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RADIOLOGICAL RESURVEY OF ANIMALS, SOILS AND GROUNDWATER AT BIKINI ATOLL, 1969-1970

by
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February 1971

Work done under Contract AT(26-1)-269 with the
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reef fish, Co-2.6, Sr-.08, Cs-.13; pelagic fish, Co-.94; spiny lobster, ^{60}Co-.12; giant clams, ^{60}Co-24; curlews, ^{60}Co-.94, ^{137}Cs-380; turnstones, ^{60}Co-7.7, ^{137}Cs-56; terns, ^{60}Co-1.1, ^{137}Cs-.08. Average concentrations of ^{90}Sr in the muscle of coconut crabs from Bikini and Eneu Islands were 12 pCi/g wet and .05 pCi/g wet, respectively. There are no striking differences between average values for edible foods of marine origin, including the sea birds, compared with values reported in 1967. Predominant radionuclides in undisturbed soils in 1969 are ^{55}Fe, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{125}Sb, ^{137}Cs and ^{207}Bi. In the crater sediments ^{55}Fe, ^{60}Co, ^{90}Sr, and ^{207}Bi predominate. There are quantitative and qualitative differences in radionuclide content associated with the feeding habit of fish and there appears to be an increasing concentration of some radionuclides with increasing age of fish and clams. The radionuclide content of bird species presents a sharp contrast, both qualitatively and quantitatively, associated with feeding habit. It appears that some ^{60}Co and ^{207}Bi is being transported eastward by the bottom current in the lagoon. Silver-108m, previously unreported in fallout, was found in the hepatopancreas of the spiny lobster. Tritium levels in groundwater are within the range of values for continental surface water samples. The present levels of radionuclides and their distribution at Bikini are not likely to change significantly except for decrease in amounts, due to physical decay.

trations of Sr, and covering the village area at Bikini Island with coral gravel from the beaches, which is consistent with local custom and provides a shield against radiation from the soil. The panel also recommended that old structures and other such debris from the tests be removed from the islands and beaches and that the island be further monitored during the cleanup. Additional monitoring was necessary because dense vegetation on [redacted]

The panel's recommendations were made to the Chairman of the Atomic Energy Commission, who informed the Secretary of the Interior, the administrator for the Trust Territory of the Pacific.

Health Service took the responsibility for external radiation measurements, and for the collection and analysis of those land plants that are food items; the U of W Laboratory of Radiation Ecology was asked to sample and analyze other biological and environmental samples in 1969. Additional samples were collected in 1970, with the emphasis on air filters and soil samples. The former were analyzed and reported by the U.S. PHS (SWRHL-111r). This report presents the results of the Laboratory's analyses.

SELECTION OF SAMPLES AND SAMPLING SITES

The sampling program was based on the objective of obtaining data for evaluation of potential radiological hazards to man. The samples were limited, for the most part, to things that might be eaten by returning Bikinians, except for land plants. Additional samples, for example soils, crater sediments and groundwater, were taken to provide data for estimating the future distribution and amounts of radionuclides in the biota.

[redacted]

fish and the pelagic or "troll-caught" fish. The reef fishes

[redacted]

Table 20.

[redacted]

were found near Bikini Island.

In response to a special request to check the levels of radioactivity at Aerokoj Islet, received during the survey, the land hermit crab, a known concentrator of ^{90}Sr, was collected. Since coconut crabs are both an indicator organism and a food item, they would have been sampled instead of hermit crabs, but coconut crabs were not found on Aerokoj.

Thousands of terns nest at Bikini Atoll, mostly on the western islets. Both the birds and their eggs will be used as food. The terns almost always feed at sea, outside the lagoon or reefs. On the other hand, the curlews and turnstones feed along the shores and on the reef, and the curlew also eats the seeds of an endemic shrub, Scaevola serica, or the beach magnolia. Although the curlews and turnstones are transients and are present in small numbers, at most a few hundred, they contain the highest levels of radionuclides among the birds. Curlews, turnstones, noddy terns, and fairy terns were sampled.

Rats are not used as food but they are the only mammal living on the atoll, and a few were taken to determine their radionuclide content.

Groundwater was collected by driving half-inch pipe with well points into the soil. The well-point sites on Bikini and

resampled and the subsamples were retained and analyzed indi-
vidually to indicate the variability between subsamples. Samples from soil profiles were taken at well points 1, 4, and 5.

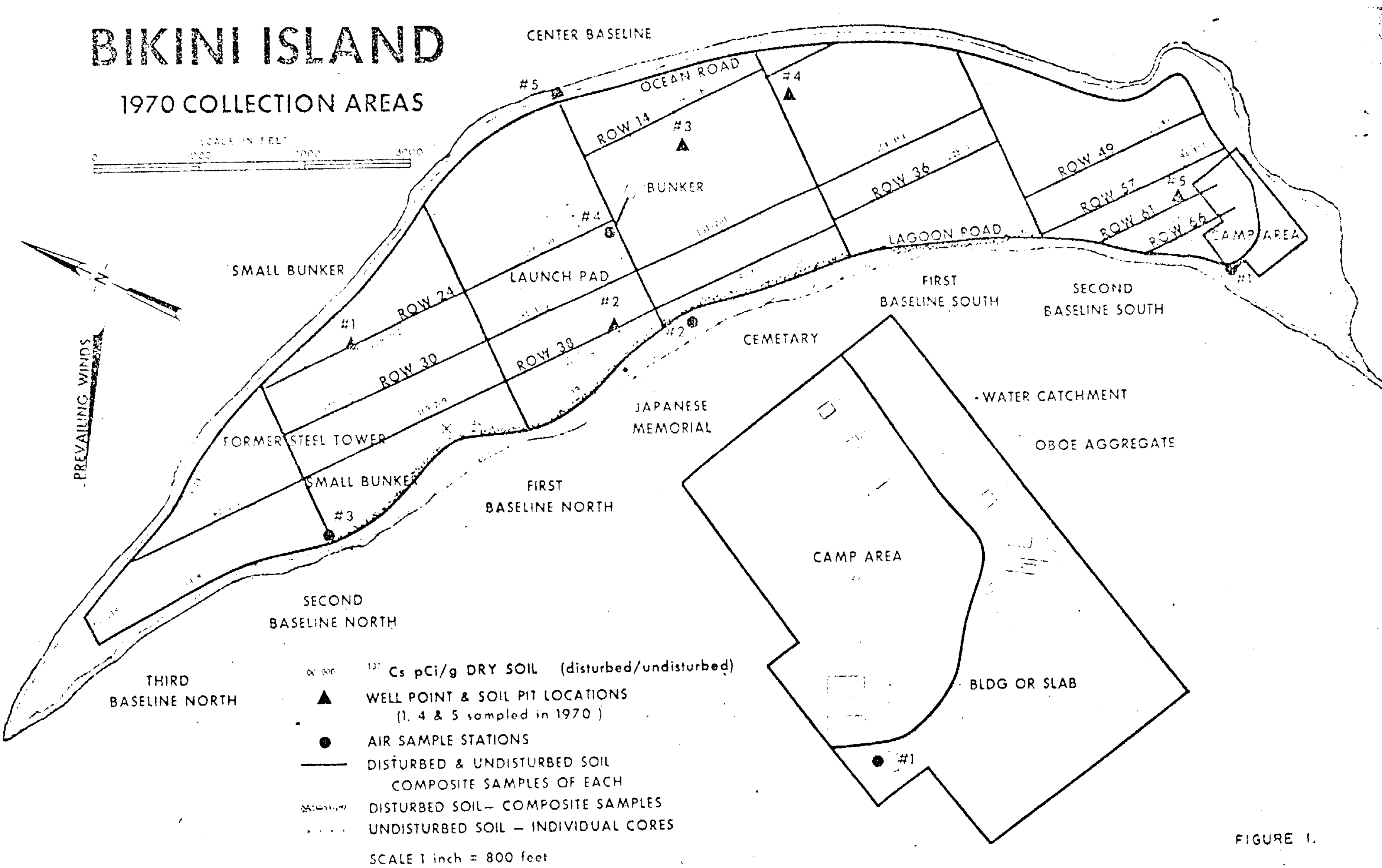
BIKINI ISLAND
1970 COLLECTION AREAS
CENTER BASELINE
OCEAN ROAD
ROW 14
ROW 24
ROW 30
ROW 36
ROW 38
ROW 49
ROW 57
ROW 61
ROW 66
BUNKER
LAUNCH PAD
LAGOON ROAD
SMALL BUNKER
FORMER STEEL TOWER
SMALL BUNKER
CAMP AREA
FIRST BASELINE SOUTH
SECOND BASELINE SOUTH
CEMETARY
JAPANESE MEMORIAL
WATER CATCHMENT
OBOE AGGREGATE
FIRST BASELINE NORTH
SECOND BASELINE NORTH
THIRD BASELINE NORTH
CAMP AREA
BLDG OR SLAB
PREVAILING WINDS
N
#1
#2
#3
#4
#5
^{137}Cs pCi/g DRY SOIL (disturbed/undisturbed)
WELL POINT & SOIL PIT LOCATIONS (1, 4 & 5 sampled in 1970)
AIR SAMPLE STATIONS
DISTURBED & UNDISTURBED SOIL COMPOSITE SAMPLES OF EACH
DISTURBED SOIL– COMPOSITE SAMPLES
UNDISTURBED SOIL – INDIVIDUAL CORES
SCALE 1 inch = 800 feet

