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LAND CRABS AND RADIOACTIVE FALLOUT AT ENIWETOK ATOLL

By
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May 27, 1957

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ABSTRACT

The pattern of changing levels of radioactivity is given for the tissues of land hermit crabs, Coenobita perlatus, from Belle Island, Eniwetok Atoll, during a period of nearly two years following the 1954 series of atomic tests. Sr^{90} + Y^{90}, and Cs^{137} were the principal long-lived fission products found. Sr^{90} levels in the skeleton remained constant throughout the period of study.

ACKNOWLEDGMENTS

The wholehearted cooperation of all members of the staff of the Applied Fisheries Laboratory, who at various times participated in the collection and preparation of samples, made this report possible. Miss Dorothy J. South supplied the results of the radiocesium, radiocerium, and some radiostrontium determinations. The cooperation of the U. S. Atomic Energy Commission Division of Biology and Medicine and the Eniwetok Field Office, Task Group 7.1, and Holmes and Narver greatly facilitated the field collecting.

CONTENTS

LAND CRABS AND RADIOACTIVE FALLOUT AT ENIWETOK ATOLL

Introduction

Periodic studies of the effects of the atomic testing program on the biota of the Marshall Islands have been made by the staff of the Applied Fisheries Laboratory, University of Washington, since 1946.[1-13] During the 1954 testing program at Eniwetok a continuous biological survey was initiated. In this report the portion of the survey concerned with the uptake of radionuclides by the land hermit crab, Coenobita perlatus Edw. T.*, is presented. Results of possible ecological and physiological significance in the movement of strontium and cesium through the food cycle have been obtained. Strontium-90 concentration in the land crab skeleton may be a sensitive index of biologically available radiostrontium in the environment.

Coenobita is an omnivorous scavenger which feeds primarily on land plants and on detritus washed up on the beaches. It is primarily nocturnal and spends the daylight hours hidden in shrubs or under debris.

The crabs were taken from Belle (Bogombogo) Island which lies 2.3 nautical miles southwest of the site of the Mike test of 1952 and the Nectar test of 1954. This island is downwind from the site of these tests.

Prior to the Mike test Belle Island had a covering of shrubs,

* We are grateful to Dr. C.H. Edmondson, Bernice P. Bishop Museum, Honolulu, Hawaii, for identification of the species.

coconut palms and trees.[14] The island was denuded by the blast in November 1952, but by April 1954 had regained a heavy growth of shrubs, principally Scaevola frutescens and Messerschmidia argentea. The regrowth was from seedlings and stumps of old plants. A rookery of fairy and noddy terns had also become established. Belle Island was again denuded by the Nectar test of May 1954 save for stumps and some stripped branches. Dead birds and fish were found in the center of the island as well as along the shores. One dead Coenobita was found, but almost all of a population of about 50 in one pile of debris survived, probably because of the protection of the debris and their habit of quickly withdrawing into their shell when disturbed. It is probable that they withdrew at the first flash of light before the blast reached them.

Belle Island regained a lush cover of shrubs by August of 1954, less than three months after the Nectar test, and a fairy tern egg found three months later, in late November, marked the beginning of a new rookery on the island.

Methods

Collections were made at approximately daily intervals commencing with the third day following Nectar until the ninth day. Thereafter, the interval between collections was progressively lengthened to approximately monthly intervals. Three crabs were taken at each collection except that in three instances five, and in one instance, only two were taken.

Samples of carapace (exoskeleton), muscle, hepatopancreas ("liver"), gut with its content, and gill were removed, either from the fresh or frozen specimens, at the Eniwetok Marine Biological Laboratory. The tissues were weighed at the time of dissection and then dried. The packaged dried samples, together with data cards, were sent by air mail to the Applied Fisheries Laboratory, University of Washington, for further processing.

There the dried samples were ashed at temperatures up to 550°C on stainless steel counting plates and then counted in an internal gas-flow counting chamber. The counts per plate were converted to disintegrations per minute per gram (d/m/g) of wet tissue, as of the date of collection, by correcting for sample weight, geometry, backscatter, self-absorption, coincidence and decay. (See WT-616 (UWFL-33) for a more complete discussion of these procedures.)

The decay corrections for all tissues except carapace were based on the decay rate of a soil sample collected at Belle Island the day after the Nectar shot. Decay corrections for the carapace were based on the decay rate of Sr^{90}+Y^{90} and Sr^{89}, which constituted virtually 100 per cent of its activity at the time the chemical determinations were made. The decay correction factors ranged from 1.09 to 12.7.

The variation in amount of radioactivity for each tissue at each collection date, although great, (Appendix Table 1) was not great enough to obscure general trends in changes of radioactivity with time or differences in levels of radioactivity between tissues.

The term "activity" as used here means radioactivity per unit weight.

"Rate of decline" refers to the rate at which radioactivity is decreasing in a given tissue, organ, or organism in its native environment.

Levels of activity in the crab tissues three days after the Nectar test ranged from 5×10^6 d/m/g in the gut to 7×10^4 d/m/g in the muscle (Figs. 1 and 2). The rate of decline of activity decreased with time and was different for each tissue, but in general followed the same trend as the decay of mixed fission products during the first 200 days. Thereafter the rate of decline for each of the crab tissues approached a constant value with a half life in excess of 20 years.

This half life is dependent on factors which include relative abundance and availability of radionuclides in the food and/or environment, rate of decay of radionuclides absorbed, biological half life and selective uptake of radionuclides. Each of these, except the rate of physical decay, is in turn dependent on varying environmental and physiological conditions. The terms "ecological half life of radioactivity," or more briefly, "ecological half life" and "rate of decline" will be used to include these factors. Ecological half life will be used as the time required for an organism, or its tissues or organs, in its native environment to lose 50 per cent of its radioactivity. When the ecological half life and physical half life are equivalent (rate of decline = rate of decay), the tissue in question must be at equilibrium with respect to the radioisotopes it contains. For single isotopes an ecological half life greater than the physical half life (rate of decline $<$ rate of decay) indicates accumulation

