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POTASSIUM AND CESIUM-137 IN *BIRGUS LATRO* (COCONUT CRAB) MUSCLE COLLECTED AT RONGELAP ATOLL*

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Introduction

Rongelap Atoll was contaminated with radioactive fallout resulting from the Bravo test on March 1, 1954, to the extent that it was necessary to evacuate the population of 82 Rongelapese. Some 200 Marshallese returned to Rongelap in June 1957, after the area had been declared safe for human habitation. Since 1954, there have been several surveys to determine the level of radioactive contamination of the biota at Rongelap Atoll (Dunning, 1957). In March 1958, a long-term study of the ecology of the atoll, relative to radioactive contamination, was initiated at the request of the U.S. Atomic Energy Commission, Division of Biology and Medicine.

The objective of this investigation was to determine the radiocesium and stable potassium content in the muscle of *Birgus latro* and to evaluate the relationship between the two, if any, under the existing conditions at Rongelap Atoll.

Birgus latro, the coconout crab, is of particular interest because it is edible and is a land crab known to contain cesium-137 in its muscle tissue. Cesium-137 is also the principal long-lived (27 years half life) fission product found in plants on contaminated islands in the Marshall Islands. There have been conflicting reports in the literature concerning the relationship of potassium to cesium-137 uptake in plants (Auerbach and Crossley, 1958 ; Nishita, *et al.*, 1958 ; Uhler, 1959 ; Nishita *et al.*, 1959). Apparently the uptake of cesium-137 by plants is directly associated with potassium uptake in some cases and not in others.

It was suggested from the results of studies of *Coenobita* at Eniwetok Atoll that seasonal differences in precipitation might influence cesium-137 levels in muscle tissue (Held, 1960) ; the data presented here do not support this suggestion.

Materials and Methods

Samples of *Birgus* muscle were collected from Kabelle, Rongelap, and Eniaetok Islands at Rongelap Atoll during March 1958, August 1958 and March 1959. Two samples were also collected at Utirik Island, Utirik Atoll (Fig. 1) in March 1959. The samples were oven-dried at 98°C and the wet weight to dry weight ratios were determined. For potassium analysis, the samples were wet ashed with concentrated HNO_3 and H_2O_2. The ash was dissolved in a known volume of 1N HNO_3 and

