UWFL-63
HEALTH AND SAFETY

FURTHER CONTRIBUTIONS ON GROSS BETA RADIOACTIVITY OF BIOLOGICAL AND RELATED SAMPLES AT THE ENIWETOK PROVING GROUND, 1952-1958

By
Kelshaw Bonham

December 4, 1959

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FURTHER CONTRIBUTIONS ON GROSS BETA RADIOACTIVITY OF BIOLOGICAL AND RELATED SAMPLES AT THE ENIWETOK PROVING GROUND, 1952-1958.

Section I. PHYSICAL DECAY OF SAMPLES FROM ENIWETOK ATOLL IN 1952.

Section II. FURTHER CONTRIBUTIONS ON GROSS BETA RADIOACTIVITY OF PLANKTON AND BOTTOM SAMPLES AT RONGELAP ATOLL, 1954-1958.

Section III. FURTHER CONTRIBUTIONS ON GROSS BETA RADIOACTIVITY OF FISHES AT RONGELAP ATOLL, 1954 THROUGH MARCH 1958.

by

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December 4, 1959

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ABSTRACT

Three sections of subject matter are combined in this paper.

Section I shows the pattern of radioactive decay over periods of about six years for 102 samples from Eniwetok Atoll, plus 2 sand samples from Nevada. Logarithmic plots commonly had slopes of from -1.2 to -1.8. The slopes for the last three years tended to be steeper and to show more variability than for the first three years. An exceptionally slow rate of decay, -0.06, prevailed for the last three years in a sample of rat muscle where Cs^{137} was almost the only radioisotope. Slow decays occurred in muscle, liver, bone, and kidney of various animals.

In Section II, available data on plankton from Rongelap Atoll for 1954-1958 are brought together, including not only values based on wet weight as reported earlier, but also new values computed on the basis of ash weight of sample, which gave more consistent results. Mesh size did not influence activity levels of the plankton samples. For August 1958, the amount of activity in 10 pumped plankton samples was shown not to be correlated with the activity of samples of lagoon bottom material taken at the same stations.

In Section III, the trends in average activity of liver, muscle, and bone of reef fish at Rongelap and Kabelle Islands, and in lagoon-pelagic fish of Rongelap Atoll are given for the period from 1954 through August 1958. Ultimate decline was to levels of about 0.005 microcuries per kilogram of wet tissue.

GENERAL INTRODUCTION

Gross beta is a useful criterion of the amount of persisting radioactivity. Plotting the logarithm of this value against the logarithm of the time after detonation depicts the trends of both physical decay and of decline in radioactivity due to a combination of physical decay and various biological and environmental factors. The term decline as used here indicates the trend with time in the amount of radioactivity in successive samples of a particular type of substance at a particular locality. The term is appropriate because the amount usually decreases with time. However, the amount may increase or remain constant for a while if there is an influx of radioactivity into the environment, so that minor fluctuations in decline are to be expected. In this respect decline differs from physical decay, which can not remain constant or increase but can only decrease.

The three sections of this paper deal respectively with decay data of early samples from Eniwetok Atoll, and with decline of plankton and fish samples from Rongelap Atoll. All have the feature in common that their radioactivity was derived primarily from a single, though not the same, detonation rather than from two or more successive detonations.

SECTION I

PHYSICAL DECAY OF SAMPLES FROM ENIWETOK ATOLL IN 1952

INTRODUCTION

Previous decay studies (UWFL-53) of the biota and other materials from the Marshall Islands have covered periods up to nearly three years following the detonation of atomic testing devices. The earliest curves (AECD-3446:27) were for oyster, XE-19, and ovary of damsel-fish, XE-40, whose slopes from 20 to 800 days were -1.6.

Decay of 83 samples from Rongelap Atoll (UWFL-42:46) over a period of from 38 to 500 days following March 1, 1954 averaged -1.4. Coconut milk was most unusual among these, having a decay rate of only -0.24.

Decay data for samples collected in 1952 offer the most comprehensive picture of long-term decay trends that may now be contributed from studies by the Laboratory of Radiation Biology. A period of approximately seven years is involved. These samples number 102, of which 96 were from Eniwetok Atoll collected within 10 days after the Mike test, 6 were within 10 days pre-Mike and would be referred to the Greenhouse series. In addition there were 2 Nevada sand samples collected on November 29, 1951, related to the Uncle-Jangle atomic tests, making a total of 104 decay curves.

METHODS

Preparation of Plates

Preparation of plates was the same as described in WT-616 (UWFL-33): 19. Briefly, the wet or moist samples were placed on weighed 1 1/2-inch (1 5/8 inch over-all) stainless steel plates, weighed, dried overnight at 97°-99°C, reweighed, ashed overnight at 550°C, and finally reweighed. The ash was slurried with alcohol to cover the plate smoothly, dried and affixed with a few drops of 0.5 per cent Formvar in ethylene dichloride.

Storage

Plates were stored on 2 1/2 x 3 1/4-inch cards perforated with a 1 1/2-inch hole into which the plates fitted. The cards bearing the plates were stored in wooden boxes with tall, narrow, slotted compartments, so that 25 cards bearing plates could be inserted in each tier, totalling 100 plates to the box. Firm fixation of ash to the plate, care in handling, and occasional inspection of the cards for evidence of spill guarded against loss or contamination of ash. However two decay curves had to be excluded, and one more curve was discontinued, on account of loss or contamination.

Counting

In addition to the description of counting methods given in WT-616 it may be said that a special 1 1/2-inch-thick lead shield surrounded each methane-flow counting chamber used in conjunction with the Nucleometers to give a background of only about 45-50 counts per minute (c/m). The same counting equipment was used throughout the seven years covered by this report.

Counting time followed the schedule of WT-616:20 during the earlier counting:

C/m, sample plus background	Counting time, minutes
< -500	20
500-1000	10
1000-2000	5
> -2000	2

For later counts, as more machine time became available, longer counts of from 30 minutes to several hours were frequently possible for the low-counting samples.

The absolute level of radioactivity as indicated in the column of Table 1 headed "Plate count, 1000 days," serves as an index to the reliability of the points.

Graphing and Reproduction

Values from the decay data-sheets were plotted as circles on thin logarithmic graph paper. Even where circles overlapped, almost all of the values were graphed. Free, outstanding circles pertain to the nearest curve, and lines connect those points whose identity was

Table 1. Data concerning 104 decay curves shown in Figures 1-6.

