MARSHALL ISLANDS FILE TRACKING DOCUMENT

Record Number: 293

File Name (TITLE): Radioactivities in Invertebrates, and other organisms ..

Document Number (ID): UWFL-53

DATE: 1/1958

Previous Location (FROM): C/C

AUTHOR: K. Bonham

Addditional Information:

OrMIbox: 17

CyMIbox: 11

19888 **UWFL-53**

BIOLOGY AND MEDICINE

9

UNITED STATES ATOMIC ENERGY COMMISSION

RADIOACTIVITY OF INVERTEBRATES AND OTHER ORGANISMS AT ENIWETOK ATOLL DURING 1954–55

By
Kelshaw Bonham

January 6, 1958

Applied Fisheries Laboratory
University of Washington
Seattle, Washington

Technical Information Service Extension, Oak Ridge, Tenn.

UWFL-53

RADIOACTIVITY OF INVERTEBRATES AND OTHER ORGANISMS AT ENIWETOK ATOLL DURING 1954-55

by

Kelshaw Bonham

Applied Fisheries Laboratory
University of Washington
Seattle, Washington

Lauren R. Donaldson
Director

January 6, 1958

Operated by the University of Washington under Contract No.
AT(45-1)540 with the United States Atomic Energy Commission

ABSTRACT

The trend in beta radioactivity as measured with methane flow counters over a period of about two years is shown, starting with the 1954 Castle series of nuclear detonations, up to but not including the series of 1956. The results are presented as graphs each showing the logarithm of the radioactivity of an organism or of a particular tissue of an organism, related to the logarithm of the time after the date of detonation, when nearly all of the radioactivity was assumed to have originated.

Invertebrates are considered in greatest detail, and other organisms and materials are included for comparison: island soil, beach sand, sea water, plankton, algae, land plants, reef fish, birds, and rats.

It is proposed for most organisms studied that after a period varying with the organism up to two to four weeks following detonation, a maximum level of radioactivity in the field samples collected is attained, followed by a decline approaching linearity on log-log plots with slopes over the major portion of the two-year period that can be represented as the negative exponent of the time after detonation. These decline slopes varied greatly with different localities and organisms, reaching a maximum of > 3.

A few decay rates of individual samples of each organism or material are included for comparison, and these generally were equal to, or less steep than, the declines, suggesting that for some organisms or tissues, the level of radioactivity in the environment decreases more rapidly than can be accounted for solely by physical decay while for others the rate of decline can be accounted for solely by the rate of physical decay. Dilution by natural water currents and rain is presumed to account for the many cases of more rapid decline than decay.

TABLE OF CONTENTS

RADIOACTIVITY OF INVERTEBRATES AND OTHER ORGANISMS AT ENIWETOK ATOLL DURING 1954-55

Introduction

Levels of radioactivity in living forms have been determined at almost all of the Pacific Proving Ground tests, both immediately before and shortly after the detonations, as well as at occasional relatively great intervals of a year or more later (UWFL-33, 42, and 43).

The present study traces the trends in the beta radioactivity of invertebrates by means of repeated observations from shortly before the Nectar detonation (May 14, 1954) for a period of nearly two years. For comparison with the invertebrates similar observations on other substances and organisms are included, using some information given more fully in reports by other members of the Applied Fisheries Laboratory who deal with their problems from different points of view. Palumbo (1957) reported on the radioactivity in algae and land plants. Held (1957) studied the trends of radioactivity in the land hermit crab and discovered the preponderance of radiostrontium in the exoskeleton. Welander (1957) described the trends of radioactivity for the reef fishes of Belle Island. Lowman, Palumbo, and South (1957) reported the identity of the radioactive non-fission products remaining in certain samples collected in 1954-55 and in 1956 as determined in late 1956 and early 1957.

Although the emphasis of the present paper is on invertebrates, certain data from many of the other areas are brought together here in order to compare the trends in levels of radioactivity in a unified form and by as nearly identical methods as is practicable. It should be possible in this way to observe the general pattern of change of radioactivity in living and non-living materials, and to detect divergences from the pattern. Study of the trends in this manner has proved useful in pointing out materials of interest for radioisotopic analysis by gamma-ray spectrometry.

