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Radioisotope cycling in terrestrial communities
at Eniwetok Atoll

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This report is derived from our current study of rat populations on Eniwetok Atoll. Some aspects of this basic ecological study are being presented later in this symposium (Jackson 1967), and in other papers. During the course of these studies, in cooperation with the Laboratory of Radiation Biology, University of Washington, tissue samples of various land vertebrates and plants were collected and analyzed for radioisotope content. Only the ¹³⁷Cesium data for rats and their principal food sources will be discussed in this paper.

Introduction

Cesium is a fallout product recorded in many places of the world. Miettinen (1967) and Davis, Hanson and Watson (1961) reviewed the relative concentrations of the isotope in various communities in Washington, Alaska and Finland; and ecosystem involvement was considered by Davis (1961). Additional studies are summarized in Schultz and Klement (1961) and Auerbach (1965).

Cesium, though widely distributed naturally over the earth's crust, occurs in small quantities and is considered a rare element.

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Metabolically functioning very much like potassium, cesium may be incorporated readily into metabolic systems in both plants and animals. Like potassium it is localized intracellularly, may readily cross the placental barrier, and may be transferred via the milk (Wasserman, 1965). Species differences in excretory route and rate have been observed (Hood and Comar, 1963).

Foliar applications of cesium are readily absorbed (Bukovac et al., 1965); and while a differential between isotopes exists, as much as 35% of 137 Cesium applications may be transported. Lane (1967) found that only about 9% of a similar alkaline metal, rubidium, was absorbed in foliar applications at Eniwetok. Plant roots readily absorb cesium from their environment, though in the presence of potassium the latter is usually selectively absorbed, since, of the two elements, cesium is the more tightly bound to soil colloids (Nishita et al., 1965). That little 137 Cesium occurs in marine life at Eniwetok is related to the abundance of potassium in sea water (Palumbo, 1961). The terrestrial environment, however, because of its potassium deficiency, behaves differently.

Studies of isotope cycling in natural terrestrial vertebrate populations have been limited to those carried out in Nevada (Turner, et al., 1966 and French, 1965) and at the White Oak Lake bed (Kaye and Dunaway, 1962 and others). Rodent populations at Eniwetok provided an opportunity to examine isotope levels in animal populations that have lived, since the cessation of testing, in an undisturbed but contaminated environment.

Testing of nuclear devices at Eniwetok began in 1948 (Sandstone series) and continued until mid-1958 (Hardtack series). Many of the detonations were in Mike crater (3.2 miles from Engebi islet), on Engebi islet, and on or near Runit islet (fig. 1). Observations on these two areas occupied a major amount of time in both earlier studies and our own.

Other reports (e.g., Hines, 1962) have described the direct impact of testing operations on these islets. Both were denuded of vegetation by the combined effects of pre-test construction and the multiple effects of the explosions themselves. Now both are covered with at least sparse vegetation; Engebi has extensive areas of scrub vegetation 20 feet tall. While radiation levels following some tests were high (2500 R/hr), ground level readings on Runit now (1964) average less than 0.1 mR/hr; those on Engebi, 0.2 mR/hr (LRB, unpublished data).

Rat populations (Rattus rattus) apparently survived the physical damage and radiation effects on Engebi (Jackson, 1967). With the return of vegetation to the islets, nesting birds returned (Carpenter, Jackson, and Fall, MS), and all terrestrial vertebrates demonstrated marked recovery.

Methods

In our studies rats were collected on various islets with standard rat snap-traps or live traps. Tissue samples from five animals (usually bone, muscle, kidney, skin, liver, gut, and gonads) were removed, pooled, weighed (wet weight), oven-dried at least overnight, packaged in aluminum foil, sealed in plastic envelopes, and eventually shipped to

the Laboratory of Radiation Biology. Because of limited field time and analysis facilities, only selected plant samples were taken; preparation was the same. Prior to processing, the samples were again oven-dried and then weighed.