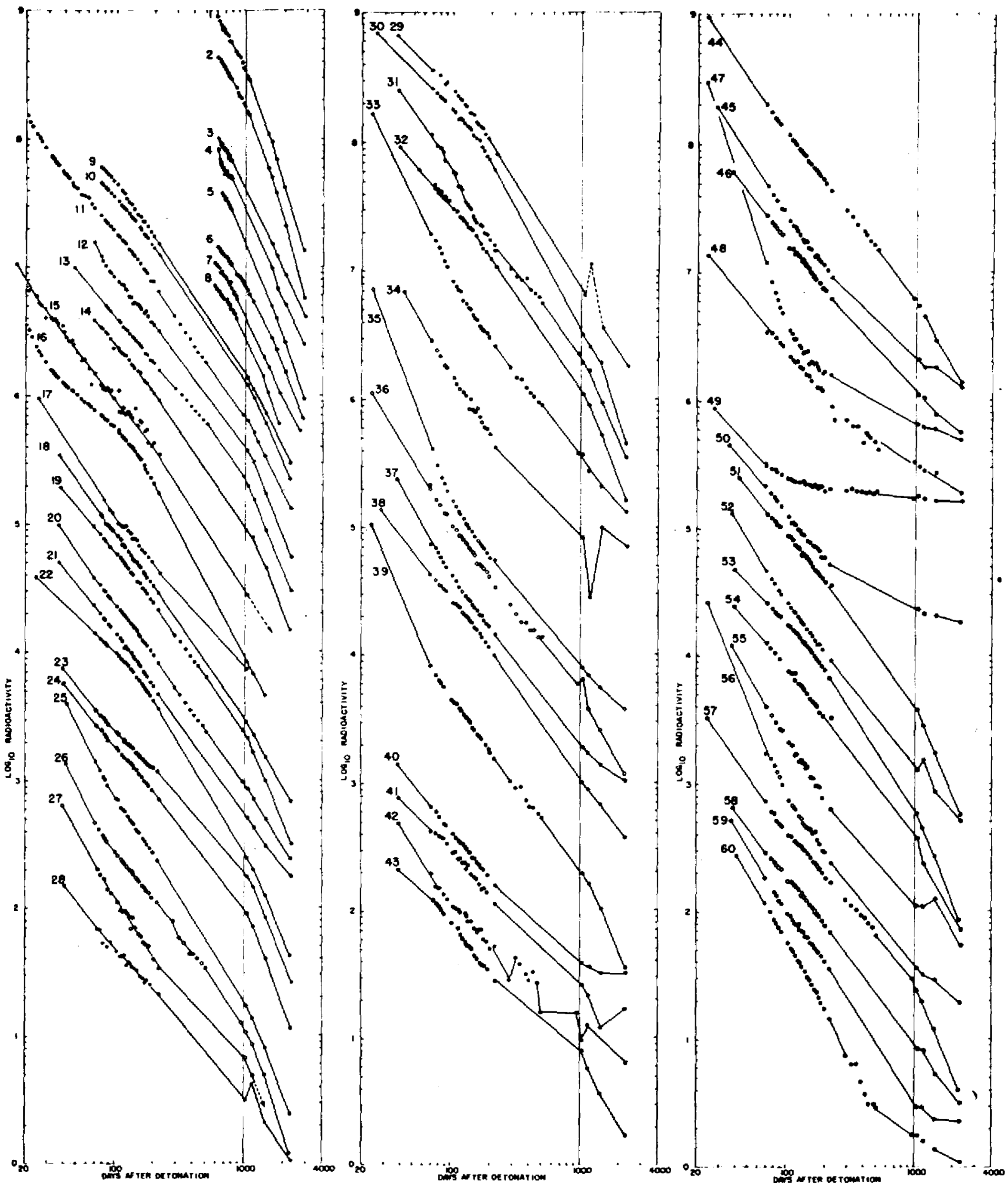
Curve no.	Decay no.	Plate no.	Substance or organism: Name (Common, Scientific)	Tissue	Date of collection, 1952*	Island, Eniwetok Atoll*	Plate c/m at 1000 days	Negative slope for indicated time span in days				
1	27	1227	alga Padina	entire	10-24	Engebi	1300			1.7 600-1000		3.0 1000-2
2	28	1247	alga, blue-green	entire	10-22	Runit	3900			1.7 600-1000		3.3 1000-2
3	29	1532	mycelia in wet wood		10-28	Igurin	590			1.8 600- 800		2.0 800-2
4	30	1996	grass	roots	10-27	Rigili	250			~2.2 600-2800		
5	20	183	sponge	entire	10-24	Engebi	1400			2.0 640- 800		2.5 800-2
6	21	201	snail, conch, Strombus	soft parts	10-24	Engebi	2900			1.4 600-1000		2.3 1000-2
7	121	7	sand "Uncle Jangle" fine fraction		11-29-51	Nevada*	2000			1.1 570- 750		2.1 750-2
8	122	14	sand "Uncle Jangle"		11-29-51	Nevada*	1900			1.5 570-1000	2.5 1000-1800	
9	5	1	sand, lagoon, dredged		11-7	Rojoa-Biijiri	580	1.0 75- 120				1.5 120-2
10	6	2	sand, lagoon, dredged		11-7	Rojoa-Biijiri	1400	1.0 75- 120				1.5 120-2
11	1	I	sand, lagoon, dredged		11-7	Rojoa-Biijiri	320	1.5 20- 35	1.15 35-150		1.4 150-1050	2.0 1050-2
12	22	2044	sand, beach, intertidal		11-8	Engebi	3700	2.2 67- 80			1.3 80-1050	2.5 1050-2
13	119	1297	sand, sphere on coral (WT-616:73&75)		11-8	Bogallua	950	1.2 47-1050				2.5 1050-2
14	4	360	plankton, lagoon		11-8	Bogallua	1700	1.1 67- 160			1.45 160-1160	2.5 1160-2
15	2	1B	water, lagoon, surface		11-8	Alice	2.2	1.3 17- 200			1.5 200-1050	
16	3	1BB	water " " 500ml Fe scavenge		11-8	Alice	120	1.9 20- 35	.9 35-150		1.8 150-1450	
17	118	2C	water " bottom, oxalate ppt.		11-8	Bogallua	14	1.4 25- 100			1.15 100-1050	
18	23	801	alga Halimeda	entire	11-8	Bogallua	1800	1.4 36-1050				1.8 1050-2
19	24	806	alga Caulerpa	entire	11-8	Bogallua	3000	1.2 36- 110			1.4 110-1050	2.4 1050-2
20	25	857	sedge Fimbristylis	roots	11-8	Engebi	3600	1.5 37- 70	1.2 70-160		1.4 160-1050	1.6 1050-2
21	26	858	vine Triumfetta	leaves	11-8	Engebi	3900	1.2 36- 120				1.4 120-2
22	68	405	sponge, encrusting	entire	11-8	Bogallua	470	1.0 24- 150			1.6 150-1050	2.2 1050-2
23	92	1159	sponge "	entire	11-6	Runit	450	1.2 39- 85	.96 85-210		1.1 210-1050	2.3 1050-2
24	105	1301	sponge "	entire	11-5	Rigili	270	1.3 39- 90	1.0 90-150		1.3 150-1050	2.5 1100-2
25	77	479	coral Acropora	entire	11-8	Bogallua	700	2.0 42- 90	1.4 90-200		1.6 200-1050	2.3 1050-2
26	79	496	coral Acropora	entire	11-8	Engebi	2900	2.0 42- 70	1.2 70-500		1.5 500-1050	2.8 1050-2
27	116	1364	coral Acropora	entire	11-5	Rigili	7.3	1.8 39- 75	1.6 75-210		1.2 210-1050	2.4 1050-1
28	117	1365	coral Pocillopora	entire	11-5	Rigili	3.1	1.3 42- 75	1.1 75-200		1.2 200-1050	1.4 1050-2
29	85	1109	sea cucumber Stichopus sp.	body wall	11-7	Aaraanbiru	12	1.0 38- 140				1.6 140-2
30	75	476	sea cucumber Stichopus sp.	body wall	11-8	Bogallua	230	1.0 26- 160		1.9 160-1040	1.4 1040-1460	3.0 1460-2
31	83	1101	" " Holothuria atra	body wall	11-7	Aaraanbiru	330	1.4 38- 90	2.2 90-150	1.0 150- 500	1.3 500-1160	2.2 1160-2
32	111	1341	" " H. fusco-rubra	body wall	11-5	Rigili	140	1.2 39- 150			1.5 150-1050	2.5 1050-2
33	44	424	fish,damsel Abudefduf biocell.	skin	11-8	Bogallua	120	2.0 24- 130	1.4 130-300			1.2 300-2
34	64	504	" " Pomacentrus jenkensi	skin	11-7	Aaraanbiru	6.2	1.7 42- 200				~1.1 300-2
35	48	431	" surgeon Acanthurus elongatus	skin	11-8	Bogallua	71	2.6 24- 100			1.2 100-1460	.8 1460-2
36	53	419	" grouper Epinephalus merra	skin	11-8	Bogallua	26	1.6 24- 150			1.2 150- 960	1.8 960-2
37	58	1073	" wrasse Thalassoma quinquev.	skin	11-8	Bogallua	29	1.8 38- 100			1.3 100-1160	.8 1160-2
38	32	625	rat Rattus exulans	skin	11-9	Biijiri	29	~1.3 28-2300				
39	70	407	clam Tridacna sp.	muscle	11-8	Bogallua	440	2.3 24- 75			1.3 75-1050	2.2 1050-2
40	87	1134	crab Grapsus grapsus	muscle	11-6	Runit	21	1.2 38- 220		.9 220-1050	.5 1050-1450	.2 1450-2
41	103	1188	" Grapsus grapsus	muscle	11-5	Rigili	14	1.0 39-2300				
42	95	1166	" Eriphia laevimana	muscle	11-6	Runit	8.0	1.6 39- 75			~1.1 75-1160	
43	110	1333	crab Eriphia laevimana	muscle	11-5	Rigili	38	.9 39- 75	1.3 75-180		.9 180-1050	1.9 1050-2
44	43	423	fish,damsel Abudefduf biocellatus	"	11-8	Bogallua	210	1.5 24- 65			1.3 65-1050	1.7 1050-2
45	63	503	fish,damsel Pomacentrus jenkensi	"	11-7	Aaraanbiru	15	1.5 28- 150			1.0 150-1160	0.1 1160-2
46	57	1072	" wrasse Thalassoma quinquevittata	"	11-8	Bogallua	50	1.2 38- 160			1.1 160-1050	.9 1050-2
47	47	430	" surgeon Acanthurus elongatus	muscle	11-8	Bogallua	68	3.0 24- 100	1.7 100-150		.6 150-1050	.3 1050-2
48	52	418	" grouper Epinephalus merra	muscle	11-8	Bogallua	53	1.2 24- 300				.6 300-2
49	36	642	rat Rattus exulans	muscle	11-9	Biijiri	230	1.1 28- 90	.3 90-200			.06 200-2
50	38	984	bird,noddy tern Anous stolidus	muscle	11-5	Rigili	46	1.2 36- 210			.5 210-1050	.25 1050-2
51	74	411	clam Tridacna sp.	shell	11-8	Bogallua	48	1.0 42- 100			1.4 100-1000	2.5 1050-2
52	89	1136	crab Grapsus grapsus	carapace	11-6	Runit	24	1.7 38- 50				1.3 50-2
53	104	1191	" Grapsus grapsus	swimmerettes	11-5	Rigili	210	1.0 39- 140			1.6 140-1050	2.5 1050-2
54	96	1168	" Eriphia laevimana	swimmerettes	11-6	Runit	39	1.3 39-1050			1.3 42-1050	2.0 1050-2
55	65	505	fish,damsel Pomacentrus jenkensi	bone	11-7	Aaraanbiru	6.3	1.7 37- 200				1.0 200-2
56	49	432	" surgeon Acanthurus elongatus	bone	11-8	Bogallua	740	2.5 24- 100			1.3 100-1050	.85 1050-2
57	54	420	" grouper Epinephalus merra	bone	11-8	Bogallua	67	1.4 24- 70			1.2 70-1050	2.4 1050-2
58	59	1074	" wrasse Thalassoma quinquevit.	bone	11-8	Bogallua	42	1.3 38-2300				
59	33	627	rat Rattus exulans	bone	11-9	Biijiri	29	1.5 37-1050			.7 1050-1460	.03 1460-2
60	39	985	bird,noddy tern Anous stolidus	bone	11-5	Rigili	69	1.7 41- 180	2.0 180-500			.63 500-2
61	72	409	clam Tridacna sp.	gill	11-8	Bogallua	930	.9 24- 100			1.4 100-1050	2.5 1050-23
62	88	1135	crab Grapsus grapsus	gill	11-6	Runit	190	1.0 38- 75			1.3 75-1050	2.5 1050-23
63	102	1187	crab Grapsus grapsus	gill	11-5	Rigili	280	.85 39- 90	1.3 90-200		1.7 200-1050	2.5 1050-23
64	94	1164	crab Eriphia laevimana	gill	11-6	Runit	190	1.4 39- 100	.9 100-400		1.3 400-1000	2.2 1000-23
65	107	1329	crab Eriphia laevimana	gill	11-5	Rigili	630	1.2 39-1050				2.5 1050-23
66	42	990	bird,noddy tern Anous stolidus	lung	11-5	Rigili	28	1.3 36- 200			1.0 200-1000	.5 1000-23
67	120	404	octopus Polypus sp.	digestive gland	11-8	Bogallua	1700	.95 24- 90			1.5 90-1050	2.5 1050-23
68	99	1183	crab Grapsus grapsus	liver	11-5	Rigili	360	.80 40- 100			1.4 100-1050	2.5 1050-23
69	108	1330	crab Eriphia laevimana	liver	11-5	Rigili	130	.9 39- 100			1.2 100-1000	2.2 1000-23
70	46	426	fish, damsel Abudefduf biocell.	liver	11-8	Bogallua	3800	1.3 42- 150			1.5 150-1050	2.2 1050-2
71	66	506	" damsel Pomacentrus jenkensi	liver	11-7	Aaraanbiru	76	1.6 28- 100	1.3 100-160			1.7 160-23
72	50	433	" surgeon Acanthurus elongatus	liver	11-8	Bogallua	200	1.3 24- 200				1.7 200-23
73	60	1075	" wrasse Thalassoma quinquevittata	"	11-8	Bogallua	160	1.1 38- 140				1.5 140-23
74	35	636	rat Rattus exulans	liver	11-9	Biijiri	950	2.5 33- 70	1.0 70-250		.2 250-1050	.3 1050-23
75	40	986	bird,noddy tern Anous stolidus	liver	11-5	Rigili	54	1.2 35- 130	1.7 130-400	1.2 400-1000	2.1 1000-1160	.6 1160-23
76	76	477	sea cucumber Stichopus sp.	gut	11-8	Bogallua	3100	1.4 42-1050				2.5 1050-23
77	84	1102	" " Holothuria atra	gut	11-7	Aaraanbiru	4300	1.4 38-1000				2.5 1000-23
78	113	1343	" " Holothuria fusco-rubra	gut	11-5	Rigili	500	.55 39- 80			1.1 80-1050	2.9 1050-23
79	101	1185	crab Grapsus grapsus	gut	11-5	Rigili	650	1.2 39- 70	1.0 70-200		1.4 200-1050	2.6 1050-23
80	109	1331	crab Eriphia laevimana	gut	11-5	Rigili	100	.9 39- 80	1.2 80-220	1.0 220-1050	2.2 1050-1460	1.5 1460-23
81	31	614	rat Rattus exulans	gut	11-9	Biijiri	230	1.3 31-2300				
82	37	676	bird,tattler Heteroscelus incan.	gizzard	11-7	Aaraanbiru	880	1.0 34- 70	1.2 70-200		1.6 200-1050	1.7 1050-23
83	41	989	bird, noddy tern Anous stolidus	gut	11-5	Rigili	150	1.4 36- 100			1.8 100-1050	1.0 1050-23
84	71	408	clam Tridacna sp.	kidney	11-8	Bogallua	270	1.3 24- 280				1.0 280-23
85	82	538	clam Tridacna sp.	kidney	11-7	Aaraanbiru	120	.8 28- 80	1.0 80-200			.5 200-23
86	98	1178	clam Tridacna sp.	kidney	11-5	Rigili	87	.8 39- 100			.35 100-1050	.8 1050-23
87	34	632	rat Rattus exulans	kidney	11-9	Biijiri	60	1.8 28- 70	1.1 70-180		.6 180-1050	.4 1050-23
88	69	406	clam Tridacna sp.	mantle	11-8	Bogallua	950	1.5 24- 80	.8 80-170		1.3 170-1050	2.3 1050-23
89	90	1148	snail, money cowry Cypraea moneta	"	11-6	Runit	40	.95 39-1050				2.1 1050-23
90	115	1362	snail Cypraea moneta	foot & mantle	11-5	Rigili	51	.5 39- 70			1.2 70-1050	2.2 1050-23
91	106	1325	crab Eriphia laevimana	eggs	11-5	Rigili	170	1.0 39- 100			1.2 100-1050	2.5 1050-23
92	112	1342	sea cucumber Holothuria f.	respir. tree	11-5	Rigili	13	.9 39- 100			1.5 100-1100	2.2 1100-23
93	73	410	clam Tridacna sp.	visceral mass	11-8	Bogallua	1400	1.1 24- 130			1.5 130-1050	2.5 1050-23
94	81	537	clam Tridacna sp.	visceral mass	11-7	Aaraanbiru	190	1.4 28- 200			.9 200-1000	1.3 1000-23
95	97	1177	clam Tridacna sp.	visceral mass	11-5	Rigili	6.4	1.7 39- 70			.9 70-1000	~2 1000-23
96	91	1149	snail Cypraea moneta	viscera	11-6	Runit	190	.9 39- 100			1.1 100-1050	2.2 1050-23
97	114	1361	snail Cypraea moneta	viscera	11-5	Rigili	180	1.0 39- 70			1.3 70-1160	2.5 1160-23
98	86	1133	crab Grapsus grapsus	viscera	11-6	Runit	870	1.1 38- 70	1.0 70-200		1.2 200-1160	2.7 1160-23
99	93	1163	crab Eriphia laevimana	viscera	11-6	Runit	120	.9 39- 70			1.1 70-1050	2.5 1050-23
100	67	507	fish,damsel Pomacentrus jenken.	viscera	11-7	Aaraanbiru	3900	1.0 42- 100			1.4 100- 960	2.2 960-23
101	51	434	" surgeon Acanthurus elongatus	viscera	11-8	Bogallua	870	1.5 24-1050				2.3 1050-23
102	56	422	" grouper Epinephalus merra	viscera	11-8	Bogallua	740	1.5 24-1050				2.3 1050-23
103	61	1076	" wrasse Thalassoma quinquev.	viscera	11-8	Bogallua	1100	1.1 38- 100			1.4 100-1050	2.2 1050-23
104	62	1080	" goby Gobiodon citrinus	entire	11-8	Bogallua	210	2.4 38- 100			1.7 100-1050	1.0 1050-23