A comparison of the rate at which levels of activity in organisms of the same species change with the passage of time, herein termed decline, with the rate of physical decay, should indicate changes in availability of the radioactivity to the organism concerned. If decline is more rapid than decay a reduction of activity in the environment beyond that caused solely by physical decay is suggested, and conversely, a steeper decay than decline suggests either an increase in availability in the environment or an accumulation or concentration of radioactivity by the organism. Equality of decay and decline suggests that uptake and excretion of radioisotopes have reached an equilibrium with the environment. It will be shown that cases in which physical decay progressed more rapidly than did the rate of decline over the same period of time were rare or lacking.

METHODS

Radioactivity of common substances and organisms at Eniwetok Atoll was evaluated in two ways, first by concentrated study involving many organisms collected frequently at one island, Belle, and second, by less intensive study at several islands around the atoll in order to elucidate the geographical distribution of the activity.

Belle Island (Fig. 1) was the major collecting and observation site, except for rats, for which it was Janet Island. Collections were made on April 15, 1954 at Belle before the Nectar test, almost daily for the week after, and at increasing intervals later. The second aspect of the study, at several islands, involved pre-Nectar collections in April and May, and nine to ten post-Nectar collections, usually expedited by helicopter, at intervals increasing from one to nine months, at which time six islands, Henry, Leroy, Alice, Olive, Vera, and Bruce were visited. The remaining two islands, Janet and Elmer, were sampled at approximately the same times in connection with other studies.

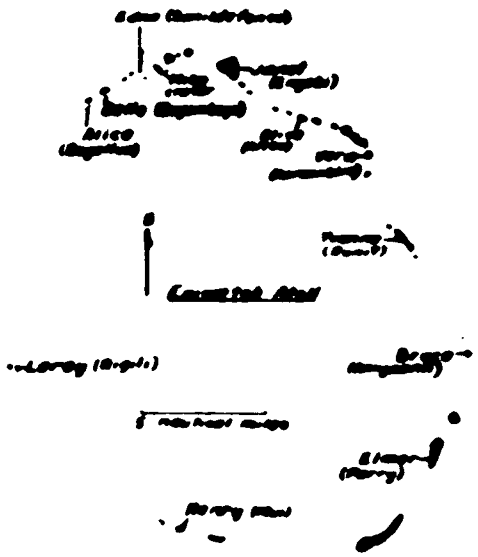

Fig. 1. Map of Eniwetok Atoll

Survey meter readings were taken frequently at Belle, but on only about half of the visits to other islands. The Juno meter was used for high (Table 2) levels of activity and the Geiger counter (Nuclear, MX-5) for low levels. Several spots were usually monitored with the instrument one inch from the ground and with the shield both open and closed. Similar readings three feet from the ground were taken less frequently and are not included.

For the distributional study on the various islands a handful of island soil from the top inch, intertidal beach sand, a few milliliters of sea water, algae, and three sea cucumbers were taken. Periodic trips by M-boat around the periphery of the lagoon, a mile or two centrally from the islands, served for sampling sea water, plankton, and pelagic fish by rod and reel. Plankton tows usually lasted from 15 to 30 minutes at from one to two knots per hour using two 1/2-meter nets, fine (No.20 of 173 mesh/inch) and coarse (No.6 of 74 mesh/inch) towed simultaneously from either side of the M-boat. Large jellyfish if present were removed and the samples preserved by adding formalin to make 5%.

At Belle Island, the invertebrates usually sampled were the killer clam Tridacna, the spider snail Lambis, the land hermit crab Coenobita, the black sea cucumber Holothuria atra, and the branching corals Acropora, Porites, Pocillopora, and Heliopora. Fish, and aquatic invertebrates were usually collected along the north or ocean side, algae on the lagoon and ocean sides, land plants in the central portion, land hermit crabs among the bushes of the north edge, and terns nearby. Rats were obtained centrally on Janet Island.