FIGURE 1.

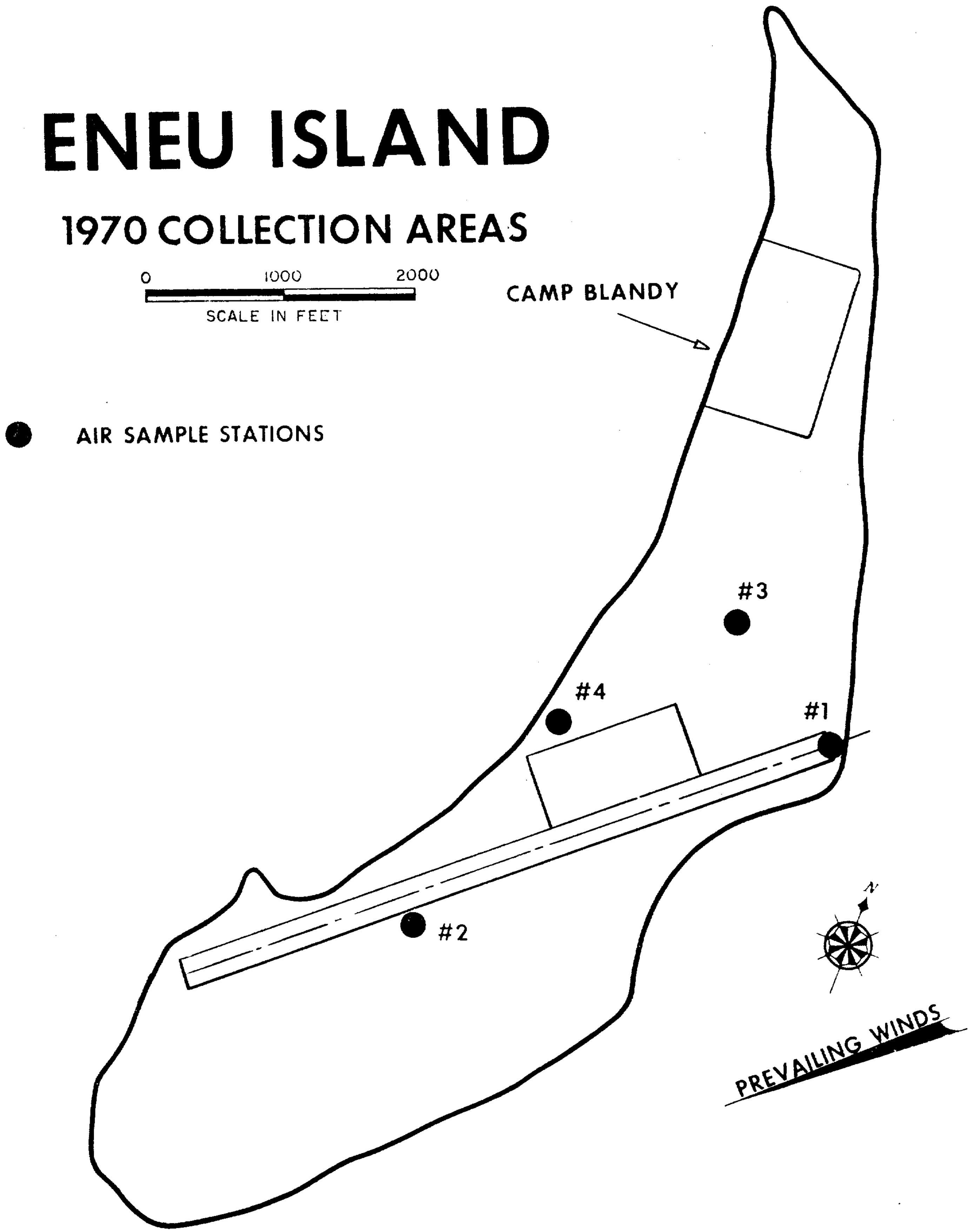
ENEU ISLAND
1970 COLLECTION AREAS
0
1000
2000
SCALE IN FEET
CAMP BLANDY
AIR SAMPLE STATIONS
#3
#4
#1
#2
N
PREVAILING WINDS

FIGURE 2.

for the different geometries and [illegible]

values were corrected for decay to the date of collection. The error given for individual values is the 95% error.

Strontium-90 Analyses

Strontium-90 was determined by measuring the equilibrium concentration of its ^{90}Y daughter. Yttrium-90 was separated by solvent extraction and precipitation techniques (Petrow,1965), with stable yttrium serving as both a carrier and a yield de-

[redacted] were used for separating and purifying ^{207}Bi. Bismuth-212 was used as a yield determinant.

Plutonium-238, 239 Analyses

[redacted] extraction and anion exchange techniques (McCowan and Larsen, 1960; Kressin and Waterbury, 1962), with electrodeposition as the final step in the separation. Plutonium-236* was used to determine yield. A quantitative separation of plutonium from the coralline soils and sediments is exceptionally difficult and it is therefore essential that ^{236}Pu be used as a yield determinant and that counting be done by alpha spectrometry.

Tritium Analyses

Well water samples were measured for tritium content by a liquid scintillation technique with a minimum level of detection of 200 tritium units.

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* Provided by the USAEC Health and Safety Laboratory, New York.

and maximum values often differ by factors of four or five and sometimes by a factor of ten. The values for concentration of radionuclides in individual samples are given in Tables 1 through 19.

Dry weights were used for the basic calculations because the true water content of some samples is difficult to determine. [redacted]

[redacted]

are ^{55}Fe, ^{60}Co, ^{90}Sr, ^{125}Sb, ^{137}Cs and ^{207}Bi (Tables 1-5).

[redacted]

well-point four at Bikini Island were sampled by one-half centimeter increments in 1970, and the samples show a gradient of concentrations of Pu of the samples analyzed.

The radionuclides are available to the land animals through the vegetation, or other animals, where there is selection of specific radionuclides, or through direct ingestion of soil. Similarly, the marine animals may ingest radionuclides by eating another organism or by ingesting sediments. In addition, the marine organism may absorb radionuclides directly from the water, or radionuclides may be adsorbed on the surface of the organism. Although adsorption is an important means of contamination of organisms by fresh fallout, it is probably no longer important

[redacted]

[redacted]

(Table 9).

