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UNITED STATES ATOMIC ENERGY COMMISSION

LAND CRABS AND RADIOACTIVE FALLOUT AT ENIWETOK ATOLL

By Edward E. Held

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May 27, 1957

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Applied Fisheries Laboratory University of Washington Seattle, Washington

Lauren R. Donaldson Director

May 27, 1957

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ABSTRACT

The pattern of changing levels of radioactivity is given for the tissues of land hermit crabs, <u>Coenobita perlatus</u>, from Belle Island, Eniwetok Atoll, during a period of nearly two years following the 1954 series of atomic tests. $3r^{90}$ + Y^{90} , and Cs^{137} were the principal long-lived fission products found. $3r^{90}$ 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 radio ARCHIVES strontium 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.

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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 Enivetok 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, <u>Coenobita perlatus</u> 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.

<u>Coenobita</u> 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. DOE ARCHIVES

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,

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^{*} 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 <u>Scaevola frutescens</u> and <u>Messerschmidia</u> <u>argentes</u>. 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 <u>Coenobita</u> 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.

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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

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from the fresh or frozen specimens, at the Enivetok 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 $\mathrm{Sr}^{90}+\mathrm{Y}^{90}$ 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. DOE ARCHIVES

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.

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"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 Mectar 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 <u>Coenobita</u> gill, muscle, hepatopancreas ("liver") and gut on successive collection dates. Values in disintegrations per minute per gram wet weight.

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decay of radiostrontium. Values in disintegrations per minute per gram wet weight.

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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 DOE ARCHIVES 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 <u>Eupagurus bernhardus</u>.¹⁵

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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 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 Sr⁹⁰ in rats during continuous feeding at the same rate, and apparent shifting of the plateau with change in daily dose.¹⁶ DOE ARCHIVES

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

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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.

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

Date collected	Total B-activity JanFeb., 1956 d/m/g wet	Sr ⁹⁰ +Y ⁹⁰ activity Feb. 1956 <u>d/m/g vet</u>
b /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*

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

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

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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. DOE ARCHIVES

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 contrib-/

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

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

the pre-Mike tests and the Bikini tests of 1954 together contributed 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 omnivorous hermit crab can be considered an accurate index of biologically available strontium. However, the ratio of the strontium in the crab skeleton to that in food items is not known. Judging from the meager data presently available, the radiostrontium content 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. Cs¹³⁷, Sr⁹⁰+ Y⁹⁰, and Ce¹⁴⁴+Pr¹⁴⁴ 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-livedDOE ARCHIVES 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 20

-14-



Fig. 6. Counts per minute per gram in <u>Coenobita</u> 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 shruts, 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 incnes 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 DOE ARCHIVES 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

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

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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.

Hepatopancreas ("liver")

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 preexisting level of long-lived activity approximately equal to the level existing 537 days post-Nectar. Sr⁹⁰, Cs¹³⁷, and Ce¹⁴⁴ Were found. DOE ARCHIVES

Equilibrium must be quickly reached and maintained at a constant level proportional to the availability of the long-lived

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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 $(5 \times 10^6 \text{ d/m/g})$. 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 longlived isotope Sr⁹⁰ by the carapace.

No chemical analyses of gut samples were made. DOE ARCHIVES

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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 2

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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

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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. Ce¹⁴⁴ 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 B-activity). 10,26 DOE ARCHIVES

It therefore appears that in so far as the long-lived radioactive fission products strontium, cesium and cerium are concerned