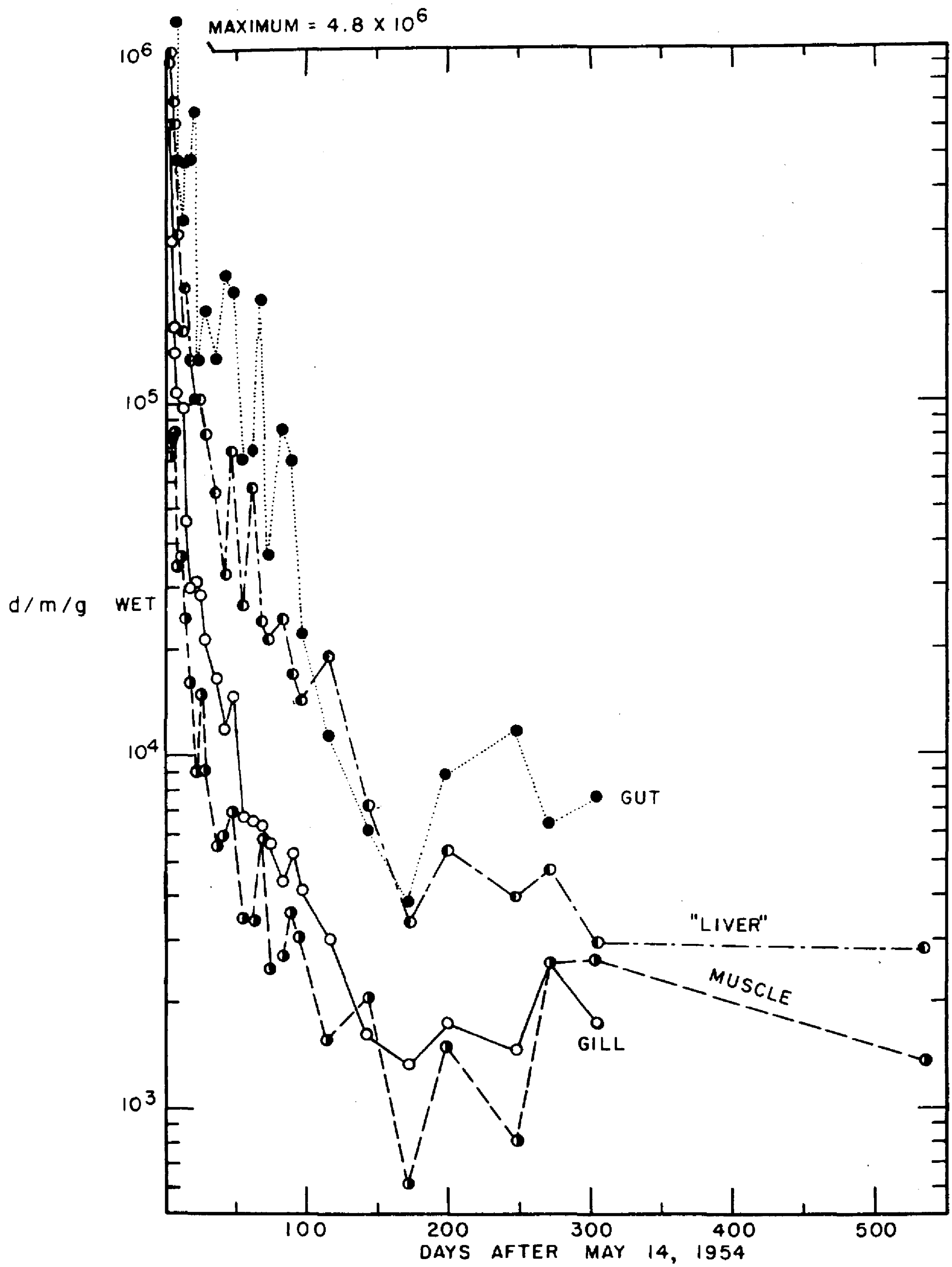

Fig. 1. Beta-activity in Coenobita gill, muscle, hepatopancreas ("liver") and gut on successive collection dates. Values in disintegrations per minute per gram wet weight.

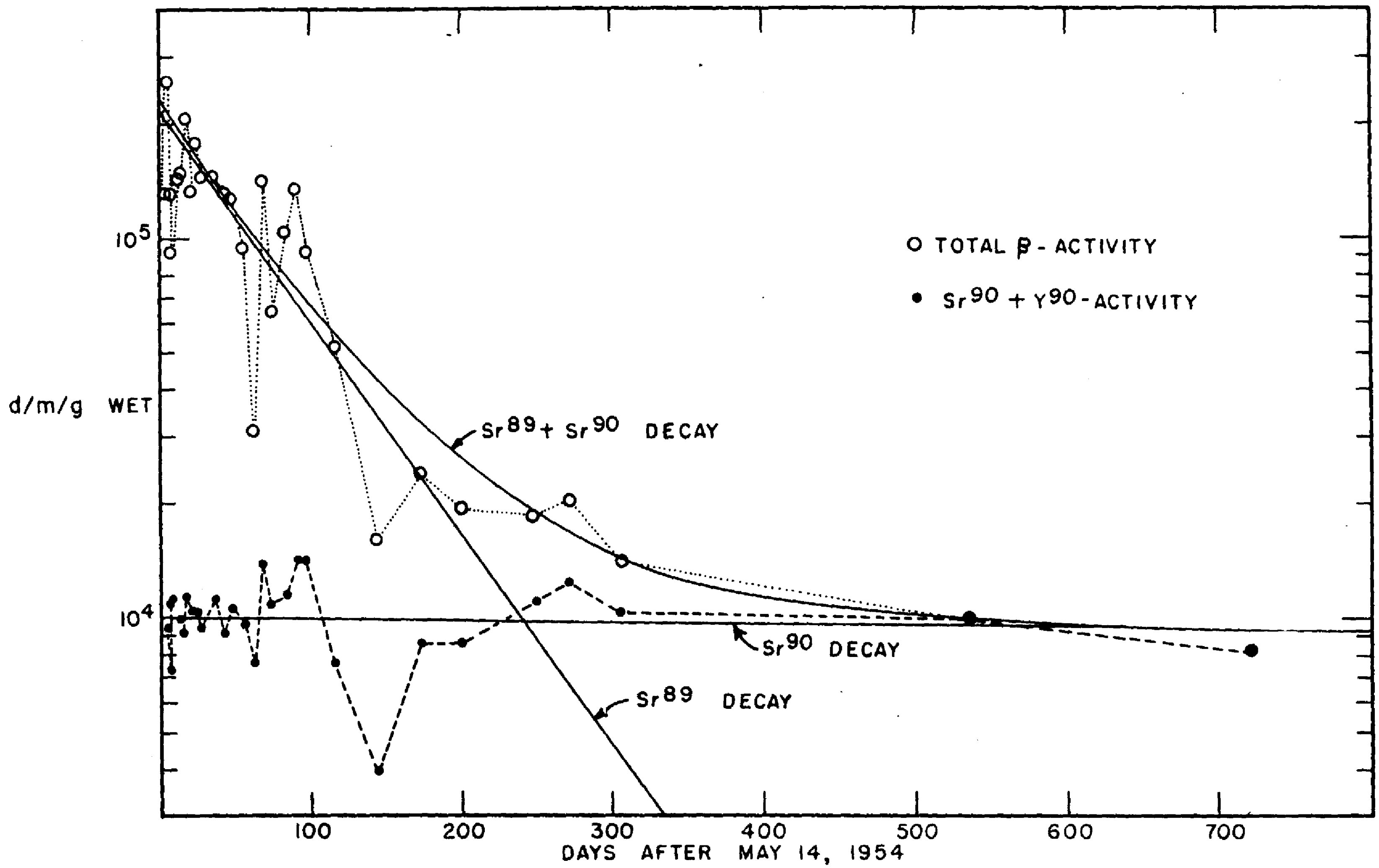

Fig. 2. Radioactivity in Coenobita carapace on successive collection dates compared with the decay of radiostrontium. Values in disintegrations per minute per gram wet weight.

of the isotope. In the converse situation where the ecological half life is less than the physical half life, a net loss of the isotope is indicated. This condition could result from loss of the isotope by the environment, or eco-system, or from a physiological change in the organism or its primary food source. Such physiological changes may be transitory or seasonal.

The increase in radioactivity over preshot levels during the first few days after the Nectar test was less in muscle and carapace than in the four other tissues by a factor of 5 to 10. Maximum post-Nectar levels of activity were 100 to 250 times greater than pre-Nectar levels in gut, liver, and gill, but only 22 and 26 times greater in muscle and carapace respectively. The lower rate of accumulation in muscle and carapace would be expected since the material must be absorbed from the gut and hepatopancreas where some selection takes place. The specific patterns of changing radioactive content of the tissues with.time, rate of decline, will be presented individually for each tissue.