The spiny lobster, a strictly marine crustacean, contains no detectable ^{137}Cs or ^{90}Sr and only small amounts of ^{60}Co (Table 10).

There are quantitative and qualitative differences in the radionuclide content of organisms associated with feeding habit. The goatfish, a bottom-feeding carnivore, contains more ^{60}Co and ^{207}Bi than the convict surgeonfish, a grazing herbivore,

[redacted]

of ^{60}Co in the kidney, and the longer the clam lives in an environment where ^{60}Co is available, the more ^{60}Co it accumulates in the kidney, if ^{60}Co has a long biological half-life. This is not a concentration through the food web, since the clams are filter feeders.

The radionuclide content of bird species presents a sharp contrast, both qualitatively and quantitatively, associated with feeding habit (Table 17). The fairy terns and noddy terns feed mostly at sea outside the lagoon and contain small amounts of fallout radionuclides, less than the amount of naturally occurring

[redacted]

that a major amount of the ^{55}Fe in the Bikini tuna is from world-wide fallout.

[redacted]

Bravo Crater and 16 miles eastward near Bikini I. is only by a factor of less than two. At the same time, the ^{60}Co concentrations in goatfish from near the crater and those at Bikini I. differ by a factor of about ten.

It appears that the physical redistribution of ^{207}Bi in the lagoon is similar to that of ^{60}Co, but since the levels of ^{207}Bi are lower than those of ^{60}Co by a factor of about 20, we are at

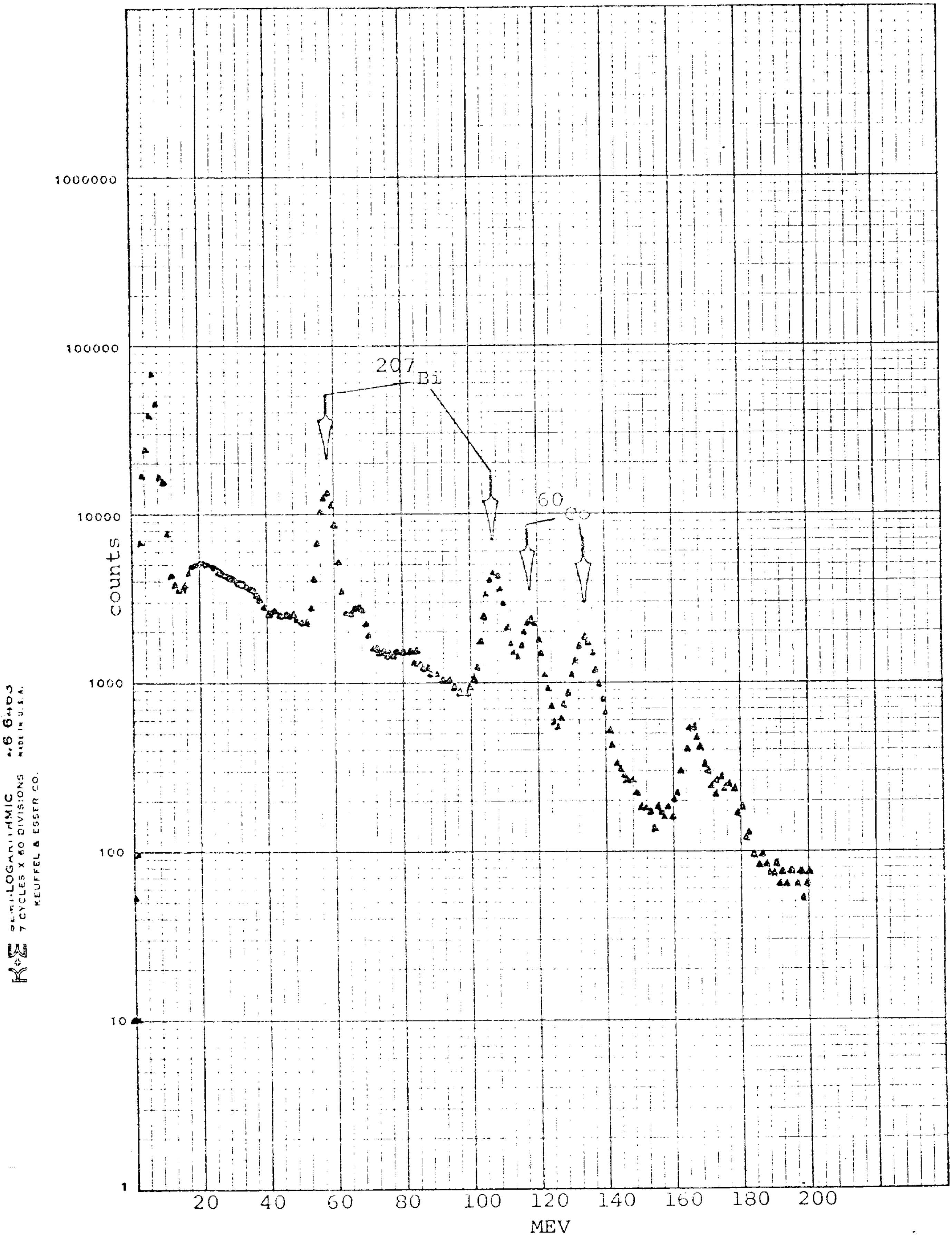

Fig. 3. Gamma-ray spectrum of sediment from Bravo Crater collected at a water depth of 160 feet, August, 1969.

the limits of detection, with the method used, for samples distant from the crater. The use of larger samples, chemical separation and more sensitive counting methods would make it possible to determine ^{60}Co:^{207}Bi ratios in sediments, lagoon water and organisms in different parts of the lagoon. These ratios would indicate whether transported radionuclides were primarily in solution or on particles. If the ratios remained constant, that would be a strong indication of transport on particles. The results of analyses of selected samples for ^{207}Bi by gamma-ray spectrometry and by chemical separation are compared in Table 19. Bismuth-207 will be a useful tracer in the future because it has a long half-life, 30 years compared to 5.2 years for ^{60}Co.

Plutonium-239, with a half-life in excess of 24,000 years, is another potentially useful tracer at Bikini. The presence of ^{239,240}Pu and ^{207}Bi (Table 12) in goatfish viscera is consistent and probably results from direct ingestion of fine particles of sediment during feeding. Two samples of goatfish viscera collected at Nam I. in 1969 contained ^{239}Pu in concentrations of 13 pCi/g dry and 29 pCi/g dry. The absence of ^{238}Pu in goatfish viscera as compared with the sediment merely reflects a low concentration of this radionuclide, below the limits of detection.

Although none of the 1969 or 1970 samples were analyzed for the X-ray emitter ^{63}Ni, this radionuclide was found in concentrations of 80 d/m/g dry weight in Bravo Crater sediment collected in 1967 (Beasley and Held, 1969). Nickel-63 is of particular interest as a tracer since it has a half-life of 92 years. In addition, the clam kidney accumulated ^{63}Ni, as it does ^{60}Co, and is therefore an indicator organism for the presence of ^{63}Ni.

Another long-lived radionuclide, ^{108m}Ag, with a half-life of approximately 125 years, has been identified for the first time among the radionuclides at Bikini (Beasley and Held, 1970). This radionuclide was first detected from the gamma-ray spectrum of the hepatopancreas of spiny lobsters collected in 1969 (Fig. 4). The spiny lobster hepatopancreas is a known concentrator of silver isotopes (Seymour, 1963). Thus, ^{108m}Ag is another potentially useful long-lived tracer, with its indicator organism.