Invertebrates and fish were collected at low tide when possible. Biological specimens were put on ice in insulated containers and transported to the laboratory at Elmer Island for immediate preparation or for freezing until time was available for dissection.

Soil samples were dried and packaged for shipment. Five-milliliter samples of sea water were dried on 1 1/2-inch stainless steel plates and ashed, except that in 1956, 100-milliliter samples were used because of the low level of the activity. These were treated with sodium carbonate to remove potassium (K^{40} contributes about 0.6 disintegrations per minute per milliliter), and then filtered [illegible] the precipitate used for counting. Radiocesium is also lost by treatment with sodium carbonate (UWFL-46: 10).

Plankton was prepared by filtering and removing as much as 1-2 grams to the 1 1/2-inch counting plates, drying, and ashing. From occasional poor tows the wet sample weight was as low as 0.1 gram.

Portions usually sampled from the invertebrates were: from clams, mantle, adductor muscle, gill, kidney, visceral mass, and shell; from spider snails, mantle, muscle of foot, terminal portions of liver and gut, visceral mass, and shell; from the land hermit crab, gill, digestive gland or liver, gut, carapace, and muscle of leg; from sea cucumbers, gonad when sufficiently plentiful, gut and contents, muscle of the body wall, and body wall or integument with or without attached muscle; and from coral the terminal portions of small branches. Shell samples of clams and snails were usually taken from the thin edge to include periostracum.

The term gut as used in this report implies any portion of the digestive tract not more specifically designated and includes the contents.

Sample size was influenced somewhat by the nature of the sample and the amount of radioactivity present. When activity was low, larger samples were used. Between 50 and 200 milligrams of ash were usually considered desirable, but weights ranged widely, from less than 10 to more than 1000 milligrams. Shell and gut with sandy content were more lightly sampled on a wet weight basis than soft tissues.

Weighed samples of tissues in pliofilm bags were dried overnight at 100° C and sent to the Applied Fisheries Laboratory in Seattle for processing, which was usually accomplished about a month after collecting.

In processing, the samples in pliofilm bags were applied to the plates (1 1/2-inch stainless steel, previously weighed), ashed overnight at 500° - 550° C, slurried with alcohol, and dried. The plated ash received a few drops of Formvar dissolved in ethylene dichloride (up to 1 mg dry equivalent) to affix the ash to the plate. The plates were then weighed, and counted in methane gas-flow counters.

Except in the case of rats, counts were corrected back to date of collection using the decay rate of island soil (plate 7542) collected May 15, 1954 at Belle (Fig. 5, p. 11). For rats the decay correction was based upon the individual decay rate for each plate.

Self-absorption correction factors were based upon land soil collected June 7, 1954 at Edna, the decay curve of which (plate 9170) appears in Figure 5, page 11. Within seven months after Nectar an increase in average energy necessitated a reduction in the self-absorption correction factor for the later counting. The following tabulation illustrates these changes.

Ash weight in mg/plate	Self-absorption correction factor for counting	
	Before November 1, 1954	After November 1, 1954
3	1.0	1.0
10	1.1	1.1
30	1.4	1.3
100	2.0	1.6
300	2.9	1.9
1000	4.3	2.5

Geometry and backscatter for the counters and plates used required a combined correction factor of 1.54. Coincidence correction factors were determined and applied for the counters employed. For the decay curves plate counts were used, corrected only for coincidence.

Applying these correction factors gave values in disintegrations per minute per gram (d/m/g) of wet tissue as of the date of collection. Processing techniques are further discussed in UWFL-43 and WT-616. Three significant figures were retained throughout the calculations, finally being rounded to two. After plotting d/m/g against time the ordinate was in some graphs calibrated also in microcuries per kilogram (uc/kg), assuming 1 uc to equal 2.2 x 10^6 d/m.

The Nectar test (May 14, 1954) was used as the date of origin except where otherwise indicated, but earlier shots also contributed radioactivity to the samples studied. Especially the Bikini (March 1, 1954) shot contributed greatly to some of the samples. Residual long-lived products from earlier detonations prior to 1954 rendered the curves less steep than they would have been as a result of the 1954 series alone.