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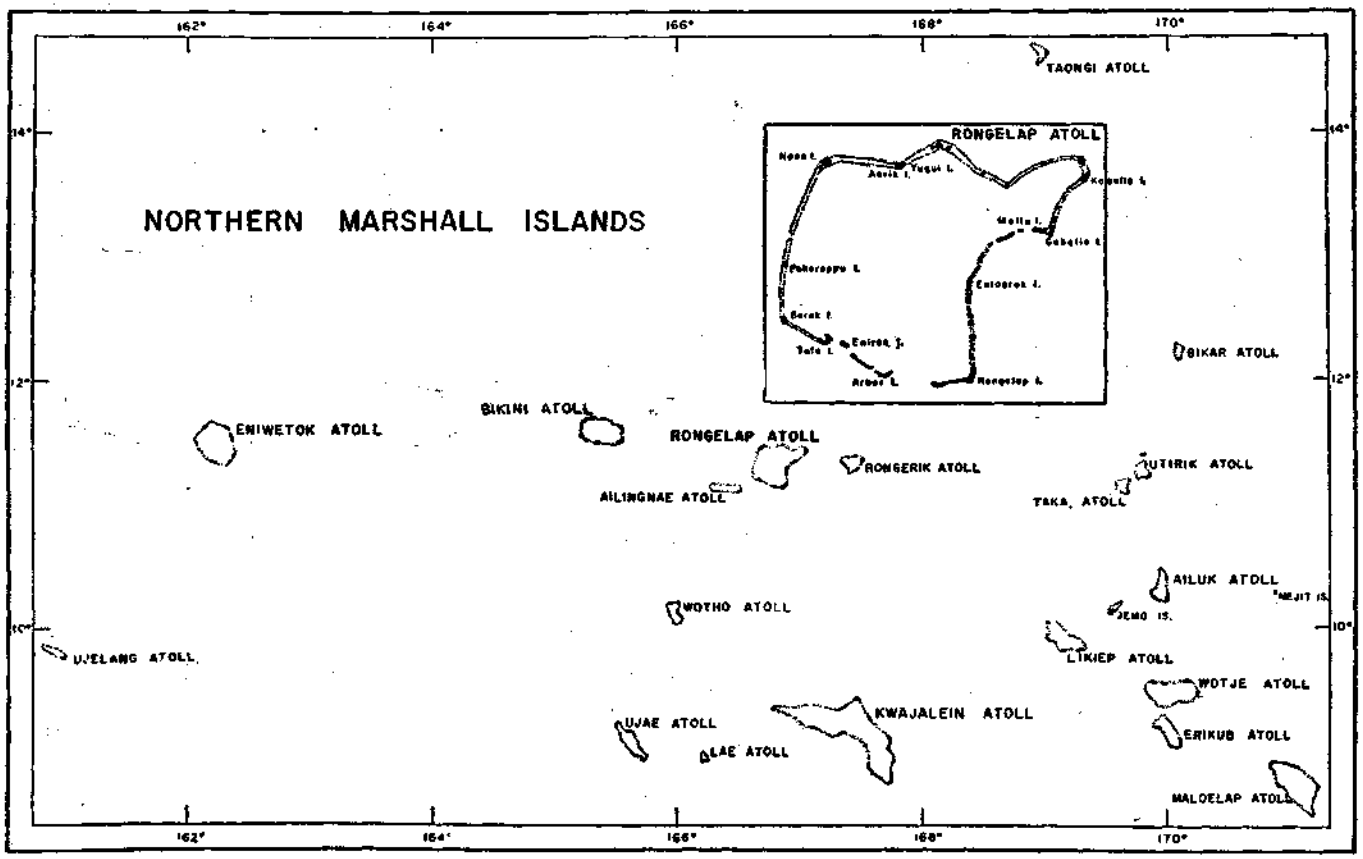
NORTHERN MARSHALL ISLANDS
RONGELAP ATOLL
TAONGI ATOLL
BIKAR ATOLL
ENIWETOK ATOLL
BIKINI ATOLL
RONGELAP ATOLL
RONGERIK ATOLL
AILINGNAE ATOLL
UTIRIK ATOLL
TAKA ATOLL
AILUK ATOLL
WOTHO ATOLL
LIKIEP ATOLL
UJELANG ATOLL
WOTJE ATOLL
UJAE ATOLL
KWAJALEIN ATOLL
LAE ATOLL
ERIKUB ATOLL
MALOELAP ATOLL
162°
164°
166°
168°
170°
14°
12°
10°

the potassium content determined by flame photometry. Details of the method used have been reported by Chakravarti and Joyner (1959).

The levels of cesium-137 were determined by gamma spectroscopy. Five to ten-gram samples of dried muscle were counted. The counting equipment consisted of a three-inch thallium-activated sodium iodide crystal used in conjunction with a 256-channel analyzer with digital print out. The total counts per minute under the photopeak were calculated by summing counts per minute of all channels included in the peak and subtracting the background counts. The counting efficiency for the gamma energy measured was determined by calibrating the instrument with a cesium-137 standard with an error of $\pm$ 10 per cent. The factor used for converting counts per minute to disintegrations per minute was derived from the counting efficiency and from the fraction of the distintegrations giving rise to the gamma radiation being counted. The factor used for cesium-137-barium-137 was 18.0. Detailed descriptions of the counting equipment and standardization procedures used have been given by Lowman *et al.* (1958).

Results and Discussion

The individual values for potassium and cesium-137 in *Birgus* muscle collected at Rongelap Atoll and Utirik Island are presented in Table 1. Average values and their standard deviations for each collection also are given.

The levels of cesium-137 found in individual samples ranged between 731 d/m/g dry weight at Kabelle Island, Rongelap Atoll, and 28 d/m/g dry weight at Utirik Island, Utirik Atoll. The individual variation at any one island was large. Range in values in d/m/g/dry weight at three islands at Rongelap Atoll was as follows: Kabelle 324-731, Eniaetok 369-498, and Rongelap 199-330. However, the average ceisum-137 levels were highest at Kabelle Island, which lies in the northern part of the atoll, and lowest at Rongelap Island, in the southern part. Analysis of variance gave an F value of 23.98 (significant at 1 per cent level), indicating that the difference in cesium-137 values between these two islands is statistically significant. At Eniaetok Island, which lies about half way between Rongelap Island and Kabelle Island, only three samples were obtained, two in March 1958, and one in August 1958. In the former collection the levels were higher than at Kabelle while in the latter collection the level was lower than at Kabelle for the corresponding dates. This apparent inconsistency is probably a result of individual variation. At Utirik Atoll, which lies some 200 miles to the east (Fig. 1), the levels were about one-tenth of the lowest levels at Rongelap.

