.3	11 ± 2.2
		11 ± 1.5	
Scaevola	Leaves		67 ± 7.4
Soursop	Fruit		4.8 ± 2.6
Screwpine	Fruit		11 ± 5.3
Sugar cane	Stem		Bgd.
Sweet potato	Meat		Bgd.
Taro	Meat		34 ± 7.6
Invertebrates			
Ghost crab	Entire		14 ± 6.0
			Bgd.
Hermit crab	Carapace	Bgd.	76 ± 20
	Abdomen		16 ± 4.6
Sea cucumber	Muscle		38 ± 8.6
			22 ± 6.9
			18 ± 5.9
			13 ± 5.4
	Integument		28 ± 4.7
			38 ± 5.6
			24 ± 4.2
			19 ± 4.0
	Gonad		30 ± 6.5
			18 ± 5.6
			18 ± 3.4
			16 ± 3.2
	Gut and contents		Bgd.
			Bgd.
			Bgd.
			Bgd.
Sponge	Entire		64 ± 10
Fish			
Mixed fish	Muscle	49 ± 15	
		313 ± 14	
		207 ± 9.8	

Appendix Table C. (continued)

Species	Tissue	1956* Collection d/m/g	1958** Collection d/m/g
Mixed fish (contd.)	Liver	212 ± 11 51 ± 4.3 143 ± 15	
Parrot fish	Muscle Liver		4.4 ± 3.7 Bgd.

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

Species	Tissue	d/m/g
Marine Plants		
Neomeris	Entire	129 ± 16
Padina	"	462 ± 25
Rhipilia	"	300 ± 28
Land Plants		
Banana	Meat	26 ± 3.4
Coconut	Meat	12 ± 3.0
		9.8 ± .84
		24 ± 4.4
	Milk	12 ± .86
		19 ± 2.8
		12 ± .69
Screw pine	Fruit	33 ± 4.4
		23 ± 4.6
Taro	Meat	13 ± 4.3
		13 ± 3.8
Invertebrates		
Coral *Acropora* sp.	Entire	106 ± 27
		94 ± 30
Fungia sp.		83 ± 17
Sea cucumber	Muscle	524 ± 19
		245 ± 10
	Integument	63 ± 13
		587 ± 25
	Gonad	622 ± 28
	Gut and contents	78 ± 10
		2,400 ± 70

*Samples were collected seven months after Operation Castle and were counted 2/24/55 to 3/29/55.

Appendix Table D. (continued)

Species	Tissue	d/m/g
Fish		
Blenny - red spotted	Entire	35 ± 9.2
		28 ± 6.9
		43 ± 10
- bluedash	Muscle	11 ± 4.3
	Liver	48 ± 32
	Viscera	69 ± 21
	Bone	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
Damselfish	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	14 ± 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
Marine Plants					
Halimeda	Entire	71 ± 25	65 ± 7.4	5-13-56	28 ± 15
		130 ± 30	60 ± 7.8	"	
		89 ± 21	59 ± 13	7-13-56	
			83 ± 8.3	9-27-56	
			59 ± 8.0	"	
Padina	"		114 ± 9.0	5-13-56	230 ± 30
			171 ± 12	"	
Caulerpa	"		38 ± 5.1	"	
			57 ± 5.7	"	
Hydroclathrus	"		276 ± 16	"	
			673 ± 28	"	
Turbinaria	"		46 ± 4.3	7-13-56	
Lyngbya	"		307 ± 15	9-27-56	
			376 ± 15	"	
Jania	"		119 ± 14	"	
			91 ± 9.2	"	
Eelgrass	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 8/8-9/9/56.
" " " " 9/27/56 immediately following Operation Redwing, counted 10/27-11/19/56.