* Note exceptions.

considered to be uncertain, or where the gap between points was so great as to cause difficulty in perceiving the continuity of the curve. From the original graphs the curves were copied over a light-table onto tracing paper. A somewhat natural sequence of subject matter was arranged, progressing from soil through the plant and animal kingdoms. Each graph was oriented by means of the 1000-day vertical line.

Thus, the position of the curve in the series is no index of the amount of radioactivity involved. Absolute levels may be computed by referring to the column of Table 1 headed "Plate count, 1000 days." For example, if for curve 25, the value of the plate count at 2300 days were required, then reference to Table 1 would show a plate count at 1000 days of 700, while the ordinates as scaled from Figure 1 on days 1000 and 2300 were 18 and 2.4 respectively. The ratio, 2.4/18, is multiplied by 700 to give a result of about 93 c/m, which is reasonably close to the actual value, 90 c/m (original data, not shown here).

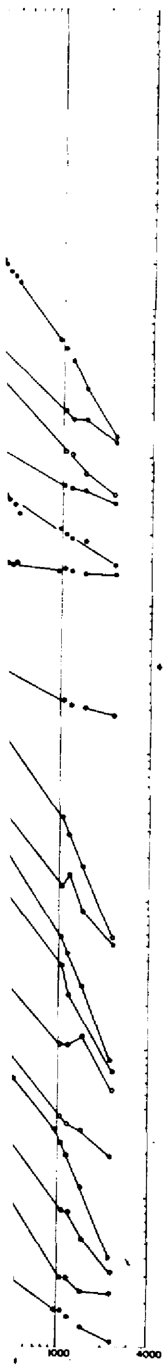
Slopes of curves were scaled from the finished drawings of Figures 1-6, using a transparent slope-scaler calibrated in tenths from slope -0.1 to -2.0 and by greater increments from -2.0 to -5. For each curve, the portions of markedly different slope were measured separately, thus necessitating subjective interpretations as to what constituted a change of slope.



Figures 1 - 3. Logarithmic plots showing radioactive decay of samples listed in Table 1. Absolute levels of curves may be calculated by referring to the column of Table 1 headed "Plate count, 1000 days". (Curves 61-104 follow in Figs. 4-6, p.7)

Dates of detonations:

Curves 1-6	"Greenhouse"	April 21, 1951
Curves 7-8	"Uncle-Jangle"	November 29, 1951
Curves 9-104	"Mike"	November 1, 1952



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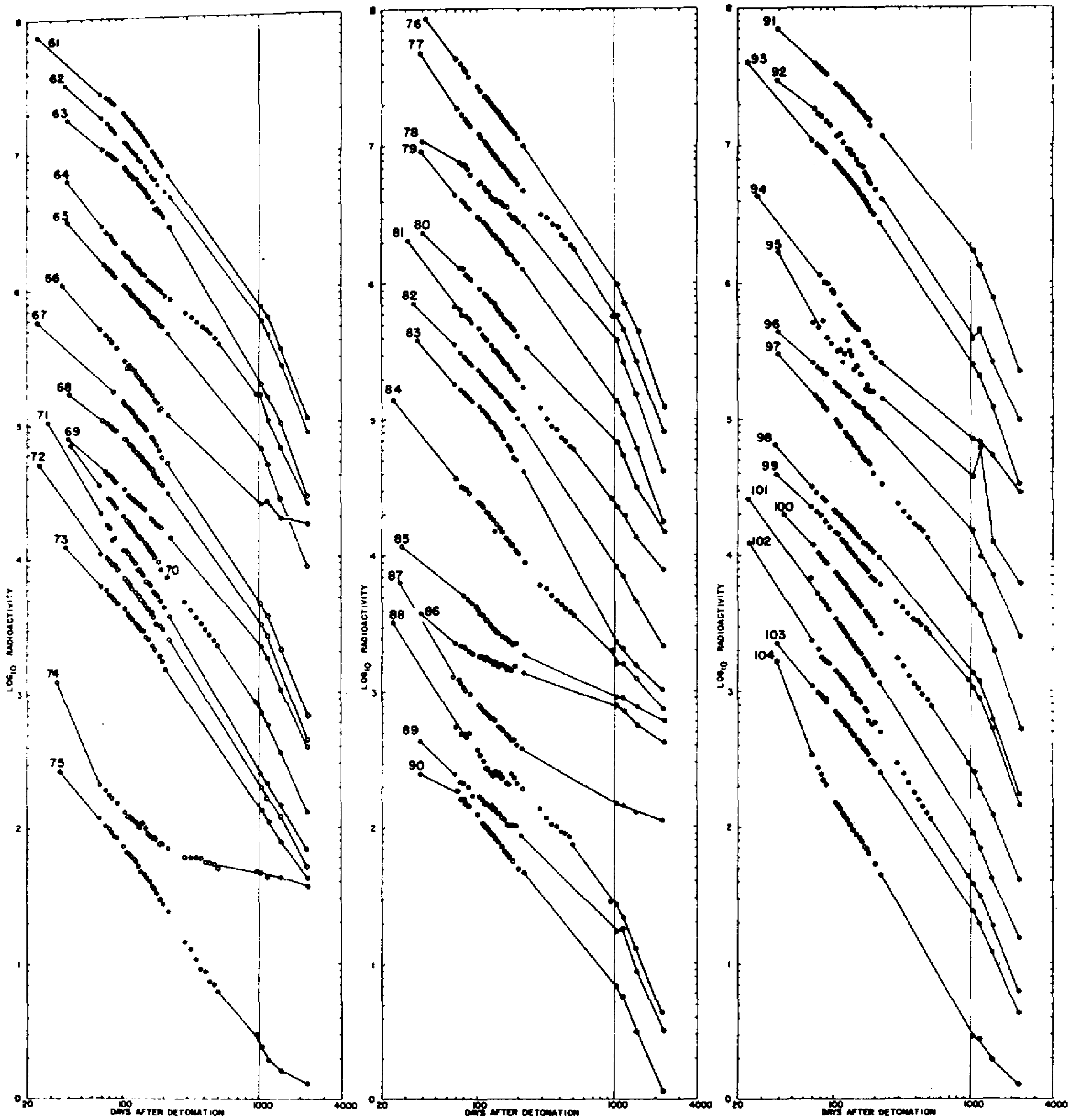


Figures 4 - 6. (For legend see Fig. 1)

RESULTS

Figures 1-6 show graphically the decay rates of 104 samples collected in 1951 and 1952. Logarithm of radioactivity is related to log of time after detonation. Detonation date is stated in the legend of the figures. The graphs do not show absolute levels of radioactivity, (although this may be computed by reference to Table 1) but rather permit a comparison of decay rates between samples.

Table 1 lists, in the left-hand portion, reference data for the samples whose decay curves appear in Figures 1-6, while the five regions in the right-hand portion give measurements of slope as scaled from the graphs in such a manner as to consider most of the major inflections of the curves where observations were sufficiently frequent. Inflections of curvature might of course also be expected during the periods when observations were not made. The slopes of the straight portions of the curves were tabulated in the region that seemed chronologically most appropriate, except that if the entire curve was straight, the data were entered only in the first region. Thus, from the first region under "Negative slope----" in Table 1 the nearly straight-line decays are seen to be numbers 38, 41, 58, and 81. Similarly, the last region contains, among others, those entries for curves that were linear from the period of the first region through 2300 days after detonation.