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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 $Sr_{2}^{90} + Y^{90}$, 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 DOE ARCHIVES 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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26. Bonham, Kelshaw. Radioactivity of invertebrates and other organisms at Eniwetok Atoll during 1954-55. Applied Fisheries Laboratory, University of Washington. MS. Appendix Table 1. Radioactivity in <u>Coenobita</u> (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	<u>Gill</u>	Digestiv gland	e Gut
115 116 117	4/15/54 "		12.06 9.07 14.06	4.86 3.34 3.10	3.61 2.65 2.85	7.17 7.59 10.9	17.0 14.0 21.1
		Av.	12.1	3.76	3.03	8.55	17.4
137 138 139	5/17/54		52.0 87.1 71.6	48.8 60.6 105	143 191 1,570	934 969 912	2,370 9,400 2,760
		Av.	70.2	71.5	63 5	938	4,840
141 142 143	5/18/54 "		153 106 141	82.2 62.4 89.0	300 222 340	1,100 520 1,420	2,040 3,260 1,300
-		Av.	133	77.9	287	1,010	2,200
149 150 151	5/20/54 "		319 71.3 393	89.4 44.7 108	142 90.5 263	777 578 827	756 1,360 2,410
		Av.	261	80.7	16 5	727	1,510
153 154 155	5/2 1 /54 "		112 236 55.9	94.1 114 40.4	96.8 229 95.2	177 833 877	6,470 5,510 205
		Av.	135	82.8	140	629	4,060
161 162 163 164 165	5/22/54 " "		70.8 141 125 33.9 91.2	24.9 52.3 42.0 20.1 31.2	73.6 152 147 53 115	199 582 435 94.3 201	190 345 318 1,290 <u>320</u>
_ ~ ~		Av.	92.4	34.1	108	302	493
201 202 203	5/26/54 "		117 160 158	48.0 23.5 39.5	127 67.8 97.1	178 138 166	DOE ARCHIVE 473 285 235
		Av.	145	37.0	97.3	161	331

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Specimen No.	Date of collection	<u>n (</u>	Carapace	Muscle	0111	Digestiv gland	e Gut	
205 206 207	5/28/54 "		139 272 	26.6 32.0 15.2	39.3 78.7 19.3	337 206 100	1,040 317 107	
		Av.	150	24.6	45.8	214	488	-
209 210 211	6/1/54		266 127 235	21.0 13.5 14.0	38.2 16.3 34.5	163 140 95.2	310 519 669	
	:	Av.	209	16.2	29.7	133	499	
234 235 236	6/4/54 "		68.6 98.2 236	11.3 6.74	18.3 34.1 41.5	97.7 89.7 124	800 587 651	
		Av.	134	9.02	31.3	104	679	
238 239 240	6/7/54		186 57.4 295	17.1 6.00 21.1	18.4 8.35 59.4	89.9 71.0 151	68.5 102 229	
		Av.	179	14.7	28.7	104	133	
242 243 244	6/11/54 "		210 129 101	6.92 12.7 7.49	22.9 26.9 14.5	97.9 102 48.0	88.7 79.7 381	
		Av.	147	9.04	21.4	82.6	183	
271 272 273 274 275	6/ <u>1</u> 9/54 " "		129 119 111 105 270	4.34 8.26 5.34 3.85 5.85	13.4 13.7 15.8 18.1 23.1	80.0 66.7 37.0 42.2 54.2	133 97.8 109 85.3 238	
		Av.	147	5.53	16.8	56.0	133	
297 298 299	6/25/54 "		180 38.5 179	3.98 5.43 8.29	11.8 9.94 14.1	30.9 40.2 27.4	210 271 215	
		Av.	132	5.90	11.9	32.8	232	
313 314 315	7/ <u>1</u> /54 "		127 72.1 188	6.83 5.52 8.14	9.75 16.8 17.5	32.9 158 29.1	101 390 132	
		Av.	129	6.83	14.7	73.3	208 DOE ARCH	IVES
324 325 326	7/8/54 "		42.0 201 42.4	6.18 2.34	4.54 13.2 2.34	32.7 31.7 16.2	25.0 140 44.0	
		Av.	95.1	3.41	6.66	26.9	69 .6	-33

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Appendix Table 1. (continued)