Appendix Table E. (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 ± 7.0	7.1 ± 0.91	7-13-56	Bgd.
			7.9 ± 0.89	"	
			22 ± 2.7	9-27-56	
			22 ± 2.6	"	
	Meat (ripe)	15 ± 5.2	27 ± 3.3	"	
			23 ± 3.1	"	
	Milk	5 ± 0.43	4.9 ± 0.54	"	
		5 ± 0.46	5.2 ± 0.50	7-13-56	
Breadfruit	Skin	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
Papaya	Skin	50 ± 6.8			
		11 ± 5.3			
	Meat	9 ± 5.0			
		20 ± 4.9			
	Seeds	21 ± 6.0			
		25 ± 6.0			

Appendix Table E. (continued)

Species	Tissue	1954* Collection d/m/g	1956** Collection d/m/g	Date	1958*** Collection d/m/g
Land Plants (continued)					
Arrowroot	Meat	35 ± 6.0			
		15 ± 5.2			
		17 ± 5.2			
	Leaves	23 ± 5.8			
		38 ± 6.6			
Tapioca	Meat		19 ± 2.6	7-13-56	
Sweet potato	Meat		9.2 ± 1.4	"	
			9.8 ± .93	"	
			12 ± 1.1	"	
Taro	Meat		11 ± 1.8	"	
Lime	Skin		48 ± 3.2	"	
	Meat		12 ± 1.2	"	
			12 ± 1.1	"	
	Seeds		218 ± 25	"	
	Entire				6.4 ± 1.9
Banana	Skin		48 ± 3.3	"	
			52 ± 3.0	"	
			38 ± 2.6	"	
	Meat		19 ± 1.5	"	
			16 ± 1.6	"	
	Entire				13 ± 3.8
Sugar cane	Meat		32 ± 3.8	"	
			28 ± 4.0	"	
Pineapple	Entire		10 ± 0.68	"	5.4 ± 1.9
			13 ± .79	"	
Soursop	Entire				31 ± 5.4

Appendix Table E. (continued)

Species	Tissue	1954* Collection d/m/g	1956** Collection d/m/g	Date	1958*** Collection d/m/g
Invertebrates					
Sea cucumber	Gonad	289 ± 12	17 ± 2.6	5-13-56	11 ± 3.3
		110 ± 11			13 ± 3.6
	Gut	88 ± 14	34 ± 7.2	"	12 ± 9.0
		136 ± 19			Bgd.
					Bgd.
	Integument and muscle		9.2 ± 3.7	"	
	Integument	40 ± 7.1			26 ± 4.2
		85 ± 9.8			25 ± 4.2
	Muscle				24 ± 4.0
					23 ± 4.8
					18 ± 4.3
African snail	Liver		21 ± 4.4	"	
	Shell	71 ± 23			
	Soft parts	190 ± 12			
Coral	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					
Barracuda	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			8.6 ± 6.6
		122 ± 16			
		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
Fish (continued)					
Bonito	Muscle	75 ± 6.6			
		20 ± 5.8			
		36 ± 5.0			
		29 ± 5.0			
	Bone	68 ± 13			
		51 ± 12			
		100 ± 14			
		48 ± 13			
	Liver	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 ± 6.9			
	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
Fish (continued)					
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				4.2 ± 3.2
	Liver				5.6 ± 4.3
Skipjack	Muscle				14 ± 4.2
					12 ± 4.0
	Skin				6.3 ± 5.0
	Bone				22 ± 11

Appendix Table F. 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.

Species	Tissue	d/m/g
Land Plants		
Coconut	Meat	17 ± 2.7
		17 ± 2.4
	Milk	14 ± .90
		16 ± .97
Tomato	Fruit	259 ± 12
	Leaf	1,050 ± 34
	Stem	870 ± 41
	Root	1,750 ± 65
Fish		
Blenny	Muscle	41 ± 7.8
		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 ± 37
		208 ± 22
	Skin	81 ± 9.4
		67 ± 6.8
		94 ± 8.5
Convict surgeon	Muscle	44 ± 5.4
		37 ± 6.3
		70 ± 4.4
		48 ± 4.6
	Liver	3,200 ± 88
		2,800 ± 86
		2,770 ± 77
		1,230 ± 60

* Samples were collected seven months after Operation Castle and were counted 3/5-28/55.