In an effort to detect a pattern, the five regions of Table 1 pertaining to slope were assigned the following approximate time-spans in days, respectively: <100, 100-300, 300-700, 700-1200, and 1200-2300. Because the points of inflection of the various curves do not coincide, these limits for the five periods had to be arbitrary. Omitting the first eight curves, and, therefore, considering only the post-Mike material (curves 9-104 inclusive), the slope for a curve was entered in the blank space so that a slope was available for each of the five time-periods involved. Computation of mean and standard deviation ($\sqrt{Sx^2/(n-1)}$), not standard error, of the 92-96 slopes for each of the five time-periods gave, respectively, these results: -1.35 ± 0.45; -1.26 ± 0.28; -1.25 ± 0.34; -1.25 ± 0.37, -1.78 ± 0.79. The mean slope of -1.35 for the period up to 100 days is steeper than for the three following periods, -1.26, -1.25, and -1.25, but is less steep than for the last period -1.78. Likewise, the standard deviation of slopes was greater for the first than for the succeeding three periods, but less than for the fifth, and this same variability is also discernible from the graphs. There is thus evidence of a general increase in rate of decay of post-Mike samples during the last three years, over the first three years, with the exception of certain samples to be discussed later.

The present decay rates may be compared to the theoretical gross beta decay curve for slow-neutron-induced fission products of U^{235} as depicted by Hunter and Ballou (1951). From their Figure 1 the following approximate slopes were obtained graphically: 20-100 days, -1.2; 200-547 days, -1.8, 2-6 years, -1.3; 10-25 years, -0.7; 150-180 years, -3.7.

Thus, the mean slope for the Eniwetok samples is slightly steeper than that of Hunter and Ballou up to 100 days; then, in the period from 2 to 6 years, the Eniwetok samples tend to be at first less steep, and toward the end of the period, steeper. Future counting may show whether these curves will level slightly to -0.7 as does Hunter and Ballou's curve at about 10 years.

For the first six curves (Table 1) of pre-Mike samples involving products of the Greenhouse tests the curves tend to be steeper than for corresponding periods for post-Mike samples. Contamination of post-Mike samples by the older products from Greenhouse would tend to produce an effect in this direction, but so marked an effect is rather surprising.

In contrast to the general tendency as noted above for the average of the slopes to become steeper after 3 years, certain curves showing a slower decay than average may be of special importance. Curve 49 for rat muscle decayed most slowly of all those studied, with a half life during the last 3 years, of more than 30 years. In gamma spectroscopy of this plate only Cs^{137} was detected. A listing of those curves which tended to level out, and the flattest slopes that they attained, appear in Table 2.

The slow decays thus include almost all of the decays available for bird and rat as well as curves for muscle and kidney of most animals. The slow rate for rats could be due to residual activity from earlier detonations in the vicinity of Biijiri Island. Muscle with its high K^{40} content and kidney with (in the tridacnid clam) an affinity for strontium would be expected to exhibit slow radioactive decay.

Table 2. Summary of the nineteen curves from Table 1 and Figures 1-6, showing the most decided tendency toward leveling and the minimum steepness attained.

Curve no.	Organism	Tissue	Latest slope	Curve no.	Organism	Tissue	Latest slope
35	fish	skin	-0.8	56	fish	bone	-0.85
37	fish	skin	-0.8	59	rat	bone	-0.03
40	crab	muscle	-0.2	60	bird	bone	-0.63
41	crab	muscle	-1.0	66	bird	lung	-0.5
45	fish	muscle	-0.5	74	rat	liver	-0.3
46	fish	muscle	-0.9	75	bird	liver	-0.6
47	fish	muscle	-0.3	85	clam	kidney	-0.5
48	fish	muscle	-0.6	86	clam	kidney	-0.6
49	rat	muscle	-0.06	87	rat	kidney	-0.4
50	bird	muscle	-0.25				

SECTION II

FURTHER CONTRIBUTIONS ON GROSS BETA RADIOACTIVITY OF PLANKTON AND BOTTOM SAMPLES AT RONGELAP ATOLL 1954-1958

INTRODUCTION

Plankton in Rongelap lagoon took up large amounts of radioactivity from fallout following the Bravo detonation at Bikini Atoll on March 1, 1954. Since then, the radioactivity has declined with only relatively slight additions from the two succeeding series of tests, Redwing in 1956 and Hardtack in 1958. Since the last summary report on the Rongelap surveys (UWFL-43) was written, plankton has been collected four times, July 1956 and 1957, and March and August, 1958, and lagoon bottom samples once, in August 1958.

The present report gives available data on plankton through 1958 including a reevaluation of 1954-1955 counts which were reported in UWFL-42:43; however, ash weight as well as wet weight is used, with a modification of results, and a comparison is made of activity yielded by fine-meshed as contrasted with coarse-meshed plankton nets. The rate of physical decay of early samples is compared with the rate of change, herein termed decline, of successive samplings at later dates, up to more than four years after the original fallout.

METHODS

Methods of collecting and processing of the 1954-1955 plankton are described in UWFL-42:32 and UWFL-43:44. In 1956 and 1957, collecting differed from that of previous years in that amphibious air craft or rubber boats were used for towing the nets. Methods of processing were unchanged.

In 1958, plankton tows were made with 1/2-meter nylon nets of 70-80 meshes per inch by towing from an LSVP (March) or a DUKW (August) for from 10 to 30 minutes at a velocity of 2-1/2 - 3 miles per hour during daylight, and within 3 (usually 1-2 miles of the localities indicated in Table 4.

In August 1958 only, plankton was also collected from the support vessel, LSM "Aloto" by means of pumping, which not only permitted a more precise measurement of volume of sea water filtered and pinpointing of location of the sampling station than is possible with tows, but also allowed simultaneous sampling of the lagoon-bottom material. Thus, at the ten consecutively numbered stations indicated in Figure 7, ranging along the southern and eastern portions of the lagoon, both plankton and bottom material were sampled. Bottom samples were obtained in August 1958 at the first nine stations by personnel of the "Aloto" using brown soap in the depression at the lower end of the sounding lead. Small amounts of sand and other bottom material adhered

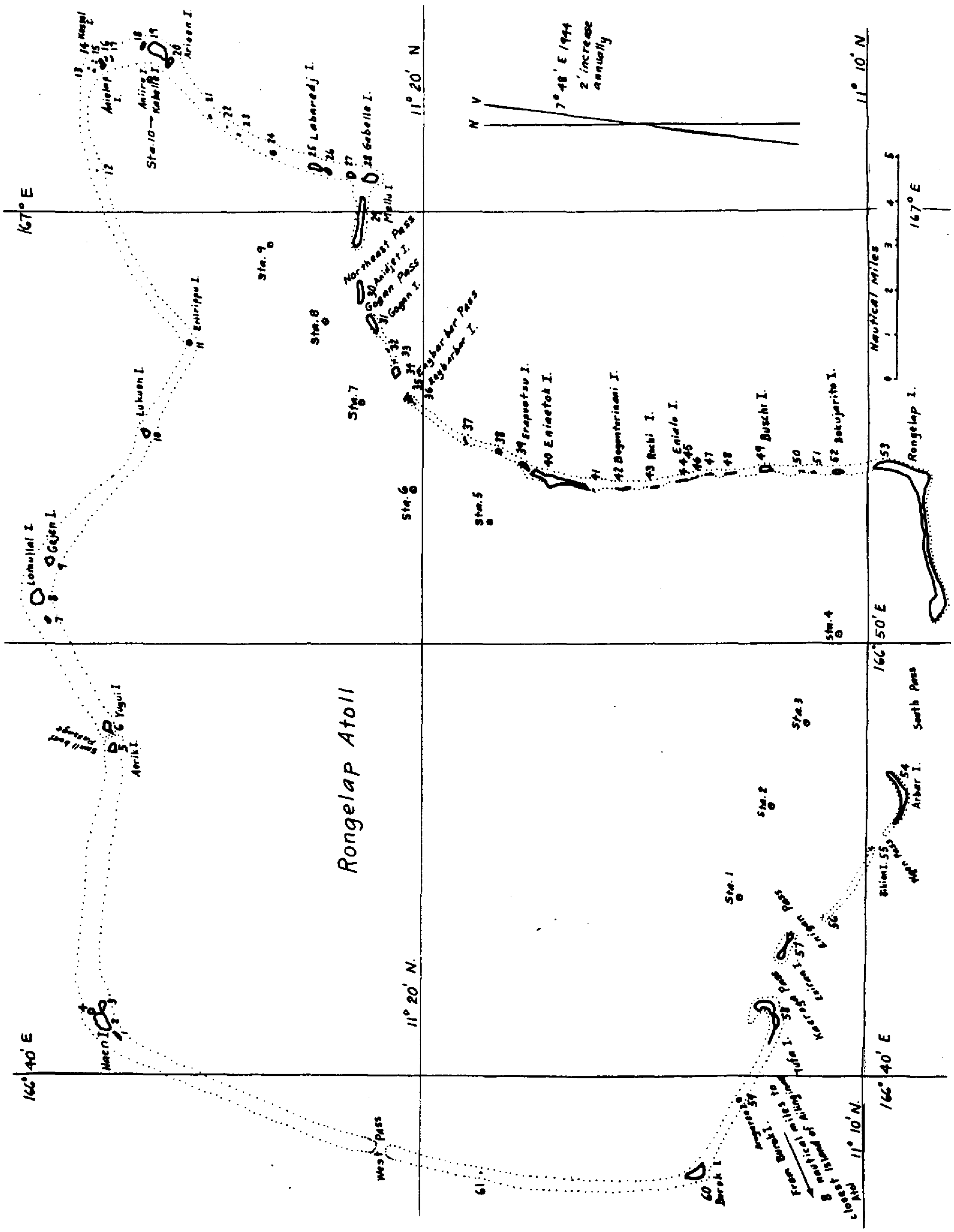
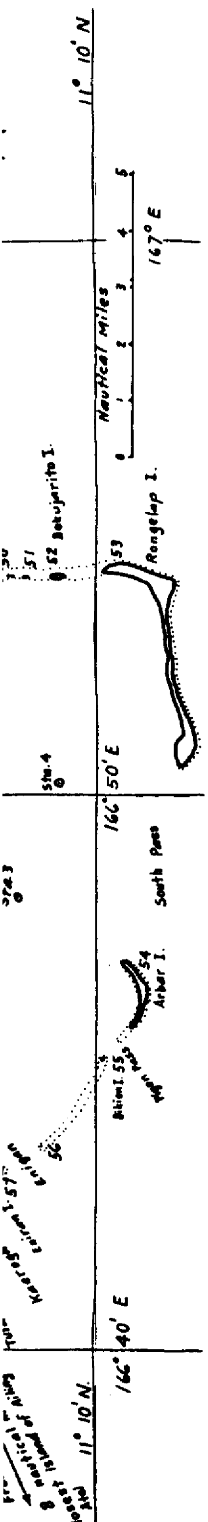


Figure 7. Map of Rongelap Atoll showing locations of ten plankton- and bottom-sampling stations in the southern and eastern portions.



lankton- and
ons.

to the soap and could be scraped off with a knife. The process was usually repeated more than once at each station. At Station 10 the anchor brought up several pounds of the bottom. Samples were taken from both the hinge of the anchor, which was considered to have been at about surface level on the bottom, and from the flukes which were estimated by both ship- and laboratory-personnel to have dug about two feet into the sand of the bottom.