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Specimen	Date of collection	Caranace	Muscle	G 1 1 1	Digestive	Gut	
327 328 329	7/15/54	34.1 21.1 46.5	3.17 2.95 3.99	5.96 4.36 9.38	99.0 18.0	29.0 32.4 160	
370 371	Av 7/22/54	223 80.1	3.36 5.52 6.64	6.56 8.43 3.98	58.1 26.7 18.4	73.8 142 163	
372	" Av	<u>125</u> . 143	<u>5.22</u> 5.80	6.35	25.4	<u>289</u> 198	-
374 375 376	7/29/54 n	86.2 39.3 68.6	2.62 1.41 <u>3.43</u>	5.77 5.23 5.82	18.2 26.5 19.5	39.3 41.7 29.4	
378 379 380	8/5/54 "	200 39.3 70.1	2.49 2.57 2.17 3.33	5.54 3.61 3.90	30.5 24.9 17.3	183 42.3 28.6	
407 408	Av 8/12/54	203 70.5	2.69 3.94 3.35	4.35 5.69 4.83	24.2 19.3 14.8	84.6 24.1 114	
409 410	Av 8/19/54	7. 137 71.8 113	3.64 3.02 2.62	5.26 4.88 3.31	17.0 16.5 15.6	69.0 22.9 29.1	
411		<u>92.8</u> 92.5	3.64	4.28	11.0	22.4	
419 420 421	9/7/54	93.7 15.7 49.2	1.96 1.09 1.56	4.14 2.49 2.40	18.1 25.9 13.2	14.3 11.3 8.82	
472 473 474	Av 10/5/54 "	52.9 17.7 14.4 16.7	1.54 1.18 3.05 1.91	3.01 1.79 1.13 2.01	19.1 12.1 4.34 5.40	11.5 9.15 5.15 4.24	
578 579	Av 11/2/54 "	. 16.3 33.5 15.6	2.05 0.611 0.584 0.603	1.64 1.24 1.39	7.26 4.21 2.53 3.19	6.16 DOE ARC 3.37 3.60 4.56	CHIVES
200	Av	. 24.4	0.599	1.32	3.31	3.83	•

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Appendix Table 1. (continued)

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Specimen	Date of	_	0	M	E	igestiv	e
<u>No.</u>	collection	2	Carapace	Muscle	<u>G111</u>	gland	Gut
618 619 620	11/30/5 ¹ "	ŧ	16.8 22.8 19.8	1.47 1.47 1.56	1.01 2.08 2.24	4.48 5.14 6.61	10.2 11.4 5.33
		Av.	19.8	1.50	1.77	5.41	8.96
664 665 667	1/18/55 "		15.7 19.8 20.7	0.853 0.692 0.897	1.93 0.778 1.68	4.56 4.66 2.73	11.1 14.5 9.72
		Av.	18.7	0.813	1.46	3.98	11.8
735 736 737	2/9/55 "		22.2 15.3 24.0	1.81 3.07 2.66	1.98 3.18 2.49	3.93 4.86 5.30	4.10 9.23 5.86
		Av.	20.5	2.51	2.55	4.70	6.40
788 789 790	3/ 1 5/55 "		15.5 13.7 13.8	2.94 2.54 2.41	1.44 1.72 2.12	3.19 2.92 2.67	10.1 8.08 4.57
		Av.	14.3	2.63	1.76	2.93	7.60
914 915 916 917 918	11/1/55 " "		14.1 8.71 8.72 12.9 7.12	1.14 1.27 1.32 2.05 0.991		1.42 4.51 2.46 2.74 3.18	
•		Av.	17.3	1.36		2.86	
52-54	4/26/56		8.14*				

* Three samples pooled .

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Appendix Table 2. Total β -activity and $3r^{90}+Y^{90}$ in <u>Coenobita</u> Carapace

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

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

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* Three samples pooled and duplicate aliquots taken for strontium determination ** Duplicate aliquots of pooled samples

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

Specimen No.	Date of collection	d/m/g wet	d/m/g ash	
115 116 117	4/15/54 "Av	7,344 5,311 <u>8,047</u> . 6,900	23,600 <u>19,300</u> 21,400	
137 138 139	5/17/54 # Av	9,080 11,223 <u>8,289</u> . 9,530	17,800 21,800 <u>21,600</u> 20,400	
141 142 143	5/18/54 " Av	8,318 10,369 <u>9,890</u> 9,530	15,500 18,300 <u>17,900</u> 17,200	
149 150 151	5/20/54 " • Av	12,219 7,538 <u>13,432</u> . 11,100	23,100 16,300 <u>29,300</u> 22,900	
153 154 155	5/21/54 " A v	6,061 10,478 <u>5,491</u> . 7,340	16,600 25,600 <u>18,200</u> 20,100	
161 162 163 164 165	5/22/54 " " " Av	13,635 13,042 13,306 8,293 <u>8,502</u> . 11,400	21,800 23,000 21,500 16,200 20,700 -20,600	DOE ARCHIVES
201 202 203	5/26/54 " Av	12,158 10,494 <u>8,078</u> . 10,200	24,400 20,100 24,800 23,100	
205* 20 6 207	5/28/54 " Av	8,844 11,453 <u>7,283</u> . 9,193	19,200 22,900 17,400 19,800	37