Tritium in well water is present at low concentrations; the maximum value found in 1969 was 14 pCi/ml, or 4300 tritium units, at Nam I., whereas at Bikini and Eneu Islands the concentration was 2 pCi/ml, or approximately 600 T. U. (Table 15). Samples taken in 1970 from well-points 4 and 5 and from the cistern at Bikini and from the well and cistern at Eneu all contained less than 400 T. U. These values fall within the range of tritium

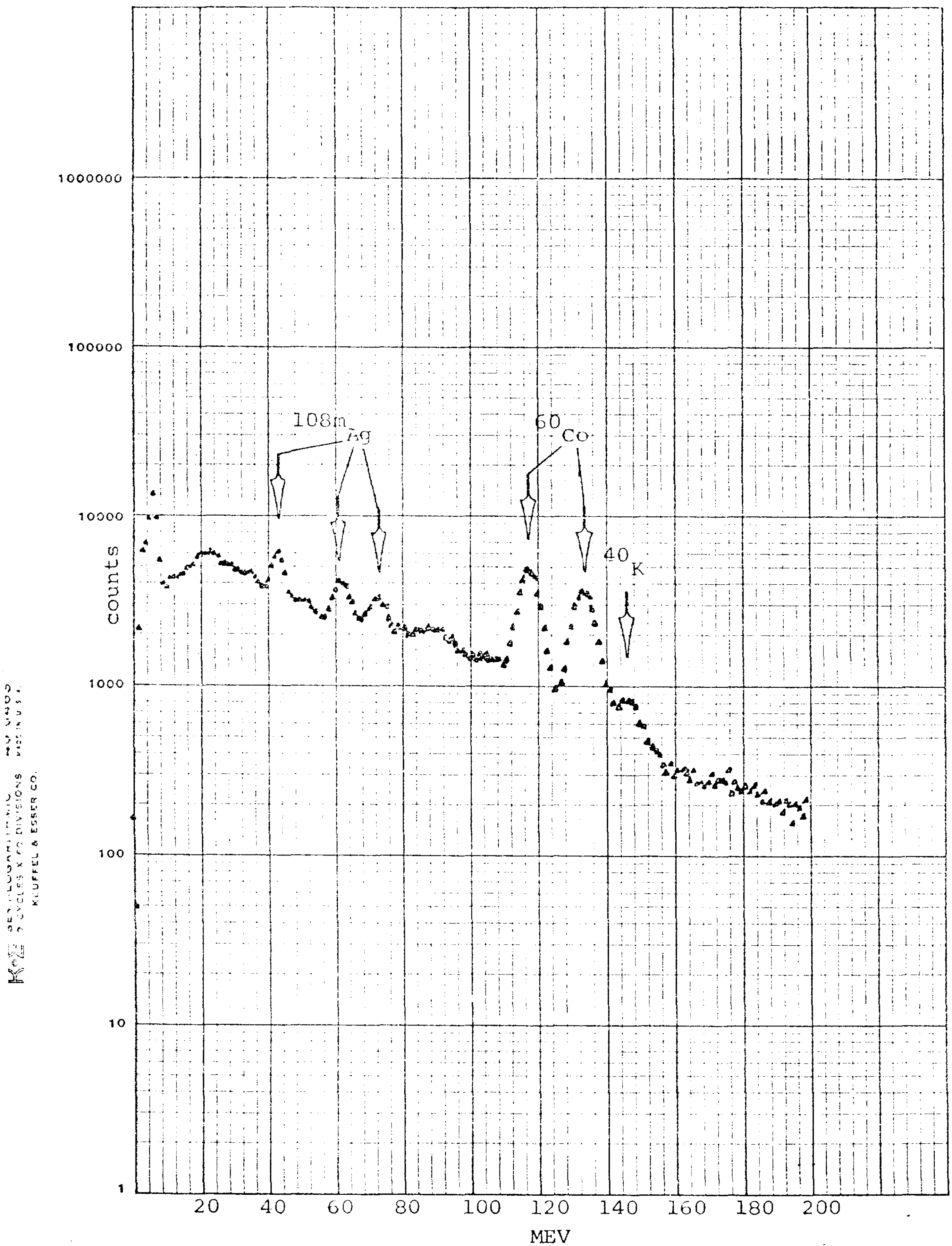

Fig. 4. Gamma-ray spectrum of spiny lobster hepatopancreas from Bikini Atoll, 1969.

redistribution within the lagoon, a flushing from the lagoon, or both.

[illegible]

supervised all of the radiochemical analyses and who did many of them himself. Dr. Allyn Seymour and Dr. Beasley were of great help in planning the collections and in interpreting the results of the survey.

I am grateful to Dr. Beasley, Rodney Eagle, Terrence Jokela, and Raymond Lusk for their part in the field collections.

I appreciate the cooperation of personnel of Joint Task Force Eight and Holmes & Narver, Inc., and recognize that the field collections would not have been successfully completed without their help.

We exchanged samples in the field with Drs. John Harshbarger and Donald Squires of the Smithsonian Institution and thank them for samples of coconut crabs from Oroken Island and rats from Bikini Island.

Dr. Jack Tobin, Trust Territory of the Pacific, made valuable suggestions regarding the collections and was instrumental in obtaining the services of two Bikini people to assist with the collections.

William Moore, U.S. Public Health Service, accompanied us during most of the collections and pointed out areas giving the highest external radiation measurements; well water and soil samples were collected from these areas.

The final guidelines for the survey were developed during a preliminary survey of Bikini Atoll in March, 1969 with Frank Cluff and Donald Hendricks, Nevada Operations Office, and Alan Smith, U. S. Public Health Service.

[illegible]
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Table 1

Radionuclides in the Surface One-Inch of Soil Collected at Bikini Atoll, June 1969

pCi/g dry

Sample No.	Island	Location	^{60}Co	^{125}Sb	^{137}Cs	^{207}Bi	^{90}Sr	^{55}Fe
506	Bikini	W-P-1	42±1.2 (1)	67±11	1220±8.0	ns (2)	462	173
507	"	W-P-2	9.3±.41	12±4.3	499±3.3	ns	256	36
504	"	W-P-3	43±2.0	88±43	1740±15	ns	830	149
505	Nam	W-P-1	1.4±.19	6.0±1.5	63±.18	ns	17.6	8.4
756	Aomen	ns	17±.45 (3)	20±1.7	29±.74	.59±.27		144
755	Enyu	Camp Blandy	.39±.13	ns	6.0±.27	.25±.12		
757	Oroken	ns	17±.41	32±1.7	24±.69	.44±.25		132
758	Aerokoj	S-11	1.2±.14	ns	2.0±.77	ns		35
481	Aerokoj	S-6	.28±.11	ns	.69±.15	.21±.10	5.6	5.5
500	Eneman	"hot" area	186±6 (4)	304±25	19±7	8.9±4.5	109	522
489	Eneman	Seaward Shore	9.0±.80 (5)	29±3.5	4.1±1.0	2.5±.63	13	

(1) 95% counting error.
(2) Value less than the 95% counting error.
(3) ^{65}Zn 2.1±1.4
(4) " 65±24
(5) " 7.7±2.9

Table 2

Radionuclides in Soil Collected from the Most Radioactive Part of Eneman Islet, June 1969

Sample No.	Depth (Inches)	^{60}Co	^{65}Zn	^{125}Sb	^{137}Cs	^{207}Bi	^{90}Sr	^{55}Fe
		pCi/g dry						
500	0-1	186±5.8 (1)	65±24	304±25	19±6.5	8.9±4.5	109	522
496	1-2	63±2.2	17±5.7	66±6.5	4.7±1.6	2.5±1.1	56	177
495	2-3	71±2.0	16±5.1	57±5.5	4.7±1.5	2.3±1.0	52	189
503	3-4	79±1.6	22±4.9	51±4.1	4.7±1.2	1.7±.82	52	253
498	4-5	47±1.2	15±3.5	38±3.1	4.3±.92	1.9±.62	50	144
502	5-6	12±.53	5.6±1.5	7.6±1.8	4.7±.57	-(2)	49	64
497	6-7	7.0±.41	3.5±1.4	4.9±1.5	4.7±.49	.65±.29	49	31
501	7-8	5.1±.41	3.3±1.3	3.0±1.6	4.4±.53	.44±.29	57	28
499	8-9	4.1±.37	3.2±1.3	4.0±1.5	3.4±.49	-	51	26
494	9-12	3.2±3.5	2.8±1.2	2.4±1.4	3.0±.45	-	46	28
493	12-17	4.1±3.1	2.7±1.1	3.6±1.2	4.0±3.9	.34±.22	59	26

(1) 95% counting error.
(2) Value less than the 95% counting error.