At the first four stations sea water for plankton was pumped from astern of the "Aloto" by means of a high-speed, gasoline powered, fire-fighting pump with a capacity of about 40 gallons per minute, while at the other six stations a more reliable, submersible, electric pump operating alongside the ship gave 180 gallons per minute. Pumping continued for 30 minutes with the mouth of the net above water, so that all pumped water went through the net.

Pumping, as here done, although more quantitative, was less desirable than towing for two reasons. Smaller samples of plankton were obtained, and picking up debris from the ship seemed unavoidable.

The plankton was preserved in alcohol except for the tows in August near Kabelle Island. Here the bucket was removed from the net and the end of the net tied closed. After towing, the net was washed down, drained, untied, and the plankton scraped directly into small plastic bags in which it was later dried at 80° C without preservative. Because this simplification not only made it possible to avoid the debris from the ship and the almost inevitable leakage at the bayonet-type fitting of the plankton bucket, but also expedited the processing, it is recommended that this technique be used where radioassay is the primary objective.

For laboratory processing of the March 1958 samples, the plankton was filtered and the preservative fluid was tested for radioactivity (practically lacking) before discarding, thus excluding most sea salt which might inadvertently have been included with the sample at the time of preservation. The August 1958 samples, including preservative, were evaporated to dryness, so that the sample from Station 7, including salt water accidentally used for washing the plankton bucket, appeared low in radioactivity[1].

Bottom samples were ashed and counted at Seattle in methane-flow counters. Plankton data after 1956 are presented as of the date of counting, rather than being corrected back to date of collecting as was done for the 1954-1955 material. It is probable that if corrections for decay could have been applied to the 1956 plankton data the levels on the date of collection would have been found to be about twice as high as those here given for the date of counting, but data from later collections would have been practically unaltered.

---

[1]The careful work of Dr. Remzi Geldiay at Seattle in processing the plankton samples of the August 1958 collections is gratefully acknowledged.

RESULTS AND DISCUSSION

Plankton

Tables 3 and 4 give the plankton data from 1954 to 1958, including the values from which Table 12 of UWFL-43 (1955) was compiled. Individual plate values appear in order to show the degree of variability, and for 1954-1955, to permit comparison of coarse- and fine-meshed net samples. Radioactivity is expressed per unit weight of both wet plankton and planktonic ash in order to assess the relative suitability of these two bases of reporting results.

Levels of radioactivity were equally high in coarse- and in fine-meshed nets. The equality prevailed on either a wet weight or ash weight basis among the ten pairs of simultaneous tows with coarse- and fine-meshed nets listed in Table 3. The higher value of the pair was from a coarse-meshed net five times and from a fine-meshed net five times on the ash weight basis, and the same was true on the wet weight basis. In only half of the cases was the specific activity higher for a certain mesh size on both the ash and the wet basis. The above observation indicates a randomness, or in other words, a lack of correlation between mesh size and specific activity.

In the Laboratory's earlier reports (AECD-3446:103; WT-616:29; UWFL-42:31; UWFL-43:47; UWFL-46:9; UWFL-47:11), beta radioactivity

Table 3. Levels and decay rates of beta radioactivity of Rongelap-Ailinginae plankton, 1954-1957

Plate No.	Atoll	Island	Plankton net: Number designation	Plankton net: Meshes per inch	Plankton net: Material	Diameter of net inches	Date of collecting	Date of first counting	First count in μc/kg*: Ash basis	First count in μc/kg*: Wet basis	Decay slope from date of first counting to October 30, 1957
8201	Rongelap	Labaredj	12	125	?	?	3-26-54	5-11-54	83	--	- 1.08
8202	"	"	"	"	?	?	"	"	2330	--	- 1.32
8303	"	"	"	"	?	?	"	"	4000	140	- 1.27
8239	"	Kabelle	6	74	Silk	20	7-16-54	8-11-54	68	2.1	- 1.32
8240	"	"	20	173	"	20	"	"	46	2.7	- 1.33
19005	"	"	6 or 20	--	"	20	12-8-54	1-3-55	168	6.2	- 1.75
19006	"	"	"	--	"	"	"	"	168	10.4	- 1.35**
19019	"	Labaredj	6	74	"	"	12-18-54	"	104	5.0	- 1.72
19020	"	"	20	173	"	"	"	"	32	3.9	- 1.73
19024	"	Rongelap	6	74	"	"	1-26-55	2-22-55	25	.54	- 1.68
19025	"	"	20	173	"	"	"	"	24	.95	- 1.72
19026	"	Labaredj	6	74	"	"	1-28-55	"	27	.93	- 1.56
19027	"	"	20	173	"	"	"	"	12	.41	- 1.55
19028	"	Kabelle	6	74	"	"	1-29-55	"	58	1.8	- 1.61
19029	"	"	20	173	"	"	"	"	93	5.8	- 1.61
19030	"	Lukuen	6	74	"	"	1-30-55	"	37	1.5	- 1.70
19031	"	"	20	173	"	"	"	"	95	4.4	- 1.70
19067	"	Kabelle	1	74	Nylon	"	10-21-55	11-26-55	6.4	.20	- 1.76
19068	"	"	2	157	"	"	"	"	6.9	.18	- 1.72
19069	"	Rongelap	1	74	"	"	10-22-55	"	2.1	.044	- .73***
19070	"	"	2	157	"	"	"	"	2.0	.047	- 1.38
19071	Ailinginae	Mojiri-Enibuk	1	74	"	"	10-23-55	"	4.5	.70	- 1.58

19069	"	Rongelap	1	74	"	"	10-22-55	"	2.1	.044	- .73***
19070	"	"	2	157	"	"	"	"	2.0	.047	- 1.38
19071	Ailinginae	Mojiri-Enibuk	1	74	"	"	10-23-55	"	4.5	.70	- 1.58

Table 3, (continued)

Plate No.	Atoll	Island	Plankton net: Number designation	Plankton net: Meshes per inch	Plankton net: Material	Diameter of net inches	Date of collecting	Date of first counting	First count in μc/kg*: Ash basis	First count in μc/kg*: Wet basis	Decay slope from date of first counting to October 30, 1957
19072	Ailinginae	Mojiri-Enibuk	2	157	Nylon	20	10-23-55	11-26-55	5.5	.34	- 1.53
19073	"	"	1	74	"	"	10-24-55	11-27-55	4.6	.94	- 1.71
19074	"	"	2	151	"	"	"	"	7.4	.80	- 1.73
6076	Rongelap	Rongelap	20	170	Silk	12	7-23-56	8-23-56	41	2.2	- 5.3
6077	"	"	20	170	"	"	"	"	178	19	-11.4
6078	"	Kabelle	20	170	"	"	7-24-56	"	20****	.45	--
6079	"	"	"	170	"	"	"	"	72	4.0	- 4.4
6121	"	Rongelap	6	74	Nylon	20	7-17-57	8-16-57	14	.20	- 3.7
6122	"	Kabelle	6	74	"	"	7-18-57	8-16-57	93	6.0	- 1.10

* As of collecting date for 1954-55, and as of counting date for 1956-57, samples.
** Last count 9-6-55. Plate missing.
*** Low plate count; large error.
**** Decay curve rose, invalidating the entry.

Table 4. Levels of beta radioactivity of plankton collected from Rongelap lagoon in 1958.

Locality	Collection date	Collection No.	Plate No. 1958 series	First count Month and day 1958	First count μc/kg ash	Second count Month and day 1958	Second count μc/kg ash	Third count Month and day 1958	Third count μc/kg ash	Preservation of plankton
Rongelap I.	March 1	Tow 1	5001	9-16	.24	11-20	.25			alcohol
"	" "	" 2	5002	"	.37	"	.34			"
"	" "	" 3	5003	"	.32	11-21	.33			"
Kabelle I.	March 9	Tow 1	5004	9-16	.33					"
"	" "	" 2	5005	"	.077	11-18	.103			"
Rongelap I.	Aug. 16	Tow 1	5023	10-22	6.8	11-19	4.5			"
"	" "	" 2	5022	"	3.5	11-19	3.5	11-19	3.8	"
"	" "	" 3	5021	"	4.6	"	2.9			"
"	" "	" 4	5019	"	3.4	"	3.0			"
"	" "	" 5	5027	"	4.2	"	3.2			"
Eniaetok I.	Aug. 18	Tow 1	5026	10-22	3.3	11-19	2.7	11-21	2.7	"
"	" "	Tows 2-5	5020	"	3.7	"	2.7			"
"	" "	" 6-7	5024	"	2.6	"	2.7			"
"	" "	" 8	5025	"	1.6	"	1.3	11-19	1.0	"
Kabelle I.	Aug. 21	Tow 1	5006	9-16	1.1	11-18	.62	11-20	.59	dried fresh
"	" "	" 1	5028	11-18	.43	"	.52			" "
"	" "	" 2	5029	"	.66	11-21	.74			" "
"	" "	" 3	5030	"	1.3	"	1.25			" "
"	" "	" 4	5031	"	1.1					" "
"	" "	" 5	5032	"	.63					" "
"	" "	" 6	5033	"	.88					" "
Enigan Pass	Aug. 15	Sta. 1	5017	10-22	5.7	11-20	4.0			alcohol
Pigen Pass	" "	" 2	5014	"	.021	"	.021			"
South Pass	" "	" 3	5015	"	.034	11-21	.019			"

"	"	" 6	5033	"	.88					" "
Enigan Pass	Aug. 15	Sta. 1	5017	10-22	5.7	11-20	4.0			alcohol
Pigen Pass	" "	" 2	5014	"	.021	"	.021			"
South Pass	" "	" 3	5015	"	.034	11-21	.019			"

Table 4, (continued)

Locality	Collection date	Collection No.	Plate No. 1958 series	First count: Month and day 1958	First count: μc/kg ash	Second count: Month and day 1958	Second count: μc/kg ash	Third count: Month and day 1958	Third count: μc/kg ash	Preservation of plankton
Rongelap I.	Aug. 15	Sta. 4	5018	10-22	.53	11-20	.41			alcohol
Eniaetok I.	Aug. 19	" 5	5011	"	.78	"	.59			"
Enybarbar I.	" "	" 6	5016	"	.46	"	.37			"
Kieshiechi I.	" "	" 7	5010	"	.057	"	.019	11-21	.019	"
Gogan I.	" "	" 8	5012	"	.077	11-21	.094			"
Mellu I.	" "	" 9	5013	"	.29	"	.14			"
Kabelle I.	" "	" 10	5009	"	.026	11-20	.026			"

of plankton as determined in methane-flow counters has been reported on the wet basis so that the specific activity of plankton may be compared with that of other substances. This involves attempting to drain water uniformly from the plankton samples at the time of preparing the plates. The varying water content of the planktonic organisms causes uncertainty in evaluating the amount of wet plankton being radioassayed. It was shown (UWFL-53:19) that if results were based on the amount of planktonic ash rather than on the amount of wet plankton, the variability in radioactivity of replicated tows was reduced to only one half the value obtained on the wet basis.