The gamma dose rates give an indication of the relative levels of radioactive contamination of the different islands. The average gamma dose rates measured three feet above ground in March 1959 at these islands were, Rongelap .031, Eniaetok .051, Kabelle .069 and Utirik .025, expressed as milliroentgens per hour.

Determinations of other radionuclides in *Birgus* muscle indicate that over 90 per cent of the radioactivity is from cesium-137.

For comparison with cesium-137 levels, the average potassium value for each collection is given in Table 1. The average potassium value for all samples was 13.05 mg/g with a standard deviation of 3.66. The range in values was 2.96 to 21.2 mg K/g dry weight, but 83 per cent of the 30 samples analyzed fell in the range of 10 to 15 mg K/g dry weight. The two lowest values of 2.96 and 3.48 mg K/g dry weight appear to be completely out of line. Repetition of the analysis of these samples gave essentially the same results and no explanation for the disparity is offered.

A significant difference in potassium levels associated either with island or season of collection is not apparent (March falls in the dry season and August in the wet season). Nor is there any correlation between potassium and cesium-137 levels at any one island. In this regard, the data should net be pooled since it has been established that there are differences in cesium-137 levels from island to island. The regression of ceisum-137 on potassium in the crab muscle, as determined in the largest sample from Kabelle Island, indicated no relation between these elements.

Cesium-137 levels have been reported as *cesium units*, micro micro-curies of cesium-137 per gram of potassium (U.S. AEC reports on fallout). This unit is based on metabolic similarity of cesium and potassium and is used to facilitate comparision of different types of materials in a manner similar to the use of the strontium unit adopted by Libby (1956). Anderson, Schuch, Fisher and Langham (1957) have used the gamma ratios of ceisum-137 to potassium-40 in place of the cesium unit. Cesium units for *Birgus* muscle are given in Table 1 for comparison with other published data on fallout given in the same units. However, since the potasium and cesium levels are both highly variable in *Birgus* muscle, there is some doubt as to the usefulness of the unit in this case. For example, the comparatively high value for cesium units of samples from Rongelap Island is due to the exceptionally low potassium content of one of the samples. On the other hand, the high value for the March 1959 collection at Kabelle Island is due to high levels of cesium-137, while the potassium levels are about average.

These differences are not surprising when the following facts are considered. Gross (1959) has reported that *Coenobita*, which has habits similar to those of *Birgus*, obtains blood salts from its food. From work in progress at this Laboratory it is known that *Pandanus* fruit, which form a part of the diet of *Birgus*, vary by as much as a factor of five in cesium-137 content and a factor of four in potassium content and that the range in potassium levels in soils on which *Pandanus* grows at Rongelap is 0.1 to 1.5 milliequivalents per 100 grams. Also, the extremes in the range of gross beta activity in the top inch of soil at a single island can differ by more than a factor of ten. On a basis of the variability in cesium-137 and potassium levels found in the environment alone, one might expect the high degree of variability found in *Birgus*.

An additional factor which may accentuate the condition found in *Birgus* is currently under study at this Laboratory in cooperation with the Department of Botany, University of Washington. The low potassium levels in the soils at Rongelap represent a potassium deficiency for at least some of the plants. Greenhouse experiments in which Rongelap soil was used as well as field trials at Rongelap have demonstrated that potassium fertilization decreases cesium-137 uptake by plants (Walker and Held, 1959). This observation is in agreement with the reported increase in cesium-137 uptake by plants in other soils as the potassium concentration in the soil is reduced by prolonged cropping (Nishita *et al.*, 1958 and 1959). It appears possible that if a surplus of potassium were present in the soils at Rongelap, potassium levels in *Birgus* muscle would be more uniform and cesium-137 levels lower.