Table 3

Radionuclides in Soil Collected on the Seaward Shore of Eneman Islet, June 1969

Sample No.	Depth (Inches)	^{60}Co	^{65}Zn	^{125}Sb	^{137}Cs	^{207}Bi	^{90}Sr
		pCi/g dry					
489	0-1	9.0±.80	7.7±2.9	29±3.5	4.1±1.0	2.5±.63	13
490	1-2	9.4±.94	8.8±3.1	28±4.3	3.9±1.1	1.5±.65	18
487	2-3	6.9±.57	6.1±.20	21±2.4	2.9±.67	1.4±.41	13
491	3-4	7.1±.61	4.6±2.2	20±2.5	3.0±.73	1.7±.45	15
492	5-6	5.4±.51	4.2±1.6	11±2.4	1.9±.55	.51±.35	10
484	6-7	7.0±.70	5.6±2.4	16±3.1	2.5±.80	.74±.47	
485	7-8	6.2±.47	4.2±1.6	14±1.9	2.0±.51	1.1±.33	14
488	8-9	6.5±.59	4.8±1.8	12±2.5	1.8±.63	3.9±.39	17
486	9-10	8.8±.71	6.1±1.1	20±2.9	2.2±.74	.89±.45	14
482	10-11	7.4±.61	3.7±1.8	15±2.5	2.2±.65	.76±.39	14
483	11-14	4.9±.35	3.5±1.2	9.7±2.7	1.2±.37	.77±.25	11

D [redacted]
Com [redacted]

Cente [redacted]
Basel [redacted]

Row [redacted]
" [redacted]
" [redacted]

Lag [redacted]

1st E [redacted]
to 2r [redacted]

Row [redacted]
" [redacted]
" [redacted]

Lag [redacted]

2nd E [redacted]
Camp [redacted]

Row [redacted]
" [redacted]
" [redacted]

Lag [redacted]
and F [redacted]

Cente [redacted]
Basel [redacted]

Row [redacted]
" [redacted]
" [redacted]

Lag [redacted]

Table 4 (continued)

Depth 0-1" Composite Samples	Values in pCi/g dry: Bulldozed Area			Undisturbed Area		
1st Baseline North to 2nd Baseline North	^{137}Cs	^{125}Sb	^{60}Co	^{137}Cs	^{125}Sb	^{60}Co
Row 24	229 ± 4	26 ± 6	7.8 ± .7	362 ± 4	29 ± 5	24 ± .9
" 30	170 ± 3	20 ± 4	7.8 ± .6	323 ± 5	35 ± 8	17 ± 1
" 38	169 ± 1	12 ± 2	6.1 ± .3	209 ± 2	23 ± 4	15 ± .5
Lagoon Road	44 ± .3	1.8 ± .6	.9 ± .1			
2nd Baseline North to 3rd Baseline North						
Row 24 and Seaward Beach Road to intersection with Row 38	53 ± 1.0	3.4 ± 1.6	1.3 ± .21	130 ± 2	12 ± 4	3.4 ± .4
Row 38 to intersection with Seaward Beach Rd.	62 ± .4	2.8 ± .7	1.1 ± .1	121 ± 2	8.7 ± 3.1	3.1 ± .4
Seaward Beach Road - 3rd Baseline North to Lagoon Road	62 ± 1.1	5.4 ± 1.8	1.7 ± .22	118 ±1.7	17 ± 2.9	8.3 ± .4
Lagoon Road	39 ± .7	3.3 ± 1	1.2 ± .15	82 ± .5	1.4 ± .65	.72± .11
Air Sampling Stations						
#1	26 ± .43	.96± .71	.58 ± .10			
2	21 ± .24	.70± .48	.22 ± .10			
3	37 ± 1.1	3.3 ± 2.0	.95 ± .28			
4	20 ± .44	1.3 ± .78	.29 ± .11			
5	54 ± .8	3.4 ± 1.2	1.9 ± .2			

Table 4 (continued)

Depth 0-1" Individual Cores	Values in pCi/g dry — Bulldozed Area			Undisturbed Area		
1st Baseline North to Centerline	^{137}Cs	^{125}Sb	^{60}Co	^{137}Cs	^{125}Sb	^{60}Co
Row 38 1	181 ± .84	6.8 ± 1.1	3.0 ± .17	316 ± 2.6	6.7 ± 3.2	2.2 ± .24
2	360 ±3.8	21 ± 5	6.9 ±.49	558 ± 8.8	35 ± 12	7.8 ±1.0
3	106 ±2.0	27 ± 3.6	15 ±.64	30 ± .33	.77± .59	.21 ± .12
4	30 ± .46	1.1 ± .7	.13 ±.09	103 ± 1.8	4.2 ± 2.4	.28 ± .21
5	78 ±1.4	5.4 ± 2.1	1.5 ±.25	58 ± 1.1	2.6 ± 1.6	.28 ± .18
6	7.3 ± .20	ns	neg	317 ± 1.5	8.1 ± 1.8	4.8 ± .24
7	75 ±1.3	3.7 ± 1.9	.73 ±.21	80 ± 3.2	ns	.56 ± .44
8	21 ± .82	neg.	ns	77 ± 1.2	5.0 ± 1.8	.84 ± .19
9	37 ± .39	1.3 ± .62	.21 ±.12	425 ± 6.7	37 ± 9.4	17 ±1.2
10	65 ±1.1	3.0 ± 1.5	.62 ±.17	293 ± 2.6	10 ± 3.5	5.8 ± .35
11	22 ± .54	2.1 ± 1.0	.38 ±.14	149 ± 1.6	4.7 ± 2.1	2.2 ± .22
12	57 ±1.0	3.8 ± 1.4	.76 ±.16	77 ± 1.1	3.8 ± 1.4	.39 ± .14
13	97 ± .57	1.6 ± .72	.53 ±.12	195 ± 3.2	12 ± 4.4	1.1 ± .36
14	196 ±2.0	8.6 ± 2.5	2.0 ±.23	108 ± .63	1.0 ± .78	.40 ± .12
15	24 ±1.0	ns	ns	225 ± 2.2	5.4 ± 2.5	.34 ± .17

Table 4 (continued)

Along Centerline		Undisturbed ^{137}Cs	^{125}Sb	^{60}Co
Even 2-40	Row 2	54 ± .45	1.2 ± .61	ns
Soil #58	4	152 ± 1.6	10 ± 2.2	3.1 ± .25
	6	61 ± 1.1	2.4 ± 1.7	ns
	8	152 ± 1.7	6.9 ± 2.3	2.0 ± .22
	10	102 ± 2.4	8.5 ± 3.7	2.2 ± .43
	12	88 ± 1.3	4.6 ± 1.8	1.4 ± .21
	14	66 ± .49	1.9 ± .67	.58± .12
	16	25 ± .49	1.2 ± .82	.25± .11
	18	93 ± 1.6	3.6 ± 2.2	.72± .22
	20	76 ± .60	ns	.38± .13
Soil #59	22	143 ± .93	ns	.67± .16
	24	36 ± .68	2.1 ± 1.2	.52± .15
	26	63 ± 1.2	3.3 ± 1.8	.45± .20
	28	111 ± 1.3	4.4 ± 1.7	1.7 ± .19
	30	134 ± .88	2.4 ± 1.1	.82± .16
	32	87 ± 1.5	5.1 ± 2.3	1.4 ± .25
	34	168 ± .91	2.0 ± 1.2	1.4 ± .16
	36	324 ± 1.6	7.2 ± 2.0	5.4 ± .26
	38	52 ± .72	1.4 ± .98	.29± .11
	40	25 ± .53	1.7 ± .92	.36± .12