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 ± 26
		386 ± 28
		302 ± 22
		451 ± 30
	Skin	214 ± 15
		179 ± 10
		161 ± 10
		240 ± 14
Goatfish	Muscle	103 ± 10
		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 F. (continued)

Species	Tissue	d/m/g
Fish (continued)		
Mullet	Liver	966 ± 50
		884 ± 46
		3,270 ± 65
		1,790 ± 28
	Viscera	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
Birds		
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)

Species	Tissue	d/m/g
Birds (continued)		
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
Marine Plants			
Caulerpa	Entire		Bgd.
			Bgd.
Enteromorpha	"	30 ± 7.4	
Padina	"		5.5 ± 2.5
			5.5 ± 2.4
Land Plants			
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.
	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	
Messerschmidia	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
Land Plants (continued)			
Papaya	Fruit		2.7 ± 1.9
			2.9 ± 1.9
	Meat	9.8 ± 1.1	
	Skin	10 ± 1.3	
		10 ± 1.3	
Scaevola	Leaf		5.9 ± 2.9
			6.9 ± 3.6
Squash	Fruit		3.6 ± 1.3
			3.6 ± 1.3
Invertebrates			
Clam (*Arca* sp.)	Shell		47 ± 28
	Soft parts		8.3 ± 3.1
Ghost crab	Entire		6.9 ± 5.5
			7.5 ± 6.0
			7.2 ± 5.3
			Bgd.
Shore crab	Entire		Bgd.
Hermit crab	Muscle	Bgd.	
	Carapace	Bgd.	
Sea cucumber	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
	Gonad		6.5 ± 1.8
			5.5 ± 1.9
			7.2 ± 2.8
	Gut and contents		Bgd.
			Bgd.
			Bgd.

Appendix Table G. (continued)

Species	Tissue	1956* Collection d/m/g	1958** Collection d/m/g
Fish			
Mixed fish	Muscle	50 ± 8.0	
		24 ± 4.4	
		50 ± 3.6	
	Liver	33 ± 4.1	
		20 ± 4.5	
		19 ± 3.7	
Grouper	Muscle		10 ± 4.0
			8.9 ± 3.6
			Bgd.
	Liver		Bgd.
Herring	Entire	59 ± 4.7	
Snapper	Muscle		7.3 ± 3.6
	Liver		5.6 ± 4.3
Squirrelfish	Muscle		8.9 ± 3.6
	Liver		Bgd.
Birds			
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 Ujelang Atoll, 1955-1958, expressed in d/m/g of wet tissue at time of analysis. The 0.95 counting error is included.

Species	Tissue	1955* Collection d/m/g	1956** Collection d/m/g	1958*** Collection d/m/g
Marine Plants				
Halimeda	Entire	160 ± 15	173 ± 12	180 ± 24
		215 ± 17	215 ± 14	
		117 ± 11		
Caulerpa	Entire	229 ± 12		110 ± 13
Microdictyon	"	761 ± 34		
Liagora	"	736 ± 31		
Land Plants				
Arrowroot	Meat		6.8 ± 1.7	
			6.5 ± 1.6	
			6.9 ± 1.1	
			8.6 ± 1.3	
Breadfruit	Meat		8.2 ± 3.5	6.6 ± 1.4
			15 ± 4.8	
Bunchgrass	Tops	60 ± 5.5		
	Roots	28 ± 6.5		
Coconut	Meat	11 ± 3.5	9.8 ± 1.2	Bgd.
		17 ± 3.9	9.8 ± 1.1	
		14 ± 2.8		
		14 ± 3.0		
	Milk	14 ± .97	11 ± 1.1	2.8 ± 7.6
		13 ± .92	4.3 ± 1.1	
		13 ± 1.2		
		11 ± .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 d/m/g	1956** Collection d/m/g	1958*** Collection d/m/g
Land Plants (continued)				
Messerschmidia	Leaf	50 ± 15		120 ± 11
		71 ± 8.9		
	Stem	50 ± 9.2		
		39 ± 11		
	Fruits	68 ± 11		
		44 ± 6.0		
Papaya	Fruit		7.6 ± .46	4.5 ± 1.8
			5.0 ± .28	
Scaevola	Leaf	63 ± 15		160 ± 15
		60 ± 6.5		
	Fruit	23 ± 3.3		
		24 ± 5.4		
Screw pine	Fruit			19 ± 5.9
	Meat	20 ± 4.8	32 ± 4.2	
			33 ± 5.5	
	Epidermis	35 ± 6.3		
Taro	Tuber			7.0 ± 2.7
Invertebrates				
Clam (Tridacna crocea)	Mantle	60 ± 9.3		
	Muscle	26 ± 5.0		12 ± 4.6
				29 ± 6.0
				16 ± 5.0
	Kidney	940 ± 46		600 ± 53
				120 ± 15
				430 ± 42