The amounts of radioisotopes involved are so small that they probably do not constitute a significant proportion of the naturally occurring isotopes. If, for example, a tissue contained 10^7 d/m/g wet of Sr^{90}, or 5,000 times the maximum level found in the hermit crab, this would represent only 0.02 mg of strontium, or about 10^{-5} per cent of the ash weight. The presence of strontium has been reported qualitatively in crustacea and a quantitative estimate of about one per cent strontium has been given for the ash of Eupagurus bernhardus.[15]

Results

Exoskeleton

The carapace was taken as the sample of exoskeleton. It is easily removed, separated from other tissues and washed free of possible external contamination.

The radioactivity in the carapace due to long-lived isotopes remained approximately constant throughout the period of 537 days during which collections were made. This was determined by re-counting all of the samples approximately 600 days after the Nectar test (Figs. 2 and 3).

Radiochemical analysis of 18 samples taken at various times during the collecting period (Table 1 and Appendix Table 2), and three samples taken 35 days before Nectar demonstrated that virtually all of the long-lived activity was 20-year Sr^{90} and its Y^{90} daughter.

The nearly constant level in the carapace (ecological half life $\cong$ physical decay) indicates that this tissue quickly reaches and maintains equilibrium with the available strontium. Gross, Taylor and Watson (1954) report a plateau of retention of Sr^{90} in rats during continuous feeding at the same rate, and apparent shifting of the plateau with change in daily dose.[16]

It would be expected that this relationship also applies to available calcium which is metabolically similar to strontium, and to 54-day Sr^{89}, and possibly Ba^{140}, which at the time the radiochemical analyses were made was present in amounts too small ($<0.2\%$ of total activity [17]) to be determined by the method used.

The amount of Sr^{89} present in the carapace immediately after Nectar was calculated from the yields given by Sullivan [18] on the

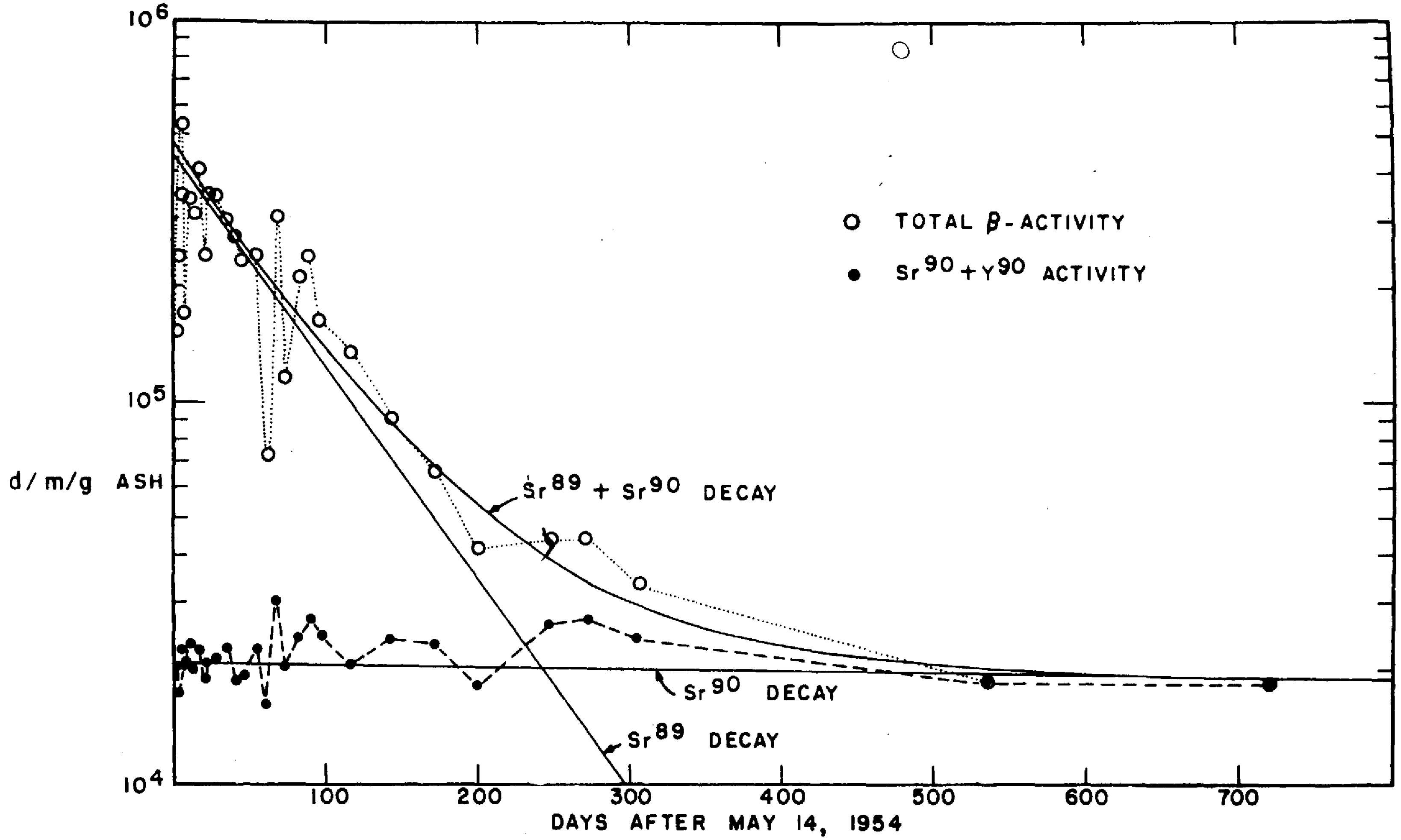

Fig. 3. Radioactivity in Coenobita carapace on successive collection dates compared with the decay of radiostrontium. Values in disintegrations per minute per gram of ash.

Table 1. Total β-activity and Sr^{90}+ Y^{90} in Coenobita Carapace

Determinations made in January and February, 1956. Averages of three samples and their standard errors are given.

Date collected	Total β-activity Jan.-Feb., 1956 d/m/g wet	Sr^{90}+ Y^{90} activity Feb. 1956 d/m/g wet
4/15/54	6900 ± 672	7454 ± 952
5/26/54	10243 ± 968	9763 ± 975
8/12/54 or 8/19/54	14851 ± 1413	15568 ± 1237
10/5/54	4362 ± 431	4043 ± 385
3/15/55	10368 ± 581	11281 ± 479
2/9/55	12516 ± 1594	12532 ± 1484*

* Average of duplicate aliquots of three pooled samples as determined by Dorothy J. South, Applied Fisheries Laboratory.

basis of the average amount of Sr^{90} in the 44 specimens collected during the first 50 days following Nectar, less the amount present before Nectar. The relative radioactivity of the two isotopes was calculated from their specific activities. A theoretical decay curve was then calculated for the combined Sr^{89}, Sr^{90}+ Y^{90} contributed by the Nectar test and the Sr^{90}+ Y^{90} residual from prior tests. Figures 4 and 5 show the actual values superimposed on this theoretical curve. Although there were no specific radiochemical determinations early in the period following Nectar it is reasonable to assume that the exoskeleton has a high degree of selectivity for strontium and that equilibrium must be reached within a few days at most. The assumptions are further supported by decay curves which approach the theoretical curve (Fig. 4).

The relatively low levels of activity at 145 days post-Nectar are a reflection of a change in ratio of ash weight to wet weight; Figure 4 represents the data on an ash weight basis. The change in ratio may be associated with molting, but observations were not made at frequent enough intervals to confirm or deny such an association.