Table 4 (continued)

Camp [redacted] Area So [redacted] 1 #60	Disturbed ^{137}Cs	^{125}Sb	^{60}Co
[redacted]1	5.2 ± .18	ns	neg
[redacted]2	4.0 ± .26	neg	ns
[redacted]3	18 ± .26	neg	neg
[redacted]4	18 ± .28	neg	.18 ± .13
[redacted]5	13 ± .31	ns	.14 ± .09
[redacted]6	14 ± .27	ns	neg
[redacted]7	5.1 ± .16	ns	neg
[redacted]8	4.2 ± .36	ns	.18 ± .16
[redacted]9	.94 ± .22	neg	.17 ± .16
[redacted]0	8.8 ± .23	.58 ± .55	neg
[redacted]1	5.0 ± .21	neg	.11 ± .09
[redacted]2	15 ± .48	1.2 ± .96	.31 ± .15
[redacted]3	20 ± .45	ns	.17 ± .11
[redacted]4	3.5 ± .22	ns	ns
[redacted]5	.7 ± .19	neg	neg
[redacted]6	.23 ± .09	.50 ± .42	neg
[redacted]7	.51 ± .11	neg	neg
[redacted]8	1.1 ± .16	ns	neg
[redacted]9	2.2 ± .17	neg	neg
[redacted]0	6.2 ± .23	neg	ns

Table 5

Gamma-Emitting Radionuclides in Soil from Well Point 4, Bikini Island, Collected June 1970

Soil #57	Depth Cm	^{60}Co	^{125}Sb	^{137}Cs
1	0 - .5	32 ± 1.7	66 ± 9.2	243 ± 4.9
2	.5- 1.0	30 ± 1.5	60 ± 8.6	274 ± 4.6
3	1.0- 1.5	15 ± .74	23 ± 4.1	302 ± 4.1
4	1.5- 2.0	6.3± 1.1	23 ± 8.0	264 ± 4.7
5	2.0- 2.5	7.8± .95	18 ± 6.6	239 ± 4.1
6	2.5- 3.0	2.2± .77	8.2± 4.7	218 ± 4.4
7	3.0- 3.5	1.6± .74	13 ± 6.0	205 ± 3.7
8	3.5- 4.0	ns	22 ±21	147 ±12
9	4.0- 4.5	ns	5.3± 4.2	145 ± 3.7
10	4.5- 5.0	1.7± .39	3.4± 2.0	111 ± 1.7

Table 6

Plutonium and Cesium-137 in the Surface One Inch of Bikini Atoll Soils and Bravo Crater Sediment

	N	$^{239,240}Pu$ (pCi/g dry)	^{238}Pu (pCi/g dry)	^{137}Cs (pCi/g dry)
Bikini Island				
1967				
Soil Pit 1		5.1 ± 0.3	ns	360 ± 6
" " 5		117 ± 7.4	ns	1200 ± 18
" " 6		36 ± 2	ns	49 ± 1
1969				
Well Point 1		130 ± 8	ns	1220 ± 8
" " 2		27 ± 2	ns	499 ± 3
" " 3		111 ± 5	ns	1740 ± 15
1970				
1st BL* N to Centerline				
Row 24 Undisturbed	13	74 ± 9	ns	299 ± 2
Disturbed**	13	27 ± 3	ns	156 ± 3
1st BL N to 2nd BL N				
Row 30 Undisturbed	20	65 ± 8	ns	323 ± 5
Disturbed	21	56 ± 8	ns	170 ± 3
1st Bl S to 2nd BL S				
Row 36 Undisturbed	18	87 ± 14	ns	470 ± 9
Disturbed	18	28 ± 4	ns	228 ± 3
Camp area to Lagoon Rd.				
Row 66 Undisturbed	14	16 ± 2	ns	175 ± 2
Disturbed	14	6.2 ± 0.9	ns	90 ± 1
Base Camp, Random Sample	16	3.9 ± 0.5	ns	0.2 to 18
Eneu Island				
1969				
Camp Blandy		.71± 0.1	ns	6.0± 0.3
1970				
North Central				
Undisturbed	5	35 ± 4	ns	156 ± 2
Disturbed	4	3.0 ± 0.4	ns	21 ± 0.5

Table 6 (continued)

	N	pCi/g dry $^{239,240}Pu$	^{238}Pu	^{137}Cs
Eneman Island				
1969				
SW Corner, 0-1" depth		79 ±3	49 ±2	19 ±6
8-9" depth		9.3±0.4	4.1±0.2	3.4±0.5
Bravo Crater				
1969		60 ±2	4.0±1	

N Number of subsamples in composite sample
ns Not detectable
* BL = Baseline
** Bulldozed planting strip

NOTE: Multiplication of the above values by 3×10^4 will give an approximate value in units of pCi/m^2.

Table 7

Cesium-137 in Rat Tissues Collected at Bikini
June 1969 and June 1970

Location	Number of Rats in Pooled Sample	Tissue	pCi/g dry
1969			
Bikini I.	5	Muscle	466 ± 7
Aerokoj I.	1	Muscle	2.4 ± 0.6
"	1	Remainder	1.6 ± 0.4
1970			
Bikini I.			
Camp Area	9	Muscle	827 ± 10
"	"	Lung	705 ± 15
"	"	Liver	627 ± 10
"	"	Bone	187 ± 1.9
Centerline Road			
Sample 1	19	Muscle	340 ± 5.3
" 2	"	"	513 ± 5.9
" 1	"	Lung	525 ± 9.8
" 2	"	"	405 ± 3.5
" 1	"	Liver	402 ± 1.9
" 2	"	"	417 ± 4.2
" 1	"	Bone	334 ± 5.4
" 2	"	"	221 ± 2.9

Island	Tissue	Samples	Avg.	Range	Avg.	Range
Bikini	Muscle	6	2.7	1.1-3.5	759	429-933
	"Liver"	6	14	5.2-23	305	122-470
	Skeleton	6	nd*	nd-.34	134	86-209
Enyu	Muscle	13	.59	nd-1.3	70	32-240
	"Liver"	13	2.6	.76-4.8	29	11-95
	Skeleton	13	.06	nd-.18	9.9	3.9-30
Oroken	Muscle	5	.70	.47-1.1	89	52-123
	"Liver"	5	3.5	2.0-6.4	74	39-118
	Skeleton	5	.09	nd-.16	24	17-28

* A single significant value was 0.34 ± 0.27

Table 9

STRONTIUM-90 IN SAMPLES COLLECTED
AT BIKINI ATOLL, MARCH, JUNE, AUGUST, 1969

Average Values and Range

	N(1)	pCi/g dry Avg.	pCi/g dry Range	pCi/g wet(2) Avg.
Coconut Crabs				
Muscle				
Enyu I.	13	2.0	(0.6-3.4)	0.05
Bikini I.	6	50.1	(16.4-99.0)	12
Oroken I.(3)	5	8.9	(4.9-14.9)	2.1
Rukoji I.(3)	3	75.2	(36.6-144)	18
"Liver"				
Enyu I.	13	9.6	(3.0-28)	5.1
Bikini I.	6	117	(38.3-204)	62
Oroken I.(3)	5	21.3	(15.4-30.0)	11
Rukoji I.(3)	3	116	(57.2-164)	61
Skeleton				
Enyu I.	8	97.2	(72.6-113)	75
Bikini I.	6	1410	(912-2035)	1100
Oroken I.(3)	5	346	(184-571)	270
Rukoji I.(3)	3	2330	(1200-3870)	1800
Troll Caught Fish				
Yellowfin Tuna				
Light muscle	3	<0.1	(<0.1-0.29)(4)	<.03
Dark muscle	3	<0.1		<.03
Bone	3	<0.1		<.04
Ulua (Jack)				
Light muscle	3	<0.1		<.03
Dark muscle	3	<0.1		<.03
Bone	3	1.4	(1.1-1.9)	0.6

(1) Number of individuals.
(2) Converted from dry weight by using average wet:dry weight ratios.
(3) Collected May, 1967.
(4) Two samples contained <0.1 pCi/g dry and one sample contained 0.29 ± 0.06 pCi/g dry. We think the sample was contaminated when being ground.