Appendix Table H. (continued)

Species	Tissue	1955* Collection d/m/g	1956** Collection d/m/g	1958*** Collection d/m/g
Invertebrates (continued)				
Clam (*Tridacna crocea*)	Visceral mass	99 ± 6.3		36 ± 5.3
				190 ± 22
				61 ± 7.6
	Gill	102 ± 7.8		
Corals-*Acropora* sp.	Entire	207 ± 20		
	"	196 ± 26		
Stylosmilia sp.	"	149 ± 16		
Heliopora sp.	"	416 ± 18		
Porites sp.	"	278 ± 13		
Coconut crab	Carapace			150 ± 28
				58 ± 21
	Abdomen			4.5 ± 3.5
				6.6 ± 3.8
Ghost crab	Entire			90 ± 12
Hermit crab	"			98 ± 13
Sea cucumber	Muscle			39 ± 5.0
				34 ± 5.2
				38 ± 7.4
	Integument			46 ± 5.7
				44 ± 5.6
				50 ± 6.3

Appendix Table H. (continued)

Species	Tissue	1955* Collection d/m/g	1958*** Collection d/m/g
Invertebrates (continued)			
Sea cucumber	Gonad		13 ± 2.4
			32 ± 5.2
			32 ± 5.2
	Gut and contents		22 ± 9.6
			26 ± 9.6
			42 ± 12
Birds			
Noddy tern	Muscle	80 ± 7.4	
		43 ± 4.3	
	Liver	593 ± 8.1	
		172 ± 3.2	
	Lung	424 ± 18	
		347 ± 7.3	
	Kidney	163 ± 9.1	
		170 ± 10	
	Ileum	98 ± 6.6	
		110 ± 6.6	
	Bone	155 ± 29	
		155 ± 22	
	Skin	377 ± 54	
		100 ± 10	

Appendix Table H. (continued)

Species	Tissue	1955* Collection d/m/g	1956** Collection d/m/g	1958*** Collection d/m/g
Fish				
Herring	Entire		110 ± 13	
Puffer	Liver		1220 ± 27	
Squirrelfish	Muscle			7.3 ± 3.6
	Liver			82 ± 11
Damselfish	Muscle			36 ± 5.9
	Liver			98 ± 12
Surgeonfish	Muscle			38 ± 6.1
	Liver			38 ± 6.7
Mixed fish	Muscle		11 ± 9.5	
			16 ± 6.4	
	Liver		14 ± 4.2	
			73 ± 8.9	
			162 ± 7.3	
			128 ± 5.5	

Appendix Table I. Gross beta radioactivity of the biological samples collected at Utirik Atoll 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	1955** Collection d/m/g	1958*** Collection d/m/g
Marine Plants				
Caulerpa	Entire	575 ± 21		
		418 ± 18		
		1530 ± 44		
Codium	Entire	1200 ± 32		
	"	1250 ± 35		
	"	7880 ± 162		
	"	6070 ± 136		
Lyngbya	"	7120 ± 142		
		4500 ± 88		
		3100 ± 77		
Land Plants				
Arrowroot	Meat		44 ± 4.4	
Breadfruit	Meat		31 ± 4.2	
	Fruit		13 ± 2.6	
Coconut	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	

* 1954 samples were collected 5-17-54 during Operation Castle and were counted 6-11-54.
** 1955 samples were collected 1-23-55 seven months after Castle and were counted 2-24 to 3-22-55
*** 1958 samples were collected 7-16-58 during Operation Hardtack and were counted 9-8 to 9-12-58.