Contributions of radiostrontium to the crab skeleton at Belle Island from past tests at Eniwetok and Bikini are represented in Figure 5. The pre-Mike level is an approximation since it is based on a single specimen and there was, unfortunately, no biological survey during the 1950 tests. The pre-Nectar curves were derived by the method outlined above. The Mike test contributed about twice as much activity as the Nectar test; fallout from

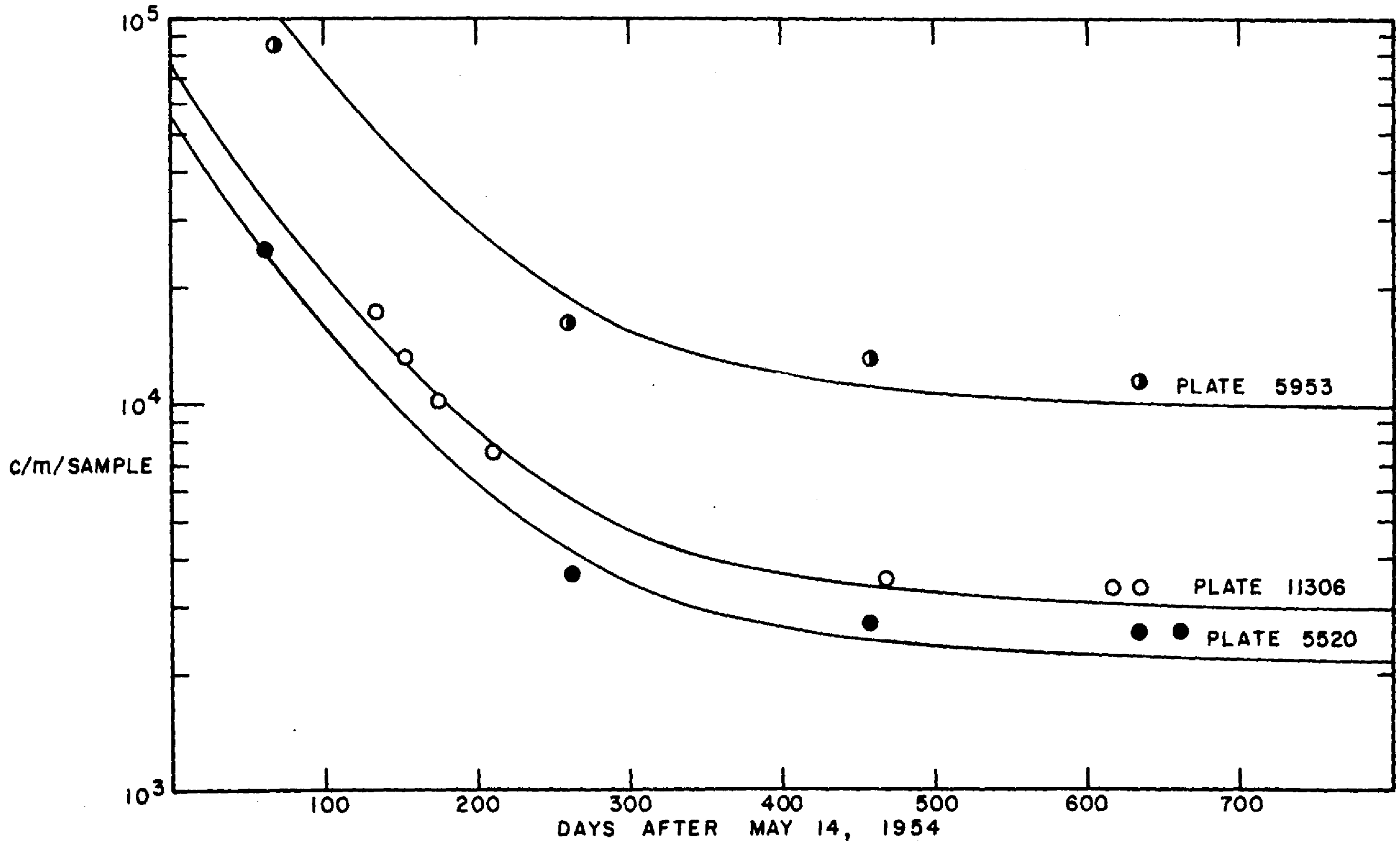

Fig. 4. Decay of beta-activity in three Coenobita carapace samples, each compared with the theoretical decay curve (solid lines) for $Sr^{89} + Sr^{90}$ from Figures 2 and 3.

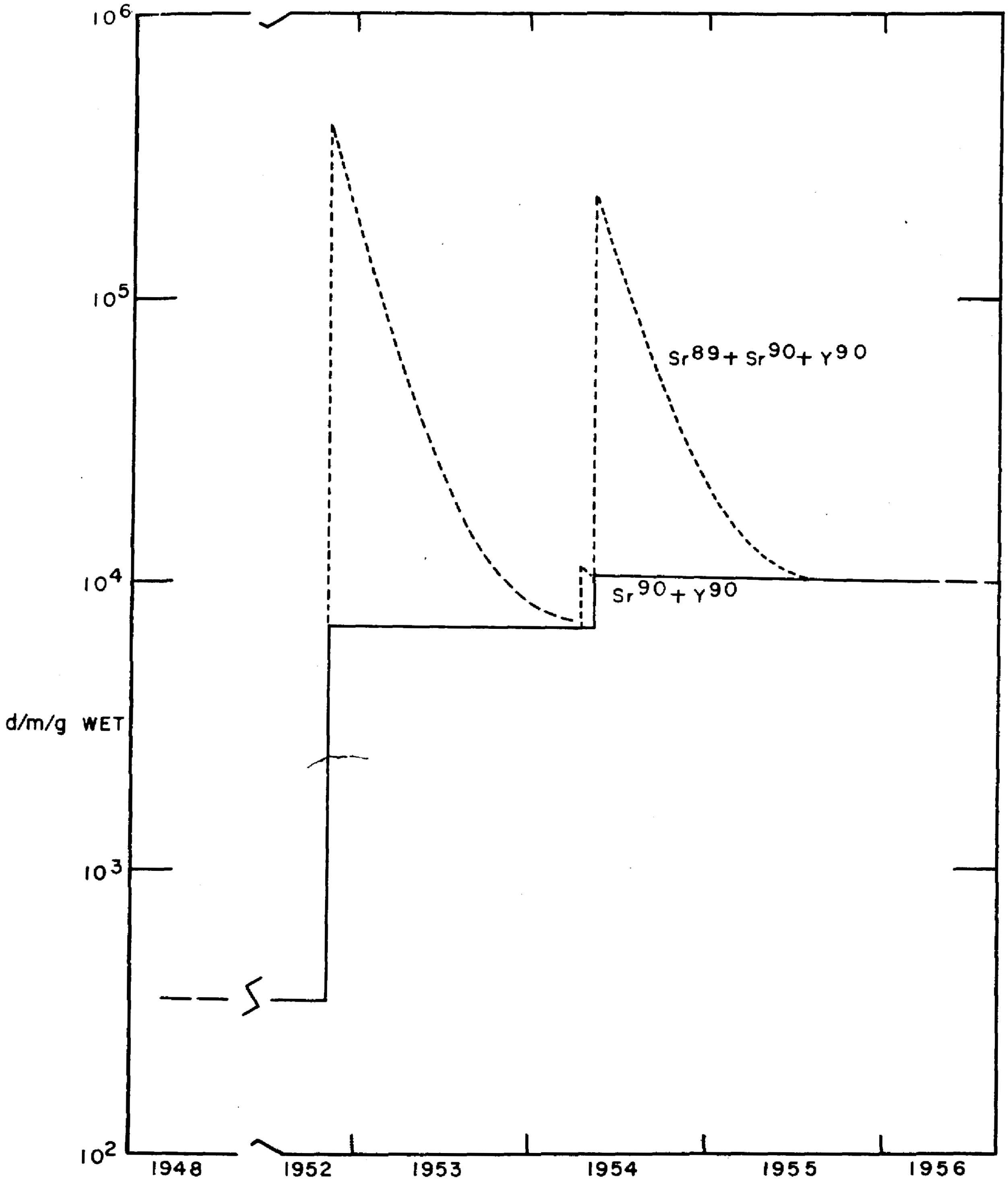

Fig. 5. Radiostrontium in Coenobita skeletons at Belle Island.