Table 10

Gamma-Emitting Radionuclides in Spiny Lobsters
Collected at Bikini Atoll, June 1969

Average Values

Island	Tissue	No. of Samples	^{40}K Avg. (pCi/g dry)	^{40}K Range (pCi/g dry)	^{60}Co Avg. (pCi/g dry)	^{60}Co Range (pCi/g dry)
Enyu	Muscle	5	12	8.7-15	.30	nd-.45
	"Liver"	5	nd		10	6-12
	Skeleton	5	3.0	2.2-4.0	.22	nd-.80
Namu	Muscle	8	13	8.8-17	.75	.37-1.1
	"Liver"	8	nd		28	15-37
	Skeleton	8	3.3	nd-5.5	.32	.14-.58
	Remainder	8	5.0	2.7-8.5	1.9	.75-2.8

Table 11

Radionuclides in Eviscerated Whole Reef Fish
Collected at Bikini Atoll, June 1969

Average Values

Island / Common Name	N*	pCi/g dry: ^{60}Co Avg.	^{60}Co Range	^{137}Cs Avg.	^{137}Cs Range	^{90}Sr Avg.	^{90}Sr Range	pCi/g wet: ^{60}Co Avg.	^{137}Cs Avg.	^{90}Sr Avg.
Bikini										
Mullet	3	3.9	2.9-4.6	.21	.12-.38	.10	.05-.12	1.1	.06	.03
Goatfish	2	2.8	2.6-2.9	nd**		.06	.05,.07	.79		.02
Surgeon	3	1.7	1.3-2.1	.73	.64-.84	.16	.16,.16***	.48	.21	.04
Enyu										
Goatfish	2	.45	nd,.90	.08	nd-.17	not done		.13	.02	
Nam										
Mullet	4	12	8.8-19	.78	.58-1.1	.39	.33-.50	3.4	.22	.11
Goatfish	2	32	31,32	.31	nd-.62	.77	.61,.93	9.0	.09	.22
Surgeon	5	2.7	1.6-4.3	.70	.28-1.2	.35	.09-.86	.76	.20	.10
Pilotfish	1	5.0		nd		not done		1.4		
Bikini										
Avg. of Avgs.		2.8		.31		.11		.79	.09	.03
Nam										
Avg. of Avgs. (except pilotfish)		16		.60				4.5	.17	

*Number of samples.
**nd, Not detectable. Value taken as zero in computing averages.
***Two samples only analyzed for ^{90}Sr.

Table 12

Gamma-Emitting Radionuclides in Viscera of Reef Fish
Collected at Bikini Atoll, June 1969

Average Values

Island / Common Name	N*	pCi/g dry ^{60}Co Avg.	^{60}Co Range	^{137}Cs Avg.	^{137}Cs Range	^{207}Bi Avg.	^{207}Bi Range	pCi/g wet ^{60}Co Avg.	^{137}Cs Avg.	^{207}Bi Avg.
Bikini										
Mullet	3	9.2	5.7-11	.81	.61-1.1	.08	nd-.23	2.6	.23	.02
Goatfish	2	20	17-24	nd		nd		5.6		
Surgeon	3	9.7	6.2-12	1.6	.78-2.3	nd		2.7	.44	
Enyu										
Goatfish	2	5.8	5.6-6.1	nd		.13		1.6		.04
Nam										
Mullet	4	18	13-22	1.3	1.2-1.4	.30	.16-.43	5.0	.36	.08
Goatfish	2	216	172-260	nd		11	9.7-12	60		3.1
Surgeon	5	11	6.0-13	1.4	.81-2.1	.24	nd-.57	3.1	.39	.07
Flagtail	1	13				.57		3.6		.16
Bikini										
Avg. of Avgs.		13		.80		.03		3.6	.22	.01
Nam										
Avg. of Avgs. (except flagtail)		82		.90		3.8		23	.25	1.1

*Number of samples.

Table 13

Gamma-emitting Radionuclides in Goatfish Collected at Nam Island, Bikini Atoll, May 1970

Tissue	pCi/g dry ^{60}Co	^{137}Cs	^{207}Bi
Eviscerated whole	13 ± .28	.72 ± .23	1.8 ± .16
Viscera	146 ± .90	.93 ± .42	3.9 ± .49
Muscle	12 ± .29	.78 ± .26	7.2 ± .23
Liver	397 ± 2.5	ns	13 ± 1.3
Bone	5.3 ± .12	.45 ± .08	1.1 ± .09
Kidney	349 ± 6.9	ns	18 ± 2.9
GIT	214 ± 1.2	.89 ± .53	15 ± .66
Ovary	179 ± 1.4	ns	3.8 ± .72
Skin	26 ± .51	ns	3.1 ± .27
Remains	35 ± .73	ns	3.1 ± .37

Table 14

Gamma-Emitting Radionuclides in Troll-Caught Fish, Bikini Atoll, March and June 1969

Averages Values

pCi/g dry

Common Name	Tissue	No. of Samples*	^{40}K Avg.	^{40}K Range	^{60}Co Avg.	^{60}Co Range	^{137}Cs Avg.	^{137}Cs Range
Yellowfin tuna	Light muscle	16	14	13-16	.09	nd-.26	.24	nd-1.3
	Dark muscle	16	11	9.0-12	1.0	.08-4.6	.10	nd-.32
	Liver	16	10	8.6-12	1.3	.21-5	.06	nd-.25
	Bone	15	1.4	nd-3.4	.06	nd-.22	.02	nd-.16
Ulua (Jacks)	Light muscle	4	15	12-18	.68	.52-.90	1.2	.83-1.6
	Dark muscle	4	11	9.6-12	12	6.7-20	.53	.49-.58
	Liver	4	14	11-18	100	26-203	.27	nd-.81
	Bone	3	1.5	nd-2.3	.17	nd-.27	.09	nd-.26
Dogtooth tuna	Light muscle	7	13	10-18	1.1	.77-1.6	.71	.32-1.3
	Dark muscle	1	13		4.1		.49	
	Liver	7					.54	.27-1.2
	Bone	1	5.8		.20		.15	

*Individual fish

Table 15

Strontium-90 in Eviscerated Whole Reef Fish
Collected at Bikini Atoll, June 1969

Sample Number	Species	Location	No. of fish in sample	Length	pCi/g dry weight
25609	Convict surgeon	Nam	4	158-175mm	0.86 ± 0.05*
25611	" "	"	6	130-155mm	0.37 ± 0.02
25613	" "	"	15	112-135mm	0.27 ± 0.04
25615	" "	"	25	95-110mm	0.14 ± 0.02
25617	" "	"	19	90-105mm	0.09 ± 0.03
25621	Grouper (muscle)	Nam	3	41,62,78mm	0.29 ± 0.06
25622	Mullet	"	16	150-175mm	0.50 ± 0.05
25624	Mullet	"	15	160-200mm	0.35 ± 0.04
25628	Mullet	"	8	195-260mm	0.33 ± 0.04
25619	Flagtail	"	8	193-214mm	0.23 ± 0.04
25661	Goatfish	"	4	200-250mm	0.93 ± 0.03
25663	Goatfish	"	3	230-250mm	0.61 ± 0.03
25605	Convict surgeon	Bikini	16	94-115mm	0.16 ± 0.04
25607	" "	"	4	132-152mm	0.16 ± 0.04
25630	Mullet	"	5	220-255mm	0.12 ± 0.04
25632	Mullet	"	13	150-175mm	0.05 ± 0.04
25634	Mullet	"	5	250-300mm	0.12 ± 0.04
25657	Goatfish	"	2	185,190mm	0.07 ± 0.02
25659	Goatfish	"	8	190-220mm	0.05 ± 0.02

* Error is 1 σ

[illegible]

except naturally occurring ^{40}K.