The trends of activity as related to time are of two kinds, the physical decay of individual samples, and the rate of change in activity of a certain type of sample at a certain locality. To distinguish it from physical decay, the latter trend will be referred to in this report as decline.

Results are shown as graphs of the relationship of logarithm of radioactivity to logarithm of time of collection after detonation. The date of origin used may deviate somewhat from detonation day or the true origin without markedly affecting linearity of the plot over the period of study. The slope is changed according to the date of origin selected, but if the same origin is used for both decay and decline, the two may be compared.

Hunter and Ballou (1951) show on logarithmic plot the theoretical decay of mixed slow-neutron-initiated fission products of U-235 over a period from 1 to 1000 days as a slightly curving line with a predominantly downward curvature (concave below) and a general slope varying from -1.0 to -1.7, averaging -1.2 (Fig. 2). A similar presentation of the trends of radioactivity observed in the present study facilitates comparison with this curve and within the study itself.

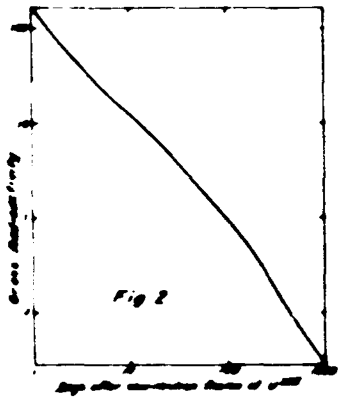

Fig. 2. Mixed fission product decay, gross beta. (After Hunter and Ballou).

In log-log graphs it will be convenient to speak of slopes or rates of decline and decay as becoming more or less steep with the passage of time, and when the terms steepening or leveling are applied to the trends, the log-log relationship is implied. A single half life when plotted semilogarithmically gives a straight line, while on the same plot a mixture of half lives results in a line of increasing steepness.

In the declines shown as straight lines on log-log plots possible fluctuations of a cyclic nature attributable to season or other variables are ignored.

RESULTS

Plan of presentation

For each of the ten primary subjects of investigation (survey meter readings, soil, water, plankton, algae, land plants, invertebrates, fish, birds, and rats), the trends or declines are shown graphically, and in some cases also in tabular form. For all subjects the regressions along with relevant data are brought together in Table 1. Where available the pre-Nectar level appears near the left edge of the decline graph as either a short horizontal bar or wedge.

For the straight lines depicting the declines where linearity appears to prevail, the time span involved is stipulated in Table 1 as well as being shown by the abscissal range of the lines in the graphs.

For conversion between microcuries and disintegrations per minute the following relationship was employed:

$$1 \text{ uc} = 2.2 \times 10^6 \text{ d/m}.$$

The log-log regression line is determined by its slope and y-intercept on day number 1, according to the relationship:

$$Y = at^b,$$

where Y is the amount of radioactivity at time t in days after assumed detonation day, and a is the y-intercept expressed in units of radioactivity of the regression line of slope b on day number 1. For example, the second entry in Table 1, survey meter readings at Belle, graphed in Figure 3, involved observations on 16 days over the period 5-540 days after Nectar. The regression was

$$Y = 2.5 \times 10^3 \, t^{-1.14} \text{ mr/hr},$$

with a correlation of -.971, which is far beyond the 1% level of P.

Along with decline data, available decays for as nearly simultaneous periods as possible are presented for comparison. Decays start later than declines because declines were corrected back to date of collection, while decays are for the actual dates of counting.

On the decay graphs the ordinate represents gross beta plus the negligible alpha and gamma activity that would be detected.

Decay curves even on the same graph are not comparable to one another as to absolute levels, because of vertical shifting to obtain compact presentation, but may be compared as to slope.

Table 1. Relationship of amount of radioactivity to time after detonation in 1954 at Eniwetok Atoll.