Radionuclide concentrations were determined ~~principally~~ through gamma spectrometry by the Laboratory of Radiation Biology. The instrumentation consisted of a single 3-inch by 3-inch solid sodium iodide (Tl) crystal detector coupled to each half of three split memory, multichannel, pulse height analyzers (two Nuclear Data N.D. 120 analyzers), and one R.I.D.L. 400 channel vacuum tube system provided a total of six KEV per channel and covered a range of 0 to 1.8 MEV. Isotope concentration values not exceeding twice the counting error (95% level) were considered non-significant.

Specimens for periods prior to 1964 were collected by LRB personnel in a variety of ways, often by hand. Sample processing was essentially the same, except for variable sample or pool sizes and the use of wet weight ratios.

Results and Discussion

Although concentrations of nine radionuclides were provided from the analyses, only $^{137}\text{Cesium}$ will be considered in this paper. Tabular data (Table 1) present the concentrations of ^{137}Cs in both rat and plant samples for our study in 1965. Graphic representations of the level of ^{137}Cs in rat and plant samples since 1954 are given for one islet (Engebi) (fig. 2 and 3); tabular results are given in

Table 2. The data for samples prior to 1964 are taken from LRB reports and unpublished data summaries.

The comparison of both plant and animal cesium levels over a ten year period demonstrates an expected decline in activity since the cessation of testing. The high level in 1959-1961 is probably a result of tests of the Redwing and Hardtack series raising the environmental ^{137}Cs level; however, no biologic data have been found for this period. The levels of ^{137}Cs in plants parallel that in soil samples; likewise the activity recorded in rat tissues parallels that of plants.

Considerable variability in the data is evident, especially in the plant data. This is probably related to the manner of collection. Leaves (and sometimes fruiting structures) were taken from several portions of one plant or from several adjacent plants. Obtaining and processing samples from several areas of the same islet usually was not possible. At best trends are evident. While the physical half-life of $^{137}\text{Cesium}$ is 26.6 years, loss from these plant and animal tissues was considerably more rapid. The biological half-life in rats has been designated as 10 days or less (Hood and Comar, 1953); but in a continuous cycling system, this is of little consequence. The soil is the most important component in this ecosystem, since as the cesium leaches from the plant root horizon, it is lost to the terrestrial community (except for recycling from nesting birds, water spray, etc.). Within the limits of the data, both plant and animal species follow the decreasing concentration of $^{137}\text{Cesium}$ in the soil. Under these conditions a 50% decrease in radiation level occurs in about two years.

Studies by Medina and Jackson (1967) of rat stomachs collected by us (1964-66) have demonstrated that approximately 90% of the diet of rats at Eniwetok consists of vegetable matter. Two plant species, Scaevola and Messerschmidia have been shown to comprise 70% or more of the rats' diet, and high levels of 137 Cesium are found in these species (Table 1).

Concentrations of 137 Cs vary considerably in plant samples among the islets at Eniwetok and even over the length of one islet (Table 1). This variation is a factor of the time since testing and of the magnitude and nature of tests on or near the islet. Four tests of the last series were carried out on Runit islet, all on the northern portion. The highest counts in plants recorded in the 1964-1965 samples likewise were found on the northern portion of this islet.

In rats a close correlation was found between the levels of 137 Cs in plants of their environment and body burdens. On Runit for example, the body burden (137 Cs) of the rats trapped on the northern portion of the island was three times or more that of those from the south of the island. On an islet like Igurin, well removed by distance from most tests, cesium levels in both rats and plants are negligible.

Some differences appear to exist between the 137 Cs levels of the two species of rats (Rattus rattus and R. exulans) in equally irradiated environments. On Parry islet, where only R. rattus occurs, the cesium level in tissues was twice the levels on Muti^(JapTan) (Table 1). Muti islet is one mile closer to testing activities but inhabited only by Rattus exulans. The causality of this difference, whether feeding pattern,

feeding preference, or environmental variables, is not known. Insufficient plant samples were taken at Muti and Parry to determine isotope differentials in plants, but at Bikini islet (Bikini Atoll) where both rat species occur, this differential also was observed (Welander, 1967 and Jackson, MS).