(2) Two samples consisted of 3 individuals pooled and one sample consisted of 2 individuals pooled.

Table 17

Gamma-Emitting Radionuclides in Birds
Collected at Bikini, 1969

Average Values

Species and Tissue	No. of Samples	pCi/g dry ^{60}Co Avg.	pCi/g dry ^{60}Co Range	pCi/g dry ^{137}Cs Avg.	pCi/g dry ^{137}Cs Range	pCi/g wet* ^{60}Co Avg.	pCi/g wet* ^{137}Cs Avg.
Curlew							
Muscle	3	2.8	nd-6.3	1174	520-2260	.94	395
Liver	3	5.9	nd-11	992	605-1510	2.1	348
Turnstone**							
Muscle	1	23		165		7.7	56
Liver	1	40		98		14	34
Noddy tern***							
Muscle	1	4		.46		1.3	.15
Liver	1	7.6		nd		2.7	nd
Fairy tern***							
Muscle	1	.87		nd		.29	nd
Liver	1	1.2		nd		.42	nd

*Calculated from pCi/g dry using average wet:dry ratios.
**Tissues from 6 birds pooled.
*** " " 5 " " .

Table 13

Iron-55 in Biological Samples Collected at
Bikini Atoll, June 1969
Average Values

Collection Site	Common Name	Tissue or Organ	No. of Samples	pCi/g dry Avg.	Range
Bikini I.	Surgeon	Whole (Eviscerated)	2	52	18-85
Enyu I.	Goatfish	Whole (Eviscerated)	2	81	74-87
Bikini I.	Mullet	Viscera	3	108	22-228
"	Goatfish	"	2	416	391-442
"	Surgeon	"	2	199	148-250
Enyu I.	Goatfish	"	2	1250	828-1670
Nam I.	Mullet	"	3	237	122-348
"	Surgeon	"	3	297	239-404
"	Goatfish	"	2	526	366-686
Enyu I.	Grouper	Muscle	4	13	7.7-18
Nam I.	"	"	1	38	
Enyu I.	"	Liver	4	14,700	9,090-25,600
Enyu Pass	Yellowfin tuna	Light muscle	16	29	8.5-62
"	Ulua	" "	3	210	72-214
"	Dogtooth tuna	" "	1	116	
"	Yellowfin tuna	Dark muscle	16	334	108-867
"	Ulua	" "	3	2,950	1,290-3,630
"	Dogtooth tuna	" "	1	915	

[redacted]

Site	Name	or Organ	Samples	Avg.	Range
Enyu Pass	Yellowfin tuna	Liver	16	374	75-894
"	Ulua	"	3	23,400	8,190-40,900
"	Dog tooth tuna	"	1	1,528	
Bikini I.	Coconut crab	Muscle	3	5.2	2.4-9.4
Enyu I.	"	"	9	3.3	1.1-7.2
Oroken I.	"	"	5	13	5.6-15
Bikini I.	"	"Liver"	2	74	65-82
Enyu I.	"	"	5	28	15-44
Oroken I.	"	"	5	54	38-60
Enyu I.	Spiny lobster	Muscle	3	1.4	.96-2.1
Nam I.	"	"	5	11	5.5-17
Enyu I.	"	"Liver"	3	74	59-96
Nam I.	"	"	5	205	32-420
Enyu I.	"	Skeleton	2	1.0	ns*-2.1
Nam I.	"	"	3	2.8	ns - 4.4
Nam I.	"	Remainder	5	18	4.0-32
Bikini I.	Giant clam	Muscle & mantle	5	27	16-51
Nam I.	" "	"	3	85	43-108
Bikini I.	" "	Viscera	5	47	35-58
Nam I.	" "	"	4	105	ns - 219
Bikini I.	" "	Kidney	5	469	163-709

* Less than the 95% counting error. Taken as zero in computing average.

Table 18 (continued)

Collection Site	Common Name	Tissue or Organ	No. of Samples	pCi/g dry Avg.	pCi/g dry Range
Nam I.	Giant clam	Kidney	3	182	133-287
Nam I.	Curlew	Muscle	3	72	18-143
"	Turnstone	Muscle	1	312	
"	Curlew	Liver	3	2610	312-5810
"	Turnstone	Liver	1(1)	2820	
Oroken I.	Noddy tern	Muscle	1(2)	497	
"	Fairy tern	"	1(2)	425	
"	Noddy tern	Liver	1(2)	1220	
"	" "	"	1(2)	763	
"	Eggs	Albumin	2(3)	12	9.1-15
"	"	Embryo & yolk	1(3)	300	

(1) Six birds pooled.
(2) Five " "
(3) Nine or ten eggs pooled per sample.

Table 19

Bismuth-207 in Soils and Sediment Collected at Bikini Atoll, 1969

Sample		Location	Type	pCi/g dry Gamma Spectrum	pCi/g dry Chemical Analyses
				(σ = 95%)	
25488		Eneman	Soil 8-9"	0.39±0.40	0.62±0.25
25500	1	Eneman	Soil 0-1"	8.9 ±4.5*	0.79±0.26
25500	2	"			0.96±0.51
25504	1	Bikini	Soil 0-1"	None	0.74±0.26
25504	2	"	Well point 3		0.46±0.36
25506	1	Bikini	Soil 0-1"	None	1.07±0.31
25506	2	"	Well point 1		0.60±0.26
25652	1	Namu	Crater	50.0±1.2	56.8 ±0.6
25652	2	"	Sediment		53.3 ±0.6

* High value due to the presence of ^{102}Rh which was not included in the reference spectra.

Table 20

List of Common and Scientific Names of Organisms Collected at Bikini Atoll, 1969

Common Name	Scientific Name
Algae	*Caulerpa urvilliana*
Barracuda	*Sphyranea* sp.
Clam	*Tridacna crocea*
Clam, killer	*Tridacna squamosa*
Clam, horsefoot	*Hippopus hippopus*
Coconut crab	*Birgus latro*
Convict surgeonfish	*Acanthurus triostegus*
Crab, hermit	*Coenobita perlatus*
Crab, shore	*Grapsus grapsus*
Curlew	*Numenius tahitiensis*
Goatfish	*Mulloidichyhys auriflamma*
Grouper	*Epinephelus* sp.
Mullet	*Neomyxus chaptali*
Parrotfish	Scaridae
Pilotfish	*Kyphosus cinerascens*
Rat	*Rattus* sp.
Skipjack	*Euthynnus yaito*
Snapper	Lutjanidae
Spiny lobster (langouste)	*Panulirus* sp.
Tern, fairy	*Gygis alba*
Tern, noddy	*Anous stolidus*
Tuna, dogtooth	*Gymnosarda nuda*
Tuna, yellowfin	*Thunnus albacares*
Turnstone, ruddy	*Arenaria interpres*
Ulua (jack)	*Caranx* sp.