the pre-Mike tests and the Bikini tests of 1954 together contri uted about 5 per cent of the total Sr^{90} activity.

Sr^{90} on the island is being maintained at an essentially constant level (decreasing only with physical decay), if the om vorous hermit crab can be considered an accurate index of biolo cally available strontium. However, the ratio of the strontiu in the crab skeleton to that in food items is not known. Judgin from the meager data presently available, the radiostrontium con tent of the crab skeleton is more than ten times that in land plants on a wet weight basis and is more than three times that in soil on a dry weight basis.

Muscle

Isotopes with half lives greater than 20 years contributed nearly all of the activity in muscle tissue 35 days before the Nectar test. Cs^{137}, Sr^{90}+ Y^{90}, and Ce^{144}+Pr^{144} accounted for 84, 10 and 1 per cent respectively, of the total activity in muscle tissue collected in February and November, 1955, and analyzed in January and March, 1956. Similar levels, 67, 10, and 1 per cent, were found in coconut crab muscle from Rongelap Atoll (UWFL-43, Table 14). In contrast to the exoskeleton, muscle tissue had a variable, though generally decreasing, level of long-lived isotopes throughout the post-Nectar collecting period (Fig. 6). Between 150 and 200 days post-Nectar, the total activity in muscle was due primarily to the long-lived isotopes as evidenced by the increased ecological half life. The level of total activity in muscle at 172 days (after Nectar) is one-sixth the pretest level, while the level of long-lived isotopes at that

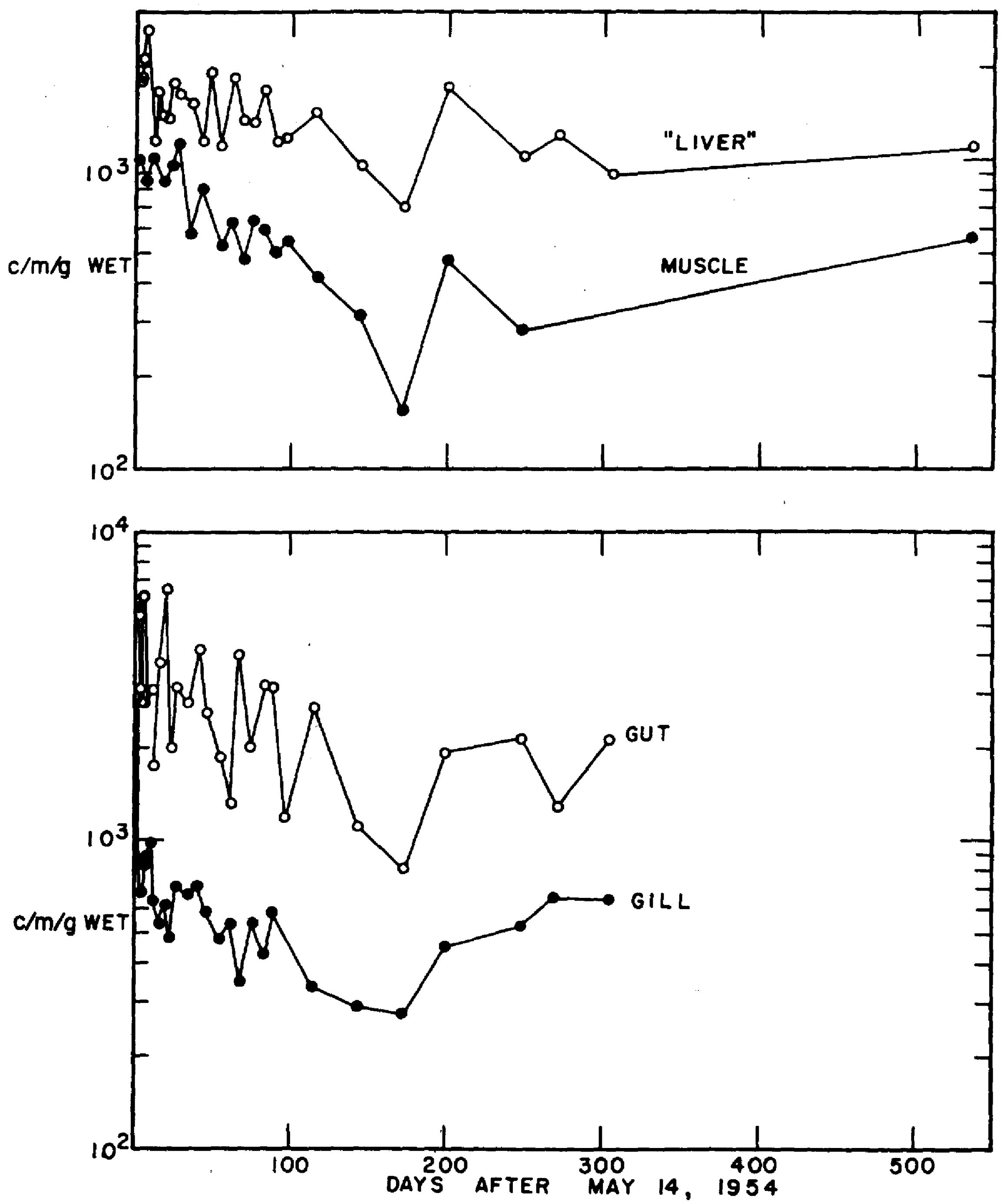

Fig. 6. Counts per minute per gram in Coenobita tissues as of 600 days after May 14, 1954, plotted for each collection date.

time is one-eighth that of the pretest level; subsequently there is an increase in activity. Since both the total activity and the long-lived activity increased by approximately equivalent amounts, the increase must be due to an increased net rate of uptake, reflecting a change in the physiology of the crab or a change in the conditions in the environment, leading to a greater availability of, in this case, Cs^{137} to the crab. The latter possibility is the more easily explained by the observations.

The same pattern of decrease in activity followed by a rise is evident in the gut and liver of the crab, the leaves of the shrubs, Scaevola and Messerschmidia, and the muscle of the field rat, Rattus exulans, from Janet (Engebi) Island, which is also in the northern part of Eniwetok Atoll.[19] During the first 200 days (May - November, 1954) rainfall at Eniwetok averaged about 4 inches per month while for the following 150 days (December - April) the average monthly rainfall was about 0.3 inches (Fig.7). Since individual variation in the level of activity is great there would be little reason to accept the validity of the correlation were it not repeated in the plants and in rat muscle, which are also high in Cs^{137} content, (56% of the total activity in the latter). It appears likely, therefore, that the changes in activity in the crab and rat muscle reflect some underlying mechanism associated with rainfall which is responsible for changes in the levels of activity in the plants.