Appendix Table I. (continued)

Species	Tissue	1954* Collection d/m/g	1955** Collection d/m/g	1958*** Collection d/m/g
Land Plants (continued)				
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
Invertebrates				
Clam (*Anadara antiquata*)	Shell			Bgd.
	Muscle			12 ± 4.6
	Kidney			45 ± 35
	Visceral mass			42 ± 5.6
Corals				
Acropora sp.	Entire		82 ± 21	
			79 ± 25	
			109 ± 16	
Fungia sp.	Entire		75 ± 20	
Ghost crab	"			67 ± 8.9
				99 ± 13
				52 ± 8.6

Appendix Table I. (continued)

Species	Tissue	1954* Collection d/m/g	1955** Collection d/m/g	1958*** Collection d/m/g
Invertebrates (continued)				
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
			376 ± 27##	
	Gut and contents		440 ± 22	Bgd.
			759 ± 35	Bgd.
			588 ± 29	
Snail (*Turbo* sp.)	Entire			190 ± 20
Fish				
Damselfish				
Abudefduf biocellatus	Muscle			74 ± 7.4
	Liver			73 ± 10
Dascyllus aruanus	Entire		57 ± 7.2	
			46 ± 6.2	
			84 ± 12	
			43 ± 6.0	
			40 ± 7.0	

1958 species not determined
contained some sand particles

Appendix Table I. (continued)

Species	Tissue	1954* Collection d/m/g	1955** Collection d/m/g	1958*** Collection d/m/g
Fish (continued)				
Pomacentrus nigricans	Muscle		7.1 ± 5.3	
	Liver		Bgd.	
	Bone		271 ± 203	
	Skin		Bgd.	
	Viscera		18 ± 12	
			22 ± 18	
			25 ± 13	
			16 ± 13	
			691 ± 28	
			871 ± 45	
Goatfish	Muscle			4.3 ± 3.6
	Liver			38 ± 6.7
Grouper				
Epinephalus merra	Entire		56 ± 18	
			32 ± 15	
E. elongatus	Muscle		8.0 ± 3.0	
	Liver		169 ± 75	
	Bone		24 ± 19	
	Skin		19 ± 7.9	
	Viscera		69 ± 26	
Jack	Muscle		14 ± 4.4	
	Liver		Bgd.	
	Bone		24 ± 19	
	Skin		22 ± 16	
	Viscera		108 ± 25	

Appendix Table I. (continued)

Species	Tissue	1954* Collection d/m/g	1955** Collection d/m/g	1958*** Collection d/m/g
Fish (continued)				
Wrasse	Entire		34 ± 2.9	
			27 ± 6.6	
			50 ± 6.6	
	Muscle		12 ± 7.6	
	Liver		Bgd.	
	Bone		18 ± 14	
	Skin		32 ± 20	
	Viscera		159 ± 30	

Appendix Table J. Gross beta radioactivity of the biological samples collected at Wotho 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
Marine Plants			
Caulerpa	Entire	460 ± 15	
		974 ± 26	
Halimeda		739 ± 33	56 ± 18
Land Plants			
Arrowroot	Meat	46 ± 2.9	21 ± 4.0
		74 ± 4.7	
Breadfruit	Fruit	76 ± 3.2	Bgd.
		89 ± 4.2	
Coconut	Meat	13 ± 1.8	3.1 ± 2.0
	Milk		2.7 ± 0.73
Messerschmidia	Leaves and stems	20,000 ± 420	
Morinda	Fruit	66 ± 2.0	
		89 ± 2.5	
Screw pine	Fruit		130 ± 20
	Meat	76 ± 5.2	
		86 ± 5.6	
	Skin	67 ± 4.4	
		67 ± 4.5	
Fish			
Mixed reef fish	Muscle	618 ± 28	8.9 ± 3.6
		657 ± 19	12 ± 4.0
	Liver	590 ± 15	20 ± 5.5
		1020 ± 43	16 ± 5.1
		720 ± 30	

* 1956 samples were collected 6/18/56 during Operation Redwing and were counted 7/25 to 8/30/56.