The simplest system studied at Rongelap with respect to cesium-137 and potassium was the soil. Cesium-137 and potassium in rain water which had percolated through undisturbed soils were found to be present in approximately proportional amounts under changing conditions of precipitation and fertilization (Cole *et al.*, 1959). However, at the second or higher trophic level, represented by *Birgus*, if any such relationship exists between the uptake of cesium and potassium, it is masked by several unknown variables in the ecosystem.

SUMMARY

Radiocesium and stable potassium levels were determined in samples of muscle tissue of *Birgus latro*, the coconut crab, collected at Rongelap Atoll, Marshall Islands, during March and August, 1958, and March 1959, and at Utirik Atoll in March 1959. Levels of cesium-137 ranged between 731 d/m/g dry weight at Kabelle Island, Rongelap Atoll, and 28 d/m/g dry weight at Utirik Island, Utirik Atoll. The average potassium value for all samples was 13.05 mg/g dry weight with a standard deviation of 3.66. No significant correlation between cesium-137 and potassium levels was found. There was no significant difference in the average levels of cesium-137 in crabs collected at different times at the same island.

TABLE I

Potassium and cesium-137 in *Birgus latro* (coconut crab) muscle collected at Rongelap Atoll and Utirik Island, Utirik Atoll

Kabelle Island

	Sample No.	Cesium-137 d/m/g dry weight	Potassium mg/g dry weight	Cesium Unit $\mu\mu c$ Cs^{137} /g K	Wet/dry ratio
March 1958 (dry season)	34	604	13.28	20489	4.212
	35	426	10.32	18594	3.794
	36	349	11.40	13789	3.591
	37	410	17.68	10447	4.082
	38	437	13.04	15092	3.743
		Av. = 445 S.D. = 95	Av. = 13.14 S.D. = 2.81	Av. = 15682 S.D. = 3966	Av. = 3.884 S.D. = 0.252
August 1958 (wet season)	7	661	17.25	17258	4.930
	8	438	14.68	13440	3.480
	9	454	11.99	17056	3.807
	10	325	15.03	9741	4.308
	11	650	11.92	24564	3.946
	12	324	13.87	10519	3.660
		Av. = 475 S.D. = 150	Av. = 14.12 S.D. = 2.02	Av. = 15430 S.D. = 5474	Av. = 4.022 S.D. = 0.424
March 1959 (dry season)	1	524	12.72	18546	4.470
	2	619	12.64	22065	4.330
	3	731	11.76	27993	4.840
	5	645	12.00	24217	5.140
		Av. = 630 S.D. = 85	Av. = 12.28 S.D. = 0.47	Av. = 23205 S.D. = 3956	Av. = 4.695 S.D. = 0.366

Rongelap Island

	Sample No.	Cesium-137 d/m/g dry weight	Potassium mg/g dry weight	Cesium Unit $\mu\mu c$ Cs^{137} /g K	Wet/dry ratio
March 1958 (dry season)	84 85 86 87 88	199 219 276 202 261	12.18 15.40 19.20 2.96 14.72	7356 6403 6474 30743 7989	3.895 4.243 4.419 3.693 5.130
		A.v. = 231 S.D. = 35	Av. = 12.89 S.D. = 6.09	Av. = 11793 S.D. = 10614	Av. = 4.276 S.D. = 0.556
August 1958 (wet season)	2 3 4 5 6	228 206 324 330 254	12.71 11.77 9.96 15.35 13.44	8080 7884 14648 9681 8512	5.254 3.784 4.238 4.373 4.144
		Av. = 268 S.D. = 56	Av. = 12.65 S.D. = 2.00	Av. = 9761 S.D. = 2819	Av. = 4.360 S.D. = 0.543

Eniaetok Island

March 1958 (dry season)	61 62	498 498	14.08 21.18	15930 10590	5.000 4.356
		Av. = 498 S.D. = 00	Av. = 17.63 S.D. = 5.02	Av. = 13260 S.D. = 3776	Av. = 4.678 S.D. = 0.455
August 1958 (wet season)	1	369	14.01	11863	4.764

Utirik Island

March 1959 (dry season)	4 6	31 28	3.48 11.64	4023 1102	4.321 4.238
		Av. = 29.5 S.D. = 4.5	Av. = 7.56 S.D. = 5.77	Av. = 2562 S.D. = 2065	Av. = 4.280 S.D. = 0.057

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