There could be one or several factors involved in the association with rainfall including, for example, such things as

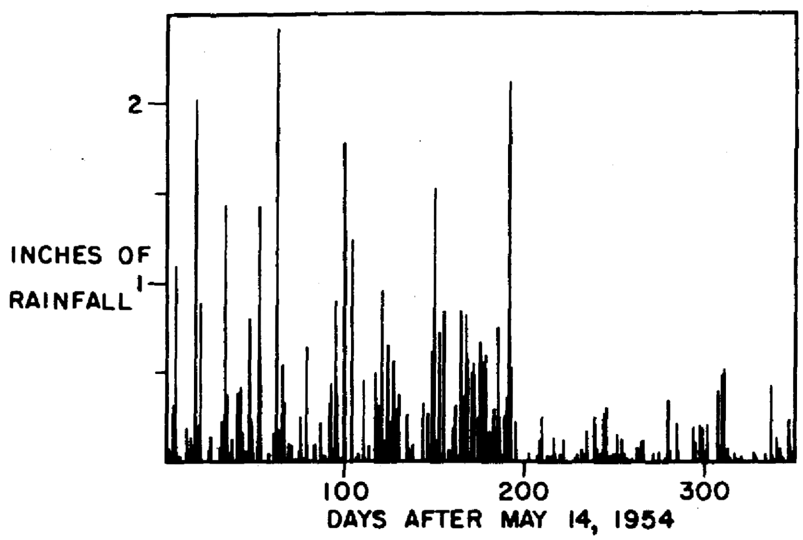

Fig. 7. Rainfall at Eniwetok Island (from records of Detachment 2, 57th Strategic Reconnaissance Squadron, Medium, Weather, USAF).

exchangeability of cesium, total amount of root surface available during the wet as compared with the dry season, and increasing acidity of the soil on drying.[20] More complete series of radiochemical determinations of the radioisotopes in both plants and soils are needed to understand the mechanisms involved. Contrary to results reported on relative availability of cesium and strontium to plants in other soils, cesium appears to be more readily available than strontium in the atoll island soil.[21-25]

The short half-life isotopes that contributed to the activity in the muscle during the first 150 days are not known. The rate of decline during this period was approximately the same as the rate of decay for mixed fission products.

Radiocesium content of hermit crab muscle is about 1.5 times that in plants (1,000 d/m/g : 700 d/m/g) on a wet weight basis. The radiocerium levels in the soil were too low ($< 1\%$ of the total activity) to be detected by the radiochemical methods used.

<u>Hepatopancreas ("liver")</u>

The rate of decline of activity of the hepatopancreas or "liver" of the crab during the first 175 days post-Nectar is not significantly different from the rate of decay of mixed fission products. This is true despite the fact that there was a pre-existing level of long-lived activity approximately equal to the level existing 537 days post-Nectar. Sr^{90}, Cs^{137}, and Ce^{144} were found.

Equilibrium must be quickly reached and maintained at a constant level proportional to the availability of the long-lived isotopes. Levels of activity were 8,500 d/m/g pre-Nectar, reached a maximum of 10^6 d/m/g four days post-Nectar, and declined to a level of 3,000 d/m/g at 305 days and 537 days (Fig. 1).

Gut with content

The hermit crab gut with its content was generally more variable than liver in levels of activity, particularly during the first month post-Nectar. This difference is to be expected since digested food would have variable amounts of surface contamination and not all crabs would feed on the same thing at any one time.

Initially, following the Nectar test, the gut had the highest level of activity of all tissues (5×10^6 d/m/g). The activity in the gut also had the shortest ecological half life of all tissues during the first 100 days post-Nectar. By 100 days, the levels of activity in gut and liver approached each other and their ecological half lives were about the same, although the gut remains so variable from collection to collection that only an approximation can be made. The activity in the carapace by 100 days was higher than that in the gut even though the latter had the highest initial activity. This variation is, of course, due to the different rates of decline, which reflect selection of the long-lived isotope Sr^{90} by the carapace.

No chemical analyses of gut samples were made.

Gill

The rate of decline of activity of the gill of the crab is more rapid than the rate of decay of mixed fission products during the first 10 to 20 days post-Nectar, but thereafter approximates the same rate until the 200th day. The early high levels may be due to contamination of the surface of the gills and possibly to excretion of salts through the gills. From the tenth day on, the pattern of decline of the gill is the same as that of muscle The activity level was generally higher in the gill than in the muscle by less than a factor of two on a wet weight basis.

No chemical analyses of gill tissue were made.

Discussion

During the first 150 days following a nuclear detonation the rate of decline of radioactivity in organisms on atoll islands may be considered to approximate the rate of decay of mixed fission products. This conclusion is supported further by data from collections at Rongelap Atoll in 1954.[9,10] Errors in the estimate of future levels based on this approximation would tend toward the prediction of higher levels than would actually be attained in the first 150 days. The wide spectrum of available radionuclides present in the early period following a detonation may be available to individual organisms in extremely minute amounts; consequently, differences in the rate of decline reflecting selectivity by an organism are masked, since various combinations of the short lived nuclides could result in an approximation of mixed fission products decay. The availability of a wide spectrum of radionuclides during the first few days might be due not only to the presence of these nuclides, but also to the fact that they could potentially be absorbed directly by the leaves of plants and thus circumvent fixation on the soil. Residual contamination from fallout a year or more old would have an insignificant effect on rate of decline during the first 150 days if the total contamination from each detonation were of the same order of magnitude or the first less than the second. This was the case following the Nectar test at Belle Island, which had residual contamination from the Mike test (1.5 years previous to Nectar).

After approximately 150 days following fallout, the rate of decline becomes less than the rate of decay of mixed fission products, reflecting the relative concentration by the island organisms of the long-lived isotopes Cs^{137} and Sr^{90}. Other isotopes, both fission products and neutron induced products, are involved, but Cs^{137} and Sr^{90} with their daughters account for 80 per cent or more of the total activity in land organisms two years following the Nectar test. This is true even though these isotopes together contribute only 18 per cent of the total activity from mixed fission products at that time. On a basis of fission yields, Cs^{137} and Sr^{90} would contribute no more than 35 per cent of the total activity even if all of the activity at Belle Island were from the Mike test. Ce^{144} activity is low (1% in crabs) in the island organisms because of its low rate of uptake by land plants from soil.[22] On the other hand, in marine organisms radiocerium does enter into the food chain in significant amounts (26%--71% of the total β-activity).[10,26]

It therefore appears that in so far as the long-lived radioactive fission products strontium, cesium and cerium are concerned there is what might be called a strontium, cesium food cycle on land and a cerium food cycle in the lagoon.

Summary

1. Periodic determinations of radioactivity in land crabs from Belle Island, Eniwetok Atoll, were made over a period of nearly two years following the 1954 atomic testing program.

2. Radioactivity in the exoskeleton was found to be due almost entirely to radiostrontium and the Y^{90} daughter of Sr^{90} and remained at a nearly constant level, excepting physical decay.

3. An estimate of contributions of radiostrontium from previous tests to crab skeleton at Belle Island is given.

4. Long-lived fission products in muscle tissue consisted of 84 per cent Cs^{137}, 10 per cent $Sr^{90} + Y^{90}$, and 1 per cent $Ce^{144} + Pr^{144}$

5. A possible association between the availability of cesium and rainfall is suggested.

6. During the first 150 days following a nuclear detonation the rate of decline of radioactivity in organisms on an atoll island may be considered to approximate the rate of decay of mixed fission products.