** 1958 samples were collected 6/30/58 during Operation Hardtack and were counted 8/28 to 9/2/58.

Appendix Table J. (continued)

Species	Entire	1956* Collection d/m/g	1958** Collection d/m/g
Invertebrates			
Coconut crab	Carapace	Bgd.	210 ± 31
			140 ± 28
			160 ± 30
			780 ± 83
	Muscle	Bgd.	6.3 ± 4.0
	Liver	Bgd.	
	Abdomen		44 ± 7.4
			46 ± 7.6
			38 ± 7.0
			210 ± 21
Sea cucumber	Muscle		13 ± 4.1
			41 ± 7.0
			31 ± 5.4
	Integument		40 ± 5.2
			130 - 14
	Gonad		Bgd.
			10 ± 2.2
	Gut and contents		Bgd.
			Bgd.
			Bgd.
Spider snail	Shell		Bgd.
			120 ± 36
			120 ± 36
	Soft parts		63 - 13
			24 ± 7.6
			19 ± 10
	Liver		53 - 4.0

Appendix Table J. (continued)

Species	Tissue	1956* Collection d/m/g	1958** Collection d/m/g
Invertebrates (continued)			
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 Collected	Date Counted	d/m/g
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	7-6-56	10-9-56	140 ± 92
	"	7-11-58	9-5-58	Bgd.
Ujelang	Island	2-8-55	4-8-55	185 ± 109
	Beach	"	"	162 ± 109
	Island	7-18-56	10-9-56	Bgd.
	"	7-19-58	10-19-59	Bgd.*
	"	"	"	"
Utirik	Island	1-23-55	4-8-55	3,140 ± 185
	Beach	"	"	416 ± 118
Wotho	Island	6-18-56	10-9-56	260 ± 98

* 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}	$Ru^{103,106}$ $Rh^{103,106}$	$Ce^{141,144}$ Pr^{144}	Co^{57}	$W^{181,185}$	Mn^{54}	Fe^{59}
KAPINGAMARANGI											
7-24-58											
Fish liver		++		+++		+++		++			
Coconut meat				++++		+++		+			
milk				++++		++		+			
Breadfruit, fruit				++++	++	+++					
KUSAIE											
7-3-58											
Yellowfin tuna											
muscle		+		++		+++					
skin		+		+++		+++					
Scaevola leaves				+++		+++	++		++++		
PONAPE											
7-25-58											
Mixed fish											
muscle				++++		+++		++			
liver		+++		++				+++			
Skipjack											
muscle	+	++++		++		+++		++			+
skin		++++		++		+++				++	
bone		++++		++		+++		+			
Yellowfin tuna											
red muscle	+	++++		+++		+++		+++			
white muscle		+++		++		++		+++			

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

Appendix Table L. (continued)

Location, Collection date and Sample	Co^{60}	Zn^{65}	Co^{58}	Zr^{95} Nb^{95}	Cs^{137}	$Ru^{103,106}$ $Rh^{103,106}$	$Ce^{141,144}$ Pr^{144}	Co^{57}	$W^{181,185}$	Mn^{54}	Fe^{59}
PONAPE (continued)											
Yellowfin tuna											
skin		++++		+++		+++		++			
bone		++++		++		+++		++			
gut	+	++++		++		+++		++		++	
Taro				+++		+++		++			
Coconut meat				+++		+++		++			
milk				+++	+	+++					
Breadfruit				+++		++++		++			
Lime				++		++++		++			
Banana				+++		++++		+			
Pineapple				+++	+	++++	++				
Sea cucumber											
gonad		+		+				++			
integument				++++		++		++			
Pinna											
kidney		++		+++		++++					
visceral mass		++		++		++++		+			
Crapsus											
entire				++++		+++		++			
UJELANG											
7-19-58											
Surgeon fish, muscle				+++		++++	++				
Mixed fish, muscle and liver		+++		+++		++++		+			
Mixed fish, liver		+++		+++		++++		+			

Appendix Table L. (continued)

Location, Collection date and Sample	Co^{60}	Zn^{65}	Co^{58}	Zr^{95} Nb^{95}	Cs^{137}	$Ru^{103,106}$ $Rh^{103,106}$	$Ce^{141,144}$ Pr^{144}	Co^{57}	$W^{181,185}$	Mn^{54}	Fe^{59}
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}	Co^{58}	Zr^{95} Nb^{95}	Cs^{137}	$Ru^{103,106}$ $Rh^{103,106}$	$Ce^{141,144}$ Pr^{144}	Co^{57}	$W^{181,185}$.	Mn^{54}	Fe^{59}
UJELANG (continued)											
Pandanus fruit				++	++++	++					
Papaya fruit				++	++++						
Breadfruit, fruit				++++	+++	++++					
WOTHO											
6-18-56											
Messerschmidia leaves				+++		++++					
6-30-58											
Halimeda, entire						+++					

Appendix Table M. Scientific names of the species.