Similarly, the present data for Rongelap Atoll were more consistent on an ash than on a wet basis. The greatest disparities between the two values for paired tows occurred in the 1956 collections, as seen in Table 3. At Kabelle Island, the ratio between the two values was only 3.6 on the ash basis, but 8.9 on the wet basis, and at Rongelap Island only 4.3 ash basis, but 8.6 wet basis, so that here, as at Eniwetok Atoll, the variability is only half as great on the ash as on the wet basis

Further, the average level of activity in plankton from Ailinginae lagoon in October 1955 was noted (UWFL-43:46) to be higher than in Rongelap lagoon on the wet weight basis. But if the radioactivity per unit of ash weight instead of wet weight is used, the Ailinginae levels are no higher than in Rongelap lagoon near Kabelle Island (Table 3).

Thus, it seems desirable to report radioactivity of plankton on an ash weight basis, even though other organisms and substances might more desirably be considered on a wet weight basis.

Figure 8 shows the trend of radioactivity in the plankton samples from Rongelap lagoon (from 1954 through 1958) related to time, using a log-log plot of the beta activity on an ash weight basis as determined with a methane-flow counter. Data are from Tables 3 and 4. The dotted line showing a decline slope of -3.5 was fitted by inspection to the minimal points near 300, 600 and 1500 days, points removed as far as possible from the peaks caused by the Redwing and Hardtack series of detonations.

The maximum level of the lagoon plankton a day or two after March 1, 1954 may be conjectured by extrapolating back one cycle on Figure 8. It appears that maxima must have been at least 20,000 $\mu c/kg$ of ash.

Further reference to Figure 8 shows that the original detonation, Bravo, must have contributed 100 times as much activity as the Redwing series, and Redwing 20 to 100 times as much as the Hardtack tests. The decline picture is characteristic in its pattern. Rises result from the fallouts, followed by steep declines until the next fallout. An exception appears in the region of Kabelle Island in late 1954 and from 1956 to 1957.

Figure 9 shows, on log-log plot, the decay patterns of six samples counted on more than three occasions. Ordinal values on the vertical

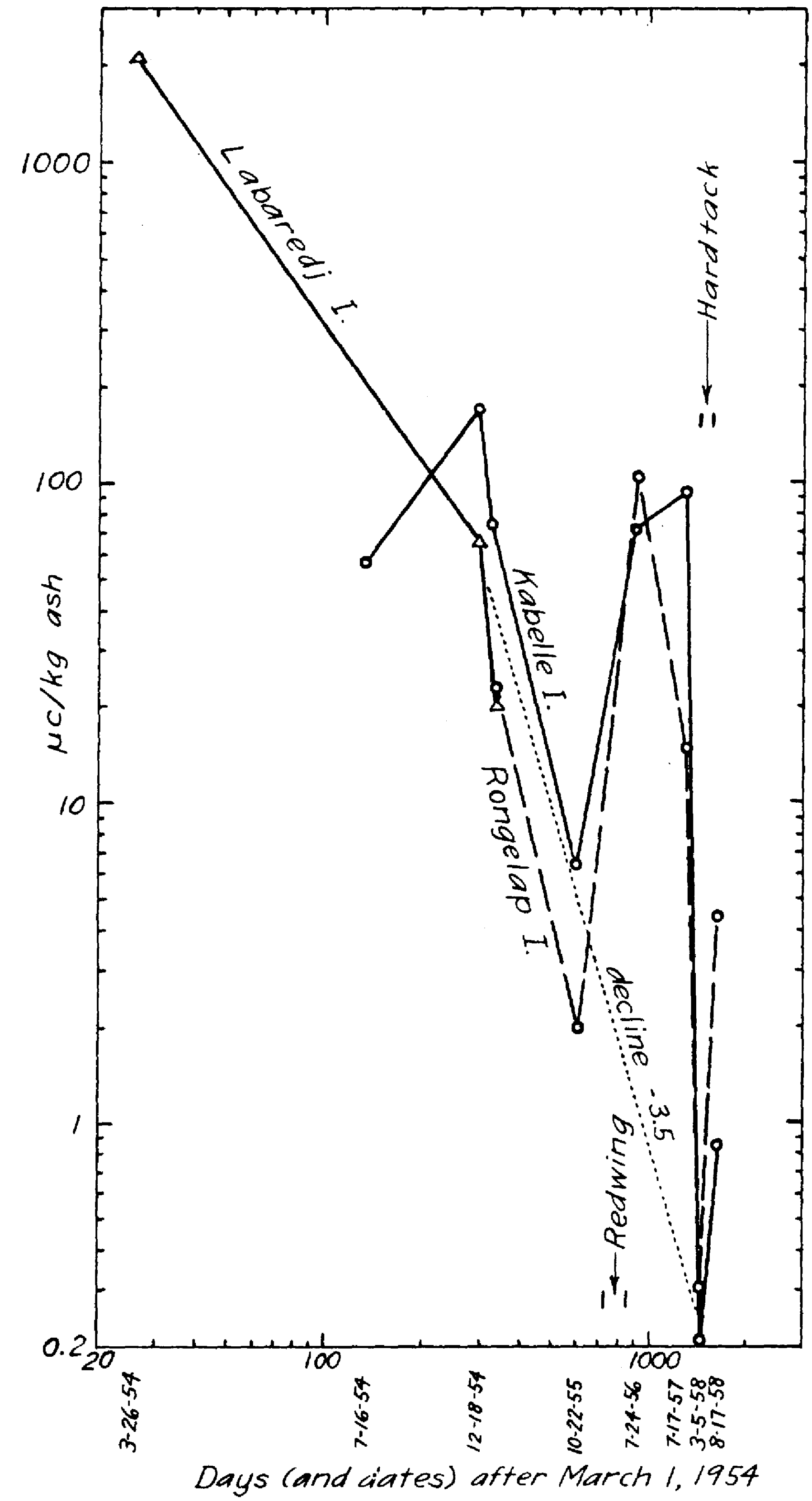


Figure 8. Trends in beta radioactivity of plankton in the eastern part of Rongelap Lagoon from 1954 to 1958.

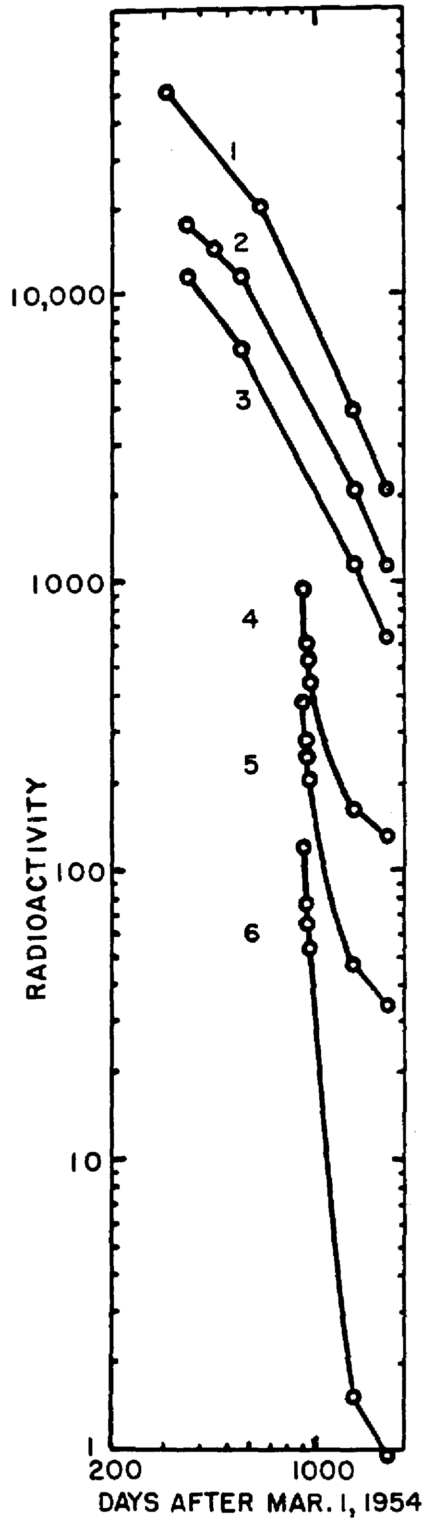


Figure 9. Radioactive decay patterns of plankton samples from Rongelap Lagoon.

1. Plate 19020, Labaredj, 12/18/54
2. Plate 19029, Kabelle, 1/29/55
3. Plate 19025, Rongelap, 1/26/55
4. Plate 6079, Kabelle, 7/24/56
5. Plate 6076, Rongelap, 7/23/56
6. Plate 6077, Rongelap, 7/23/56

axis apply only to each curve separately, and do not permit comparison of absolute radioactivity between curves. The date of reference is taken as March 1, 1954,because the detonation of this date is believed to have contributed many times as much radioactivity to the atoll as did succeeding series. Curves 1-3 (Fig. 9) represent the radio-decay of samples collected 10-11 months after March 1, 1954, while curves 4-6 pertain to samples collected shortly after the Redwing series. The two groups differ in both steepness and direction of curvature. The first group, curves 1-3, decayed with a log-log slope of -1.3 to -1.4 which agrees with the slopes of the remarkably straight decay curves over almost the same period of time for the plankton samples from Eniwetok Atoll (UWFL-53:21). However, the decay curves for plankton from Rongelap Atoll differ from those of Eniwetok Atoll in having a downward flexure. In fact, curve 2 displays up to the 1,350th day almost a uniform half life of about 310 days, and from days 1,350 to 1,740, a 430-day half life. Curves 1 and 3 deviate only slightly from this pattern, being steeper in the early sections. Gamma spectrometry of the sample of curve 2 on November 6 and December 9, 1957 showed Ce^{144}, of 285-day half life, to be the primary constituent, which is presumably accompanied by small, undetected amounts of longer-lived isotopes, contributing to the 430-day half life after 1,350 days. The second group, curves 4-6, decayed rapidly (slopes -4.1 to -10.8) because of the recent origin (Redwing) of part of the activity, but with a distinct upward flexure indicating the effect of the original fallout from March 1, 1954.

Samples 6076-77 of plankton collected July 1956 from the Rongelap Island vicinity of Rongelap lagoon were more radioactive when first counted one month after collecting than the corresponding sample (6079) from the lagoon near Kabelle Island. One of the Rongelap Island samples (6077) was about 2-1/2 to 9 times more radioactive than the other two samples and decayed most rapidly of those studied. Thus, it was evident that there was a more rapid decay of the radioactivity in plankton from the part of the lagoon near Rongelap Island than occurred near Kabelle Island. This is interpreted as indicating the influence of recent Redwing detonations whose fallout affected the southern more than the northern part of Rongelap Atoll.