7. In so far as the long-lived fission products strontium, cesium and cerium are concerned there appears to be a strontium, cesium food cycle on land and a cerium food cycle in the lagoon.

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Appendix Table 1. Radioactivity in Coenobita (land hermit crab) Tissues Collected at Belle Island, Eniwetok Atoll

(Values in thousands of disintegrations per minute per gram wet, corrected to date of collection)

Specimen No.	Date of collection		Carapace	Muscle	Gill	Digestive gland	Gut
115	4/15/54		12.06	4.86	3.61	7.17	17.[illegible]
116	"		9.07	3.34	2.65	7.59	14.[illegible]
117	"		14.06	3.10	2.85	10.9	21.[illegible]
		Av.	12.1	3.76	3.03	8.55	17.[illegible]
137	5/17/54		52.0	48.8	143	934	2,370
138	"		87.1	60.6	191	969	9,400
139	"		71.6	105	1,570	912	2,760
		Av.	70.2	71.5	635	938	4,840
141	5/18/54		153	82.2	300	1,100	2,040
142	"		106	62.4	222	520	3,260
143	"		141	89.0	340	1,420	1,300
		Av.	133	77.9	287	1,010	2,200
149	5/20/54		319	89.4	142	777	756
150	"		71.3	44.7	90.5	578	1,360
151	"		393	108	263	827	2,410
		Av.	261	80.7	165	727	1,510
153	5/21/54		112	94.1	96.8	177	6,470
154	"		236	114	229	833	5,510
155	"		55.9	40.4	95.2	877	205
		Av.	135	82.8	140	629	4,060
161	5/22/54		70.8	24.9	73.6	199	190
162	"		141	52.3	152	582	345
163	"		125	42.0	147	435	318
164	"		33.9	20.1	53	94.3	1,290
165	"		91.2	31.2	115	201	320
		Av.	92.4	34.1	108	302	493
201	5/26/54		117	48.0	127	178	473
202	"		160	23.5	67.8	138	285
203	"		158	39.5	97.1	166	235
		Av.	145	37.0	97.3	161	331

Appendix Table 1. (continued)

Specimen No.	Date of collection	Carapace	Muscle	Gill	Digestive gland	Gut
205	5/28/54	139	26.6	39.3	337	1,040
206	"	272	32.0	78.7	206	317
207	"	37.5	15.2	19.3	100	107
	Av.	150	24.6	45.8	214	488
209	6/1/54	266	21.0	38.2	163	310
210	"	127	13.5	16.3	140	519
211	"	235	14.0	34.5	95.2	669
	Av.	209	16.2	29.7	133	499
234	6/4/54	68.6	11.3	18.3	97.7	800
235	"	98.2	6.74	34.1	89.7	587
236	"	236	---	41.5	124	651
	Av.	134	9.02	31.3	104	679
238	6/7/54	186	17.1	18.4	89.9	68.5
239	"	57.4	6.00	8.35	71.0	102
240	"	295	21.1	59.4	151	229
	Av.	179	14.7	28.7	104	133
242	6/11/54	210	6.92	22.9	97.9	88.7
243	"	129	12.7	26.9	102	79.7
244	"	101	7.49	14.5	48.0	381
	Av.	147	9.04	21.4	82.6	183
271	6/19/54	129	4.34	13.4	80.0	133
272	"	119	8.26	13.7	66.7	97.8
273	"	111	5.34	15.8	37.0	109
274	"	105	3.85	18.1	42.2	85.3
275	"	270	5.85	23.1	54.2	238
	Av.	147	5.53	16.8	56.0	133
297	6/25/54	180	3.98	11.8	30.9	210
298	"	38.5	5.43	9.94	40.2	271
299	"	179	8.29	14.1	27.4	215
	Av.	132	5.90	11.9	32.8	232
313	7/1/54	127	6.83	9.75	32.9	101
314	"	72.1	5.52	16.8	158	390
315	"	188	8.14	17.5	29.1	132
	Av.	129	6.83	14.7	73.3	208
324	7/8/54	42.0	---	4.54	32.7	25.0
325	"	201	6.18	13.2	31.7	140
326	"	42.4	2.34	2.34	16.2	44.0
	Av.	95.1	3.41	6.66	26.9	69.6

Appendix Table 1. (continued)

Specimen No.	Date of collection	Carapace	Muscle	Gill	Digestive gland	Gut
327	7/15/54	34.1	3.17	5.96	99.0	29.0
328	"	21.1	2.95	4.36	18.0	32.4
329	"	46.5	3.99	9.38	---	160
	Av.	33.9	3.36	6.56	58.1	73.8
370	7/22/54	223	5.52	8.43	26.7	142
371	"	80.1	6.64	3.98	18.4	163
372	"	125	5.22	6.35	25.4	289
	Av.	143	5.80	6.26	23.5	198
374	7/29/54	86.2	2.62	5.77	18.2	39.3
375	"	39.0	1.41	5.23	26.5	41.7
376	"	68.6	3.43	5.82	19.5	29.4
	Av.	64.6	2.49	5.60	21.4	36.8
378	8/5/54	200	2.57	5.54	30.5	183
379	"	39.3	2.17	3.61	24.9	42.3
380	"	70.1	3.33	3.90	17.3	28.6
	Av.	103	2.69	4.35	24.2	84.6
407	8/12/54	203	3.94	5.69	19.3	24.1
408	"	70.5	3.35	4.83	14.8	114
	Av.	137	3.64	5.26	17.0	69.0
409	8/19/54	71.8	3.02	4.88	16.5	22.9
410	"	113	2.62	3.31	15.6	29.1
411	"	92.8	3.64	4.28	11.0	15.2
	Av.	92.5	3.09	4.16	14.4	22.4
419	9/7/54	93.7	1.96	4.14	18.1	14.3
420	"	15.7	1.09	2.49	25.9	11.3
421	"	49.2	1.56	2.40	13.2	8.82
	Av.	52.9	1.54	3.01	19.1	11.5
472	10/5/54	17.7	1.18	1.79	12.1	9.15
473	"	14.4	3.05	1.13	4.34	5.15
474	"	16.7	1.91	2.01	5.40	4.24
	Av.	16.3	2.05	1.64	7.26	6.16
578	11/2/54	33.5	0.611	1.24	4.21	3.37
579	"	15.6	0.584	1.39	2.53	3.60
580	"	24.1	0.603	1.34	3.19	4.56
	Av.	24.4	0.599	1.32	3.31	3.83

Appendix Table 1. (continued)

Specimen No.	Date of collection		Carapace	Muscle	Gill	Digestive gland	Gut
618	11/30/54		16.8	1.47	1.01	4.48	10.2
619	"		22.8	1.47	2.08	5.14	11.4
620	"		19.8	1.56	2.24	6.61	5.33
		Av.	19.8	1.50	1.77	5.41	8.96
664	1/18/55		15.7	0.853	1.93	4.56	11.1
665	"		19.8	0.692	0.778	4.66	14.5
667	"		20.7	0.897	1.68	2.73	9.72
		Av.	18.7	0.813	1.46	3.98	11.8
735	2/9/55		22.2	1.81	1.98	3.93	4.10
736	"		15.3	3.07	3.18	4.86	9.23
737	"		24.0	2.66	2.49	5.30	5.86
		Av.	20.5	2.51	2.55	4.70	6.40
788	3/15/55		15.5	2.94	1.44	3.19	10.1
789	"		13.7	2.54	1.72	2.92	8.08
790	"		13.8	2.41	2.12	2.67	4.57
		Av.	14.3	2.63	1.76	2.93	7.60
914	11/1/55		14.1	1.14		1.42	
915	"		8.71	1.27		4.51	
916	"		8.72	1.32		2.46	
917	"		12.9	2.05		2.74	
918	"		7.12	0.991		3.18	
		Av.	10.3	1.36		2.86	
52-54	4/26/56		8.14*				

* Three samples pooled.