Subject	Locality	Detonation date to which referred	Time span involved, days after detonation	Units of radio-activity	Day #1 intercept of regression	Log-log decline rate, negative	n, days sampled	Correlation coeff. r, neg	P in %
Survey meter, shield closed, 1"	Belle	5/14/54	1-311	mr/hr	5.6×10^{2}	1.06	19	.980	<<1
Survey meter, shield open, 1"	Belle	5/14/54	5-540	mr/hr	2.8×10^{3}	1.14	16	.971	<<1
Island soil, top inch	Alice	"	22-270	uc/kg dry	8.8×10^{4}	1.30	8	.866	<1
" " " "	Belle	"	1-710	" "	1.3×10^{4}	1.26	13	.987	<<1
" " " "	Janet	"	22-710	" "	9.7×10^{2}	.87	10	.606	6
" " " "	Olive	"	22-270	" "	6.0×10^{3}	1.60	8	.768	4
" " " "	Vera	"	22-270	" "	1.1×10^{2}	.64	[illegible]	.610	7
" " " "	Bruce	"	22-270	" "	1.1×10^{3}	1.69	8	.986	<<1
" " "	Elmer	"	22-710	" "	1.4×10^{2}	1.47	5	.948	<1
" " " "	Henry	"	22-710	" "	2.8×10^{2}	1.44	10	.815	<1
" " " "	Leroy	"	22-540	" "	3.7×10^{1}	.92	9	.643	7
Beach sand, intertidal	Alice	"	[illegible]	" "	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
" " "	Janet	"	22-710	" "	1.6×10^{2}	.79	10	.594	8
" " "	Olive	"	22-270	" "	1.0×10^{2}	.84	8	.617	>10
" " "	Vera	"	22-710	" "	2.1×10^{1}	.60	9	.717	4
" " "	Bruce	"	22-270	" "	9.0×10^{2}	1.36	8	.841	<1
" " "	Elmer	"	22-710	" "	3.7×10^{2}	1.23	5	.838	9
" " "	Henry	"	22-710	" "	5.2×10^{3}	1.88	10	.990	<<1
" " "	Leroy	"	22-540	" "	1.2×10^{3}	1.39	9	.915	<1
Sea water	Alice	"	38-220	d/min/ml	6.6×10^{3}	1.57	3	.976	>10
" " , ocean side	Belle	"	1-720	"	3.4×10^{3}	1.28	19	.871	<<1
" " lagoon reef	"	"	42-540	"	8.5×10^{5}	2.91	10	.944	<<1
" " plankton station	"	"	5-310	"	7.7×10^{5}	2.30	10	.986	<<1
" "	Edna	"	50-270	"	2.4×10^{5}	1.80	3	.947	>5
" "	Flora	"	5-26	"	5.4×10^{4}	1.8	2	--	-
" "	Janet	"	38-710	"	1.8×10^{4}	1.80	6	.913	1
" "	Olive	"	38-270	"	5.9×10^{3}	1.47	4	.991	1
" "	Vera	"	26-720	"	2.3×10^{5}	2.22	11	.924	<<1
" "	Bruce	"	38-720	"	1.9×10^{5}	2.14	5	.998	<1
" "	Deep Entr.	"	33-720	"	1.2×10^{5}	2.13	9	.896	<1