Decay of March 1958 samples was negligible during the two months from September to November 1958, while August 1958 samples decayed during the month of November 1958 fairly rapidly, with a half life of about 100 days, thus supporting the assumption that the increased levels were attributable to the Hardtack series of detonations.

The rate of decay of the samples collected in 1954 was less steep than the rate of decline of radioactivity in Rongelap lagoon plankton. In Figure 9 the decay slopes of curves 1 to 3 range from -1.6 to a maximum of -2.4, even in the steep portion from 660 to 1,740 days, while in Figure 8 the decline slope shown by the dotted line is -3.5. Compensating for the additions from the 1956 fallout would only tend to steepen the decline slightly, thus increasing the difference between decay and decline slopes.

The consistent agreement in decay rate between the two plankton samples resulting from paired tows (last column of Table 3) is a phenomenon of special interest. As examples, the pair of samples from Ailinginae on October 23, 1955 had decay slopes of -1.58 and -1.53 while the pair of samples from the same lagoon on the following day had slopes of -1.71 and -1.73; the counts in January 1955 also show nearly equal decay rates for the paired tows. This uniformity in decay rate for paired plankton tows suggests uniformity in radiochemical composition at any one time and locality, but different composition in the plankton at different times or localities.

During the first two years (1954-55) Kabelle Island samples were 2-3 times as radioactive as those from Rongelap Island. The 1956 Redwing series raised the July 1956 values of the Rongelap Island region above those of Kabelle Island, but by July 1957 Rongelap values declined to a level far below Kabelle, only to exceed (although not significantly) Kabelle again in March 1958. By August of 1958 Rongelap was significantly higher than Kabelle. The fallout from the Hardtack series is reflected in the higher levels of activity in August, than in March 1958.

Considering the atoll as a whole, and the three successive test series, the evidence from Figure 8 suggests that the 1956 series contributed to the plankton not more than 1/100 as much radioactivity as the original 1954 fallout, and the 1958 series, not more than 1/20 as much as the 1956 series. It is further concluded that the northern part of Rongelap Atoll received a heavier fallout from the March 1, 1954 detonation at Bikini than did the southern part. In contrast, the relatively slight fallout from later detonations affected the southern more than the northern parts of the atoll, as is evidenced by the higher levels of radioactivity in the plankton of the lagoon at Rongelap Island than at Kabelle Island.

Bottom Samples

Results of beta counting of lagoon bottom samples collected in August 1958 at the stations shown in Figure 7 appear in Table 5 and Figure 10. Sample values ranged from .051 to .28, with a geometric mean of .089 $\mu c/kg$ of ash. Ashing changed wet sample weight by an average factor of 0.47, which included the natural organic matter and the soap. The soap contained 21 per cent ash.

The highest concentrations of activity occurred at Stations 5 and 6, north and west of Eniaetok Island. Analysis of the samples from the anchor at Station 10 showed that the radioactivity was not confined to the top inch or so of the bottom material, but that it penetrated to a

Table 5. Bottom samples, in August 1958 from Rongelap Lagoon plankton collecting stations --collecting, processing, and results of beta counting with methane flow.

Station Number	Date of collection	Locality		Depth in fathoms	Weight in grams: Entire sample including soap, Wet	Weight in grams: Entire sample including soap, Dry	Weight in grams: Portion plated, Ash	µc/kg of ash
1	15	2 mi. N	Enigan Pass	25	11.0	7.69	1.726	.062
2	15	3 mi. N	Pigen Pass	25	6.4	3.82	2.257	.051
3	15	3 mi. N	South Pass	27	7.4	4.64	2.051	.058
4	15	3 mi. N	South Pass	20	12.4	8.28	2.660	.066
5	19	1½ mi. NW	Eniaetok I.	33	7.0	3.42	1.243	.23
6	19	2 mi. W	Enybarbar I.	30	5.4	2.21	1.149	.28
7	19	1 mi. N	Enybarbar I.	23	11.0	7.06	2.710	.070
8	19	1 mi. N	Gogan I.	23	10.4	7.25	2.763	.098
9	19	2 mi. N	Mellu I.	29	6.4	3.72	1.928	.130
10	23	2/3 mi. W	Kabelle I.	11	7.2*	5.20*	1.657	.072
2 feet below Sta. 10	23	" " "	" "	"	7.5*	5.47*	2.206	.052

*Samples taken from anchor; include no soap.

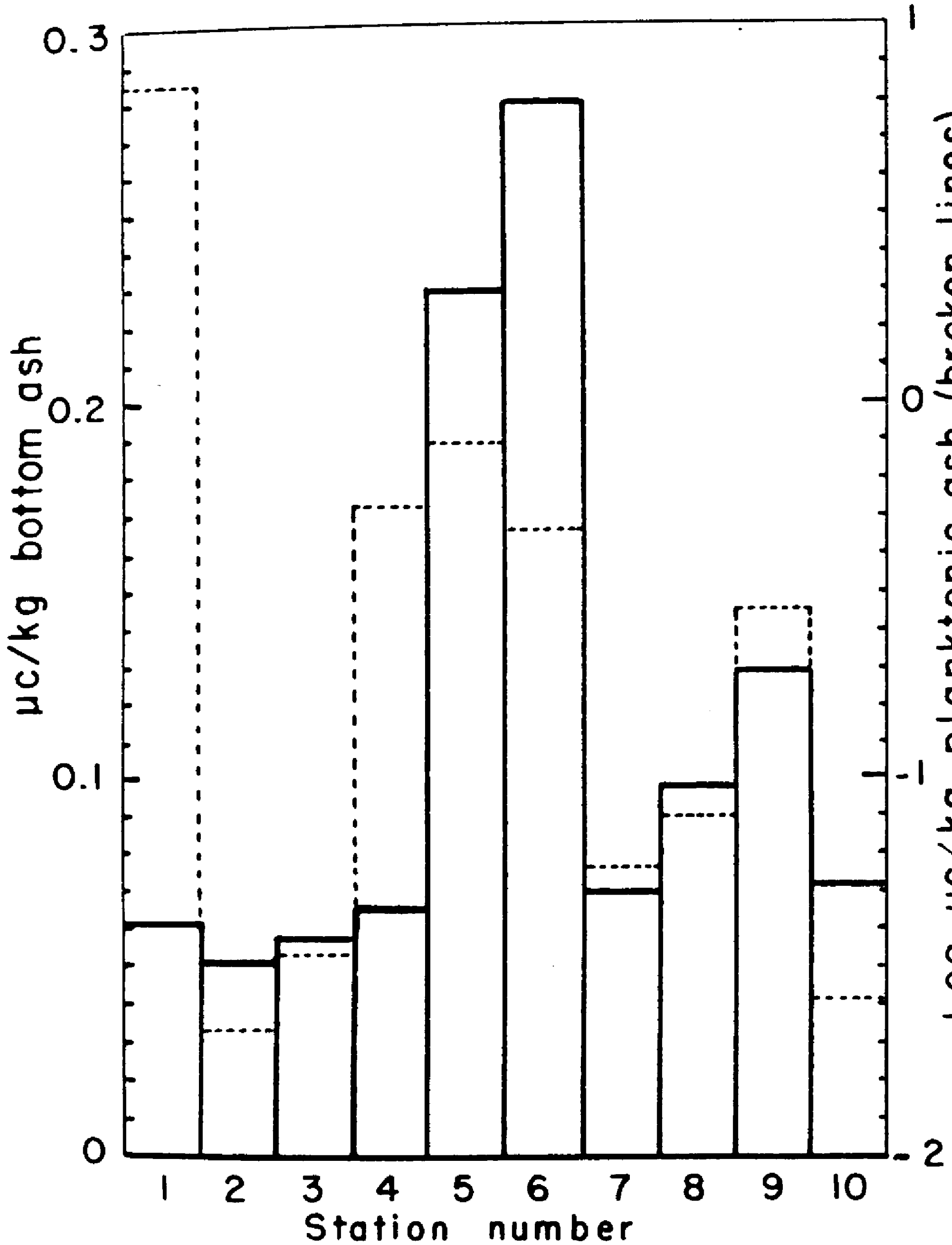


Figure 10. Histogram showing beta radioactivity of ashed samples of bottom material (solid lines) and logarithm of beta radioactivity of pumped plankton (broken lines) from ten stations at Rongelap Atoll in August 1958.

*Samples taken from anchor; include no soap.

depth of at least two feet in only slightly reduced degree.

No information is available on the radioactivity of lagoon bottom material deeper than two feet, but from the slight decrease thus indicated at two feet the activity may be assumed to have penetrated farther, constituting a reservoir estimated to exceed 20, 000 curies of beta activity in the first meter of lagoon bottom in August 1958. This amount may be compared to 54, 000 curies (380/0. 7) estimated (UWFL-43:56) for the top eight inches in 1955.

Comparison of Plankton and Bottom Samples

Plankton values might be expected to correlate with bottom sample values (Fig. 10). In a comparison of activity in August 1958 between pumped plankton and bottom samples at the ten stations, the positive correlation coefficient fell somewhat short of statistical significance, even omitting the first station, at which an exceptionally high plankton value was found. However, values for plankton tows at Stations 3 and 4, 5 and 10 near Rongelap Island, Eniaetok Island, and Kabelle Island were negatively related (non-significantly) to the values for bottom samples at the corresponding localities. Thus, there is no evidence of correlation between radioactivity of plankton and of bottom samples at the same locality.

SUMMARY OF SECTION II

Levels of activity of the plankton for the eastern lagoon were determined nine times in 1954-1958. The first observed level on March 26, 1954, 25 days after the Bravo detonation at Bikini, expressed in microcuries per kilogram of planktonic ash, was about 2,000. By mid-December 1954, it had declined to 50, and by late October 1955, to 6. Fallout from the Redwing series raised the July 1956 levels to approximately 100. In July 1957, levels were still between 15 and 100, but by early March 1958 they had declined to 0.3. Fallout from the Hardtack series raised the August 1958 levels to only 0.8 -4 μc/kg ash, the last observation. The decline rate, disregarding the two peaks following Redwing and Hardtack, but including their later residual effects, was steep, with a slope of -3.5.

From the plankton data for the years 1954-1957, it was shown that results were nearly twice as consistent when based upon ash as upon wet weight, and that there was no significant difference in activity between samples taken with fine-and coarse-meshed nets. On the ash weight basis, the levels of plankton in 1955 at Ailinginae Atoll were no higher than at Rongelap Atoll, whereas they were higher on the wet weight basis. Decay slopes of pre-Redwing plankton ranged from -1.6 to -2.4, while the decline slope for the plankton of the lagoon as a whole over this period was -3.5, so that the decline was more rapid than the decay.

Lagoon bottom samples from ten stations in August 1958, ranged from a minimum of 0.051 $\mu c/kg$ of ash near the south edge of the atoll, to a maximum of 0.28 $\mu c/kg$ near Eniaetok Island. Total beta activity in the upper meter of lagoon bottom was estimated to exceed 20,000 curies in August 1958. Activities in plankton and in bottom samples were not significantly correlated.