Appendix Table 2. Total β-activity and $Sr^{90}+Y^{90}$ in *Coenobita* Carapace

(0.95 counting error is given for individual samples; standard error is given for averages)

Date collected	Plate No.	Total β-activity Jan-Feb., 1956 d/m/g wet	$Sr^{90}+Y^{90}$ activity Feb. 1956 d/m/g wet
4/15/54	5395	7,344 ± 179	7,394 ± 191
"	5400	5,311 ± 154	5,464 ± 110
"	5405	8,047 ± 210	9,504 ± 230
		Av. 6,900 ± 672	Av. 7,454 ± 952
5/26/54	5504	12,158 ± 275	11,684 ± 197
"	5509	10,494 ± 198	10,028 ± 225
"	7499	8,078 ± 199	7,578 ± 167
		Av. 10,243 ± 968	Av. 9,763 ± 975
8/12/54	11291	17,913 ± 347	18,428 ± 314
"	11296	11,919 ± 279	13,274 ± 278
8/19/54	11301	14,720 ± 335	15,002 ± 265
		Av. 14,851 ± 1,413	Av. 15,568 ± 1,237
10/5/54	11510	3,936 ± 95	3,674 ± 104
"	11515	3,739 ± 106	3,474 ± 95
"	11520	5,411 ± 172	4,980 ± 136
		Av. 4,362 ± 431	Av. 4,043 ± 385
3/15/55	17503	11,690 ± 262	12,350 ± 285
"	17508	9,251 ± 235	10,344 ± 254
"	17513	10,163 ± 282	11,150 ± 233
		Av. 10,368 ± 581	Av. 11,281 ± 479
2/9/55	17321	8,660 *	
"	17326	14,951 *	11,790**
"	17331	13,938 *	13,274**
		Av. 12,516 ± 1,594	Av. 12,532 ± 1,484

* Three samples pooled and duplicate aliquots taken for strontium determination

** Duplicate aliquots of pooled samples

Appendix Table 3. Radioactivity Remaining in <u>Coenobita</u> (land hermit crab) Carapace in January-February, 1956

(Values in d/m/g as of counting date)

Specimen No.	Date of collection	d/m/g wet	d/m/g ash
115	4/15/54	7,344	23,600
116	"	5,311	---
117	"	8,047	19,300
	Av.	6,900	21,400
137	5/17/54	9,080	17,800
138	"	11,223	21,800
139	"	8,289	21,600
	Av.	9,530	20,400
141	5/18/54	8,318	15,500
142	"	10,369	18,300
143	"	9,890	17,900
	Av.	9,530	17,200
149	5/20/54	12,219	23,100
150	"	7,538	16,300
151	"	13,432	29,300
	Av.	11,100	22,900
153	5/21/54	6,061	16,600
154	"	10,478	25,600
155	"	5,491	18,200
	Av.	7,340	20,100
161	5/22/54	13,635	21,800
162	"	13,042	23,000
163	"	13,306	21,500
164	"	8,293	16,200
165	"	8,502	20,700
	Av.	11,400	20,600
201	5/26/54	12,158	24,400
202	"	10,494	20,100
203	"	8,078	24,800
	Av.	10,200	23,100
205*	5/28/54	8,844	19,200
206	"	11,453	22,900
207	"	7,283	17,400
	Av.	9,193	19,800

Appendix Table 3. (continued)

Specimen No.	Date of collection	d/m/g wet	d/m/g ash
209	6/1/54	10,216	19,900
210	"	9,624	21,000
211	"	14,709	26,600
	Av.	11,500	22,500
234	6/4/54	8,580	15,000
235	"	11,990	20,800
236	"	10,966	20,600
	Av.	10,500	18,800
238	6/7/54	10,903	21,000
239	"	7,372	15,100
240	"	12,650	25,600
	Av.	10,300	20,600
242	6/11/54	10,151	18,800
243	"	6,704	24,500
244	"	11,561	21,600
	Av.	9,470	21,600
271	6/19/54	10,444	18,600
272	"	10,958	20,200
273	"	10,644	21,600
274	"	9,525	21,800
275	"	14,032	30,700
	Av.	11,100	22,600
297	6/25/54	11,937	24,100
298	"	6,566	12,700
299	"	9,170	19,300
	Av.	9,220	18,700
313	7/1/54	13,041	23,300
314	"	7,342	12,850
315*	"	11,700	22,000
	Av.	10,700	19,400
324	7/8/54	9,523	17,400
325	"	12,002	34,100
326	"	7,648	16,197
	Av.	9,720	22,500
327	7/15/54	6,907	16,200
328	"	8,147	17,500
329	"	7,636	15,300
	Av.	7,560	16,300

Appendix Table 3. (continued)

Specimen No.	Date of collection	d/m/g wet	d/m/g ash
370	7/22/54	18,539	33,300
371	"	9,983	22,700
372	"	13,822	36,000
	Av.	14,100	30,700
374	7/29/54	11,483	20,600
375	"	9,912	19,900
376	"	11,467	20,200
	Av.	11,000	20,200
378	8/5/54	17,842	35,400
379	"	7,161	17,200
380	"	9,480	21,200
	Av.	11,500	24,600
407	8/12/54	17,913	29,900
408	"	11,919	24,200
	Av.	14,900	27,000
409	8/19/54	14,720	24,900
410	"	14,751	27,100
411	"	13,601	22,500
	Av.	14,400	24,800
419	9/7/54	13,712	25,500
420	"	2,894	16,800
421	"	6,468	18,800
	Av.	7,690	20,400
472	10/5/54	3,936	26,500
473	"	3,739	19,600
474	"	5,411	26,200
	Av.	4,360	24,100
578	11/2/54	9,354	26,600
579	"	6,796	20,100
580	"	9,875	24,100
	Av.	8,680	23,600
618	11/30/54	6,638	12,900
619	"	11,500	21,200
620	"	7,978	20,400
	Av.	8,700	18,200
664	1/18/55	12,305	26,100
665	"	11,473	26,700
667	"	9,636	26,800
	Av.	11,100	26,500

Appendix Table 3. (continued)

Specimen No.	Date of collection	d/m/g wet	d/m/g ash
735	2/9/55	8,660	23,700
736	"	14,951	30,900
737	"	13,938	27,900
	Av.	12,500	27,500
788	3/15/55	11,690	23,400
789	"	9,251	26,400
790	"	10,163	22,400
	Av.	10,400	24,100
914	11/1/55	7,116	23,000
915	"	12,900	16,400
916	"	8,720	15,900
917*	"	8,710	25,800
918*	"	14,100	13,000
	Av.	10,300	18,800
52	4/26/56		
53	"		
54	"	8,143 ± 233*	18,700 ± 710*

* One plate counted of three samples pooled; 0.95 counting error is given.