" "	Wide Pass.	"	26-310	"	7.8×10^{5}	2.40	9	.965	<<1
" "	Henry	"	38-270	"	2.2×10^{4}	1.66	4	.951	5
" "	Leroy	"	5-310	"	8.6×10^{5}	2.41	12	.986	<<1
" " except Belle ocean	All above	"	5-720	"	3.0×10^{5}	2.24	91	.935	<<1
" "	All	"	1-720	"	3.9×10^{4}	1.76	110	.991	<<1
Plankton	Belle	"	5-530	d/m/g wet	4.0×10^{8}	1.85	12	.955	<<1
"	"	"	"	" ash	1.9×10^{6}	1.52	12	.965	<<1
"	Mike crater	"	5-200	" wet	5.0×10^{7}	1.15	3	.998	4
"	" "	"	"	" ash	3.2×10^{5}	1.00	3	.975	>10
"	Vera	"	26-530	" wet	3.1×10^{6}	1.04	10	.515	>10
"	"	"	"	" ash	8.8×10^{4}	1.09	10	.608	7
"	Deep Entr.	"	33-710	" wet	7.9×10^{8}	2.15	13	.761	<1
"	" "	"	"	" ash	6.2×10^{6}	1.93	13	.748	<1
"	Wide Pass.	"	26-310	" wet	3.4×10^{9}	2.61	10	.840	<1
	" "	"	"	" ash	3.4×10^{7}	2.37	10	.871	<1
	Leroy	"	5-530	" wet	3.2×10^{8}	2.23	12	.947	<<1
"	"	"	"	" ash	2.6×10^{6}	1.90	12	.943	<<1
"	All six	"	5-710	" wet	2.8×10^{8}	1.96	60	.833	<<1
"	" "	"	"	" ash	2.2×10^{5}	1.74	60	.849	<<1
Halimeda (calcareous algae)	Alice	"	20-270	uc/kg wet	2.1×10^{4}	2.02	8	.963	<<1
"	Belle	"	20-710	" "	5.5×10^{4}	2.13	9	.965	<<1
"	Janet	"	20-710	" "	5.0×10^{3}	1.69	9	.947	<<1
"	Olive	"	20-270	" "	5.4×10^{3}	1.76	8	.970	<<1
"	Vera	"	20-710	" "	3.2×10^{4}	2.06	9	.954	<<1
"	Bruce	"	20-270	" "	2.0×10^{5}	2.50	3	.982	>5
"	Elmer	"	20-530	" "	3.2×10^{4}	2.28	7	.927	<1
"	Henry	"	20-530	" "	9.0×10^{3}	2.00	9	.938	<<1
"	Leroy	"	20-530	" "	1.0×10^{6}	2.91	9	.979	<<1
Land plants, green leaves	Belle	"	3-710	d/m/g wet	7.6×10^{6}	1.63	114	.883	<<1
Acropora (coral, tips)	Belle	"	36-710	" "	2.7×10^{8}	2.23	11	.976	<<1
Clam (*Tridacna*), kidney	Belle		1-710	" "	9.4×10^{5}	.71	29	.950	<<1
" " visceral mass	"	"	1-710	" "	2.0×10^{6}	1.07	29	.866	<<1
" " gill	"	"	1-710	" "	5.6×10^{5}	.96	29	.963	<<1
" " shell	"	"	1-710	"	3.3×10^{5}	.99	25	.899	<<1
" " mantle	"	"	1-710	" "	2.0×10^{5}	.94	29	.961	<<1
" " muscle	"	"	1-710	" "	7.3×10^{4}	.90	29	.967	<<1