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

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Date d/m/g of d/m/gSpecimen No. collection wet ash 6/1/54 10,216 19,900 209 9,624 <u>14,709</u> 210 21,000 = 211 26,600 11,500 22,500 Av. 6/4/54 8,580 11,990 234 15,000 235 236 20,800 Ħ <u>20,600</u> 18,800 <u>10,966</u> 10,500 Av. 10,903 7,372 <u>12,650</u> 10,300 6/7/54 238 21,000 233 15,100 Ħ 25,600 20,600 240 Av. 6/11/54 18,800 242 10,151 6,704 11,561 9,470 24,500 21,600 243 244 n 21,600 Av. 6/19/54 10,444 18,600 271 272 10,958 20,200 10,644 273 21,600 ft 21,800 9,525 274 n 14,032

Av.

Av.

Av.

Av.

Av.

6/25/54

7/1/54

7/8/54

7/15/54

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11,100

11,937 6,566 <u>9,170</u> 9,220

13,041

7,342 11,700 10,700

9,523

12,002

7,648

9,720

6,907

8,147 7,636 7,560

Appendix Table 3. (continued)

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313 314

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327 328

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23,300 12,850 <u>22,000</u> 19,400 DOE ARCHIVES 17,400 34,100 16,197 22,500 16,200

<u>30,700</u>

22,600

24,100

12,700

 $\frac{19,300}{18,700}$

17,500 15,300 16,300

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Specimen No.	Date of collection	d/m/g vet	d/m/g ash	
370 371 372	7/22/54 "	18,539 9,983 <u>13,822</u> Av. 14,100	33,300 22,700 <u>36,000</u> 30,700	
374 375 376	7/29/54 "	11,483 9,912 <u>11,467</u> Av. 11,000	20,600 19,900 <u>20,200</u> 20,200	
378 379 380	8/5/54 "	17,842 7,161 <u>9,480</u> Av. 11,500	35,400 17,200 21,200 24,600	
407 408	8/12/54	17,913 <u>11,919</u> Av. 14,900	29,900 <u>24,200</u> 27,000	
409 410 411	8/19/54 "	14,720 14,751 <u>13,601</u> Av. 14,400	24,900 27,100 <u>22,500</u> 24,800	
419 420 421	9/7/54 "	13,712 2,894 <u>6,468</u> Av. 7,690	25,500 16,800 <u>18,800</u> 20,400	
472 473 474	10/5/54 "	3,936 3,739 <u>5,411</u> Av. 4,360	26,500 19,600 <u>26,200</u> 24,100	
578 579 580	11/2/54 "	9,354 6,796 <u>9,875</u> A v . 8,680	26,600 20,100 <u>24,100</u> 23,600 _{DOE}	ARCHIVES
618 619 620	11/30/54 "	6,638 11,500 <u>7,978</u> Av. 8,700	12,900 21,200 20,400 18,200	
664 665 667	1/ <u>1</u> 8/55 "	12,305 11,473 <u>9,636</u> Av. 11,100	26,100 26,700 26,800 26,500	39

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Specimen No.	Date of collectio	d/m/g n vet	d/m/g ash
735 736 737	2/9/55 ."	8,660 14,951 <u>13,938</u> Av. 12,500	23,700 30,900 27,900 27,500
788 789 790	3/ <u>1</u> 5/55 "	11,690 9,251 <u>10,163</u> Av. 10,400	23,400 26,400 <u>22,400</u> 24,100
914 915 916 917* 918*	11/1/55 " "	7,116 12,900 8,720 8,710 <u>14,100</u> Av. 10,300	23,000 16,400 15,900 25,800 <u>13,000</u> 18,800

Appendix Table 3. (continued)

52 53 54	4/26/56		
	**	8,143 ± 233*	18,700 ± 710*

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

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