Common name	Scientific name
I. BIRDS	
Fairy tern	*Gygis alba* Sparrman
Noddy tern	*Anous stolidus* L.
II. FISH	
Barracuda	*Sphyraena japonica* Cuvier and Valenciennes
Blue dash blenny	*Istiblennius paulus* Bryan and Herre
Red spotted blenny	*Istiblennius edentulus* Bloch and Schneider
Bonito	*Katsuwonus pelamis* (Linnaeus)
Butterfly fish	*Chaetodon auriga* Forskal
Convict surgeon	*Acanthurus triostegus* L.
Damsel fish	*Pomacentrus nigricans* (Lacepede)
" "	*Dascyllus aruanus* (Linnaeus)
" "	*Abudefduf biocellatus* (Quoy and Gaimard)
Goatfish	*Mulloidichthys samoensis* (Gunther)
Grouper	*Epinephalus fuscoguttatus* (Forskal)
"	*E. merra* Bloch
"	*E. elongatus* Schultz
Herring	*Spratelloides delicatulus* (Bennett)
Jack	*Caranx sexfasciatus* (Quoy and Gaimard)
Marlin	*Tetrapterus* sp.
Mullet	*Neomyxus chaptalli* (Eydoux and Souleyet)

Appendix Table M. (continued)

Common name	Scientific name
FISH (continued)	
Parrot fish	*Scarus* sp.
Puffer	*Tetraodon* sp.
Skipjack	*Euthynnus affinis yaito* (Kishinouye)
Snapper	*Lutianus* sp.
Squirrel fish	*Myripristis murdjan* (Forskal)
" "	*Holocentrus microstomus* (Gunther)
Wrasse	*Halichoeres trimaculatus* (Quoy and Gaimard)
Yellowfin tuna	*Neothunnus albacora macropterus* (Temminck and Schlegel)
III. INVERTEBRATES	
African snail	*Achatina fulica* Ferussac
Clams	*Anadara* sp.
	Arca sp.
	Pinna sp.
	Tridacna crocea Lamarck
Coconut crab	*Birgus latro* L.
Corals	*Acropora* sp.
	Fungia sp.
	Heliopora sp.
	Pocillopora sp.
	Porites sp.
	Styosmilia sp.
Ghost crab	*Ocypode ceratophthalma* (Pallas)
Hermit crab	*Coenobita perlatus* Edw. T.
	Coenobita sp.
Oyster	*Ostrea* sp. (?)

Appendix Table M. (continued)

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

Appendix Table M. (continued)

Common name	Scientific name
LAND PLANTS (continued)	
Screw pine	*Pandanus tectorius* Park.
Soursop	*Anona muricata* L.
Squash	*Cucurbita* sp.
Sugar cane	*Saccharum officinarum* L.
Sweet potato	*Ipomoea Batatas* (L.) Poir.
Tapioca	*Manihot utilissima* Pohl
Taro	*Cyrtosperma chamissonis* (Schott) Merrill
Tomato	*Solanum lycopersicum* L.
V. MARINE PLANTS	
Algae	*Asparagopsis taxiformis* (Delile) Collins and Harvey
"	*Caulerpa serrulata* (Forsk) J. Ag.
"	*Caulerpa* sp.
"	*Codium* sp.
"	*Enteromorpha* sp.
"	*Halimeda* spp.
"	*Hydroclathrus clathratus* (Ag.) Howe
"	*Jania* sp.
"	*Liagora* sp.
"	*Lyngbya majuscula* Gomont
"	*Microdictyon Okamurai* Setchell
"	*Neomeris annulata* Dickie

Appendix Table M. (continued)

Common name	Scientific name
MARINE PLANTS (continued)	
Algae	*Padina commersonii* Bory
"	*Rhipilia* sp.
"	*Turbinaria ornata* (Turn.) J. Agardh
Eel grass	Not identified
VI. RATS	
Field rat	*Rattus exulans* Peale