Table 1, continued.

Subject	Locality	Detonation date to which referred	Time span involved, days after detonation	Units of radio-activity	Day /1 intercept of regression	Log-log decline rate, negative	n. days sampled	Correlation coeff. r, neg	P in %
Spider snail (*Lambis*), liver	"	"	8-540	" "	2.5×10^7	1.10	9	.887	<1
" " " gut	"	"	8-310	" "	8.1×10^6	.93	9	.980	<<1
" " " mantle	"	"	8-310	"	8.4×10^5	.82	8	[illegible]	2
" " " muscle	"	"	8-540	" "	2.1×10^5	.86	10	.980	<<1
" " " shell	"	"	8-310	" "	9.1×10^5	1.18	9	.986	<<1
Hermit crab *Coenobita*, carapace	"	"	3-710	" "	9.0×10^6	1.08	30	.980	<<1
" " " muscle	"	"	3-710	" "	2.7×10^6	.98	30	.980	<<1
" " " liver	"	"	3-540	" "	5.3×10^6	1.[illegible]	29	.986	<<1
" " " gut	"	"	3-308	" "	2.4×10^7	1.66	[illegible]	.980	<<1
" " " gill	"	"	3-308	" "	1.8×10^6	1.[illegible]	[illegible]	[illegible]	<<1
Sea cucumber *H. atra* gonad	Alice	"	39-710	" "	5.0×10^7	1.73	8	.908	<1
" " gut	"	"	"	" "	2.1×10^6	1.14	8	.887	1
" " muscle	"	"	"	" "	2.2×10^7	1.66	8	.980	<<1
" " integument	"	"	"	" "	9.1×10^7	2.08	8	.980	<<1
" " *H. atra* gonad	Belle	"	38-540	" "	8.2×10^7	1.64	10	.931	<<1
" " gut	"	"	"	" "	6.2×10^6	1.15	10	.930	<<1
" " " muscle	"	"	"	" "	2.6×10^7	1.67	10	.986	<<1
" " " integument	"	"	"	" "	7.8×10^7	2.01	10	.966	<<1
" " *H. atra* gonad	Janet	"	38-710	" "	4.6×10^7	1.93	7	.933	<<1
" " " gut	"	"	"	" "	2.6×10^7	1.66	7	.893	<1
" " " muscle	"	"	"	" "	2.5×10^7	1.86	6	.966	<1
" " " integument	"	"	"	" "	3.8×10^7	2.08	7	.987	<<1
" " *H. atra* gonad	Olive	"	21-280	" "	1.8×10^6	1.13	8	.817	<2
" " " gut	"	"	"	" "	1.6×10^6	1.13	8	.919	<1
" " " muscle	"	"	"	" "	5.5×10^5	1.16	8	.986	<<1
" " integument	"	"	"	" "	4.4×10^5	1.06	8	.878	1
" " *H. atra* gonad	Vera	"	39-710	" "	6.8×10^7	1.84	8	.914	<<1
" " " gut	"	"	"	" "	1.3×10^8	1.82	8	.969	<<1
" " " muscle	"	"	"	" "	4.9×10^7	1.99	8	.913	<<1
" " " integument	"	"	"	" "	1.8×10^8	2.24	8	.975	<<1
" " *H. atra* gonad	Bruce	"	39-710	" "	5.9×10^7	1.86	9	.903	<<1
" " " gut	"	"	"	" "	1.6×10^8	2.04	9	.974	<<1
" " " muscle	"	"	39-540	" "	3.2×10^6	1.48	8	.907	<<1
" " " integument	"	"	39-710	" "	3.9×10^7	1.94	9	.961	<<1
" " *H. atra* gonad	Elmer	"	41-710	" "	2.0×10^6	1.43	8	.918	<<1
" " " gut	"	"	"	" "	3.7×10^7	1.87	8	.965	<<1
" " " muscle	"	"	"	" "	1.6×10^6	1.45	7	.953	<<1
" " " integument	"	"	"	" "	4.6×10^6	1.65	8	.943	<<1
" " miscel. gonad	Henry	"	39-710	" "	7.3×10^6	1.66	9	.841	<1
" " gut	"	"	"	" "	5.4×10^7	1.97	9	.943	<<1
" " " muscle	"	"	"	" "	7.9×10^6	1.71	8	.872	<1
" " " integument	"	"	"	" "	1.4×10^8	2.19	9	.846	<1
" " miscel. gonad	Leroy	"	125-710	" "	4.9×10^9	2.75	7	.916	<1
" " " gut	"	"	"	" "	5.0×10^9	2.54	7	.932	<1
" " " muscle	"	"	"	" "	4.4×10^{13}	4.16	7	.914	<1
" " " integument	"	"	"	" "	5.1×10^{12}	3.74	7	.883	<1
Fish, all species skin	Belle	"	13-311	" "	2.5×10^7	1.90	21	.965	<<1
" " " gut	"	"	13-311	" "	2.0×10^7	1.43	21	.936	<<1
" " " muscle	"	"	13-710	" "	6.7×10^5	1.49	23	.969	<<1
" " " bone	"	"	13-540	" "	1.5×10^7	1.77	22	.990	<<1
" " " liver	"	"	13-710	" "	4.9×10^6	1.18	23	.930	<<1
Tern, mostly fairy, feathers	Belle	"	14-305	" "	7.0×10^5	1.28	17	.941	<<1
" " " muscle	"	"	"	" "	1.6×10^6	1.57	17	.926	<<1
" " " bone	"	"	"	" "	2.1×10^6	1.56	17	.833	<<1
" " " lung	"	"	"	" "	1.4×10^6	1.21	17	.814	<<1
" " " liver	"	"	"	" "	2.4×10^6	1.31	17	.859	<<1
" " " kidney	"	"	"	" "	3.2×10^6	1.36	17	.864	<<1
" " " gut	"	"	"	" "	2.5×10^8	2.40	17	.971	<<1
" " " all tissues	"	"	"	" "	7.7×10^6	1.63	17	.983	<<1
Rat, fur and skin	Janet	3/1/54	121-380	" "	2.3×10^5	1.15	14	.739	<1
" muscle	"	"	77-600	" "	9.8×10^4	.89	17	.711	<1
" bone	"	"	"	" "	1.3×10^7	1.49	17	.922	<<1
" lung	"	"	77-380	" "	2.7×10^6	1.59	16	.843	<<1
" liver	"	"	77-600	" "	7.8×10^4	.76	17	.578	2-3
" kidney	"	"	"	" "	5.2×10^5	1.12	16	.684	<1
" gut	"	"	77-380	" "	9.8×10^8	2.56	16	.896	<<1