Summary

Studies in the simplified terrestrial environment at Eniwetok have found a close correlation between the radiation levels of 137 Cesium in soil, plants, and the only terrestrial mammals, Polynesian and roof rats. Because of the short food chain, a close correlation between testing activity and the presence of radioisotopes in the ecosystem exists, and variation in exposure conditions are apparent in elements of the native biota. Continued use of these isolated and relatively undisturbed mammal populations for the study of long term radiation effects is urged.

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Table 1. A comparison of ^{137}Cs content in plant and animal tissues from islets at Eniwetok for 1965 (pc/gm dry). Numbers in parenthesis indicate number of determinations from which an average value was calculated. "P" indicates a pooled sample and a single determination. Values without notation are derived from single samples.

Species	Engebi	Biiijiri	Runit (N)	Runit (S)	Muti	Parry	Igurin
<u>Rattus</u> sp.* (5p)							
gut	319	127	12400	671	14.6	48.9	5.3
kidney	292	142	12100	455	NS	35.5	NS
liver	188	657	9300	260	7.5	18.6	4.4
muscle	228	105	9020	421	14.1	26.2	NS
skin	121	451	3840	134	NS	10.8	NS
testes	529	233	15000	740	22.0	51.9	NS
<u>Scaevola</u>	400	16.3	7990	6.7(2)			NS
<u>Messerschmidia</u>	690	101	47.8				15.8
<u>Guettarda</u>					1.5		0.85
<u>Cocos</u>		2.51					0.85
<u>Fimbrystilis</u>							60.8
<u>Triumfetta</u>			3720	6.08(2)			NS
<u>Ipomoea</u>	3570				1.7		3.3
<u>Cenchrus</u>					8.8		

* The Polynesian rat (Rattus exulans) only, inhabits Biiijiri, Muti, and Igurin. The roof rat (Rattus rattus) is found exclusively on the other islets.

NS indicates samples with non-significant determinations.

Table 2. A comparison of ^{137}Cs content in plant and animal tissues from Engebi Islet, Eniwetok Atoll (pc/gm). Numbers in parenthesis indicate number of determinations from which an average value was calculated. "P" indicates a pooled sample and a single determination. Values without notation are assumed to be derived from single samples.

Species	1954	1955	1956	1959	1961	1964	1965
<u>Rattus rattus</u>							
skin		*234			*170(2)	180(6)	121(5p)
muscle		*318			*141(4)	420(6)	228(5p)
bone		*427(2)			*239(4)	91(6)	
liver		*309			*323(4)	280(5)	188(5p)
kidney		*139			*473(4)	390(6)	292(5p)
gut					*416(4)	510(6)	319(5p)
testes					*390	430(5)	529(5p)
<u>Scaevola</u>							
				2400		460	400
<u>Messerschmidia</u>							
	405			1500		315	690
<u>Fimbristylis</u>							
	5856	1448		37600(2)	3300	1500	
<u>Triumfetta</u>							
				5440		380	
<u>Ipomoea</u>							
	66216			147	7867(3)	670	3570
<u>Cenchrus</u>							
		45		953(2)			
<u>Sida</u>							
	247297	139		1690		1300	
<u>soil</u>							
	9400	109	2450	1500		42	

* indicates wet weight; all other data are dry weight.

Legends

- Figure ² 1. Level of ¹³⁷ Cesium in plants and soil of Engebi islet
Eniwetok Atoll from 1954 to 1965 (pc/gm dry wt). Additional
symbols represent wet weight ratios for appropriate species.
- Figure ³ 2. Level of ¹³⁷ Cesium in rat tissues from Engebi islet,
Eniwetok Atoll for the 1955 to 1965 period.
- Figure 1. Map of Eniwetok Atoll.