SECTION III

FURTHER CONTRIBUTIONS ON GROSS BETA RADIOACTIVITY OF FISHES AT RONGELAP ATOLL 1954 THROUGH MARCH 1958

This report extends the observations on Rongelap fishes beyond that of Welander (UWFL-55), up to the fall of 1958 and shows the trends on a log-log, rather than a semi-log basis. Methane-flow counters were used as described in UWFL-43:7 except for the August 1958 samples (Eisler, Held, and Joyner, in preparation) which were counted with flat, Anton 2-inch end-window tubes, using self-absorption correction factors for K^{40}.

Results, starting with the first fish collections at Rongelap Atoll in 1954, appear in Table 6 and Figures 11 and 12, showing separately liver, bone, and muscle of fishes at Kabelle and Rongelap Islands, and in Rongelap lagoon, chiefly in the vicinity of Rongelap Island. Data are most plentiful for Kabelle Island where four full years are represented, while at the other localities observations were not begun until nearly a year after the detonation of March 1, 1954 at Bikini Atoll.

The rate of decline of beta radioactivity in fish at Kabelle Island is shown in Figure 11 where the slopes of the dashed regression lines for liver, bone, and muscle were, respectively, -1.75, -1.46, and -1.24. For reef fish liver at Rongelap Island, Figure 12 shows a

Table 6. Gross beta radioactivity in μc/kg wet tissue of fishes from Rongelap Atoll, 1954 through August 1958.

Locality	Date	Days after 3-1-54	Muscle	Liver	Bone
Kabelle I.	3/26/54	25	2.7	200	13
Reef fish	7/16/54	146	.5	22	2.9
	1/29/55	335	.083	3.2	.49
	10/21/55	600	.026	1.6	.12
	7/24/56	877	.045	1.35	.36
	7/18/57	1236	.028	.18	.074
	3/3-10/58	1470	.026	.22	.048
	8/58	1630	.0085	.13	.016
Rongelap I.	1/25/55	331	.034	2.0	.30
Reef fish	10/22/55	601	.009	.60	.070
	7/23/56	876	.097	1.34	.45
	7/17/57	1235	.020	.29	.021
	3/7/58	1468	.0062	.054	.017
	8/58	1630	.0046	.098	.010
Lagoon fish	12/54 and 1/55	307	.081	2.1	.28
	10/22-24/55	602	.014	.31	--
	2/28-3/2/58	1460	.015	.077	.023
	8/58	1630	.0056	.113	.0071

of fishes
st 1958.

	Bone
	13
	2.9
	.49
	.12
	.36
	.074
	.048
	.016
	.30
	.070
	.45
	.021
4	.017
8	.010
	.28
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	.023
	.0071

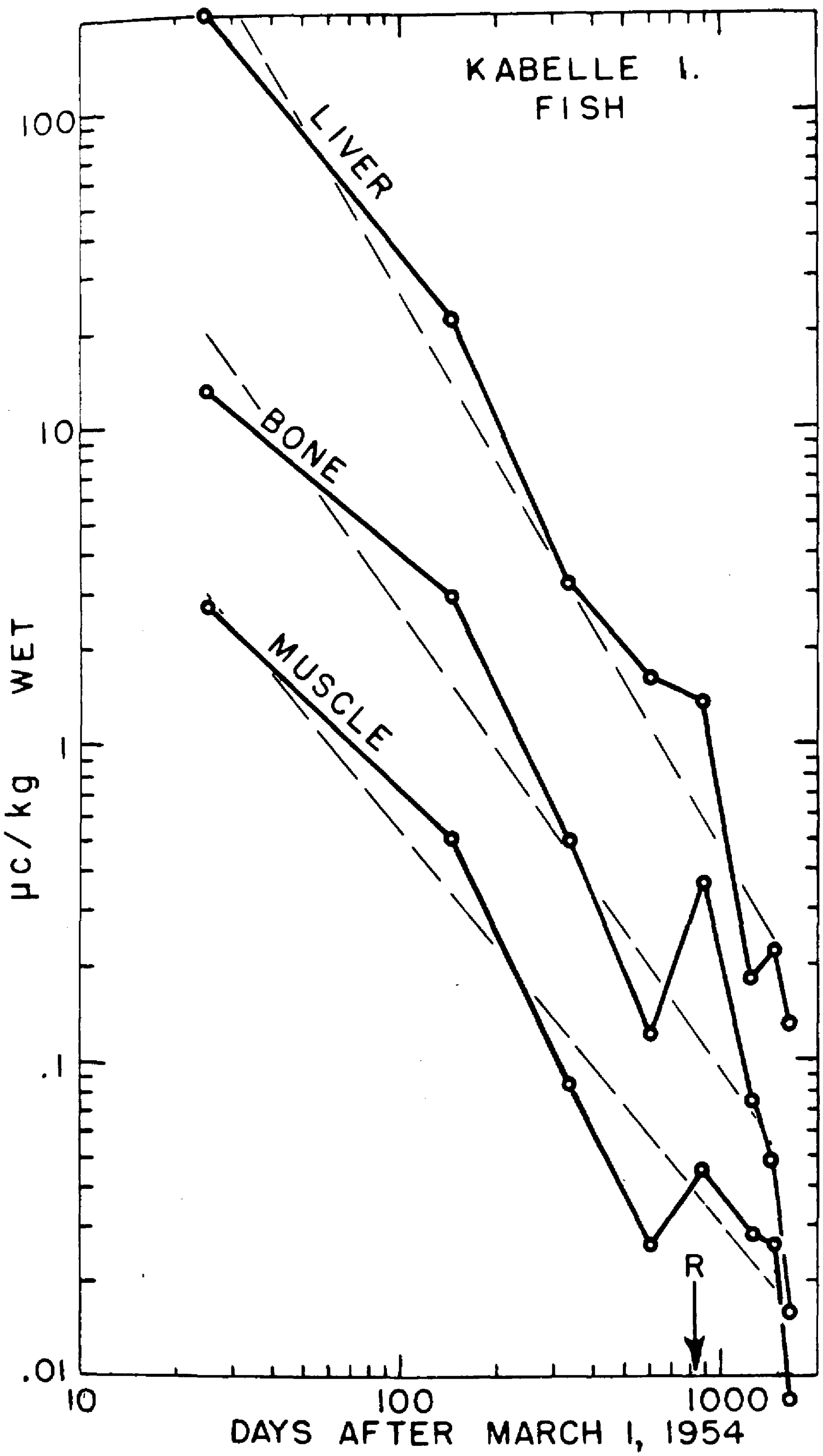

Fig. 11. Decline of gross beta radioactivity in reef fishes at Kabelle I. Dashed lines are calculated regressions; "R" indicates Redwing series.

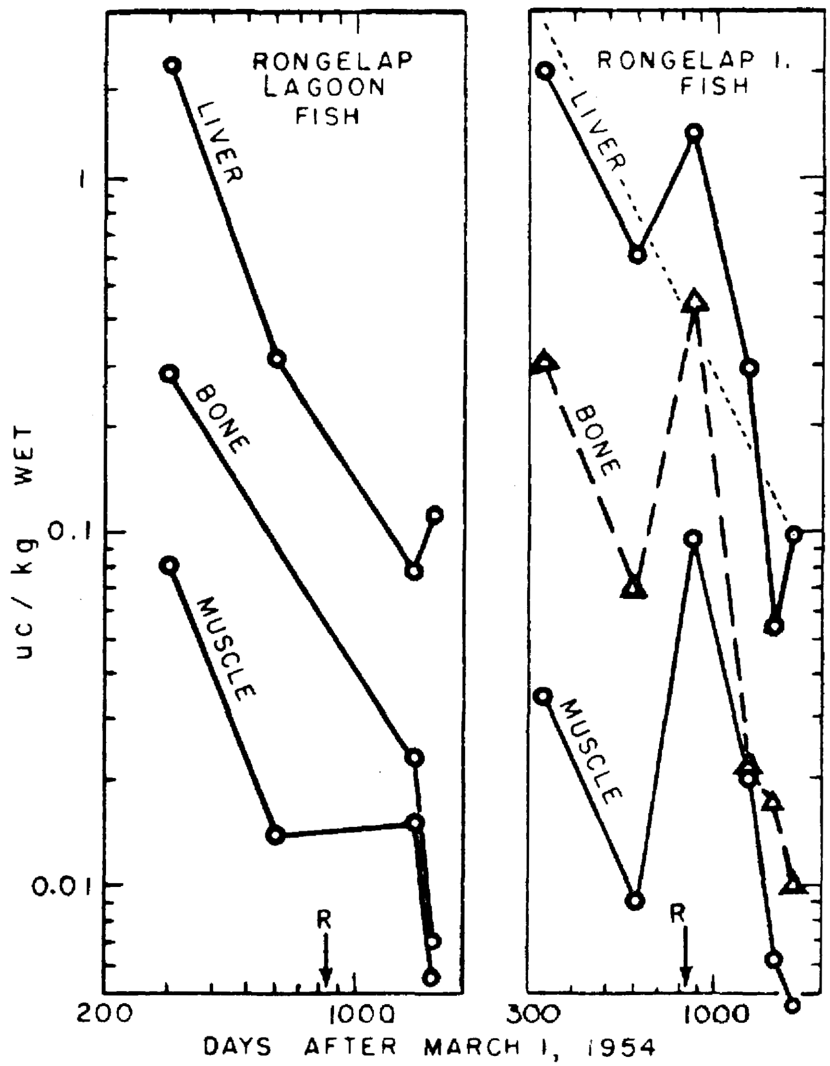

Fig.12. Decline of gross beta radioactivity in lagoon-pelagic fishes (left graphs) and in reef fishes (right graphs) near Rongelap I. Dotted line is calculated regression; "R" indicates Redwing series.

decline to which a significant regression line can be fitted with a slope of -2.02 (dotted line).

In conclusion, gross beta levels of fish at Rongelap Atoll in the fall of 1958 were only slightly higher at Kabelle Island than in the vicinity of Rongelap Island. For the areas of the lagoon sampled, these levels were (expressed in $\mu c/kg$ wet tissue): muscle, 0.005-0.008; bone, 0.008-0.016, and liver, 0.10-0.13. Rates of decline ranged from -1.2 for muscle to -2.0 for liver.

In the absence of further contamination from fallout, and at the rates of decline shown in Figure 11, fish muscle at Rongelap Atoll may be expected to decline from its present low level of less than 0.01 $\mu c/kg$ wet to about 0.002 $\mu c/kg$ wet, within 20 years. The latter figure is approximately the level due to naturally occurring K^{40} in tuna muscle.

Due to its predominant gamma content and low beta energy the disintegrations from Zn^{65} may be detected by beta counting to only a slight extent--anywhere from about 1 to 10 per cent of their actual intensity. However, since its 245-day half life allows Zn^{65} to decay to about 1.5 per cent in 4 years, and to 0.024 per cent or 1/4000 in 8 years, Zn^{65} could be ignored after a few years.

The almost complete absence of Cs^{137} or other long-lived isotopes in fish muscle as reported by Welander (UWFL-55:15) suggests that flattening of these decline curves probably will not occur before the background levels due to K^{40} are reached.

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