Survey meter readings

Table 2 gives survey meter readings at nine islands, of which Edna, adjacent to the site of the Nectar detonation (Mike crater), was highest, with 600 mr/hr on June 7, 1954.

Figure 3 shows the series of readings at Belle with meter one inch from the ground, the shield both open and closed. Slopes of the two regression lines, -1.14 and -1.06 (Table 1) do not differ significantly. The slope is approximately that of mixed fission product decay, assuming there was a slight leveling influence due to detonations prior to 1954.

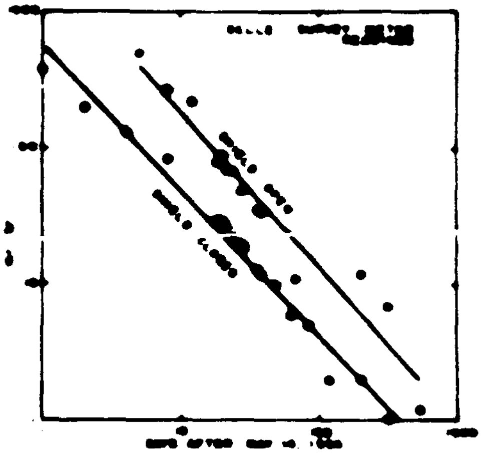

Fig. 3

Table 2. Survey meter readings in milliroentgens per hour at one inch from the ground on various islands of Eniwetok Atoll in 1954-55. Values above 20, with Juno, others with Geiger counter. Shield open except at Belle, first column, for which, shield closed.

Date	Alice	Belle		Daisy	Edna	Janet	Olive	Vera	Henry	Leroy
5/15/54		375								
16		200								
18		130								
19			500							
22		86	270							
26			280							
6/1/54		30	80							
2		30	80							
3		29	90			20	5	6		
4		27	70							
7		22	70	60	600					
10		20	50							
11		19	50							
18		13	35							
21	40	12	34		400	14	6	4	0	
7/1/54		10								
14				13						
15		6								
20	18		11			12	.7	0	.3	.1
8/5/54		5								
17	11				180					
9/7/54		2								
11/17/54	.7						.3	0	.12	.10
30		2	12							
12/3/54					20					
2/11/55	.8				16		.18	.2		.15
3/21/55		1	7							
11/1/55			1.2		3					

Island soil

Figure 4 shows the decline for island soil as well as the only two observations for beach sand at Belle. The slope for island soil of -1.06 (Table 1) corresponded closely with that of survey meter readings.

From an initial level on the first day of 13 millicuries per kilogram, the island soil declined fairly regularly for a period of two years. The dip at 130-200 days is reflected in the decline curves for land hermit crab but is not apparent in the data for green leaves of plants on Belle.

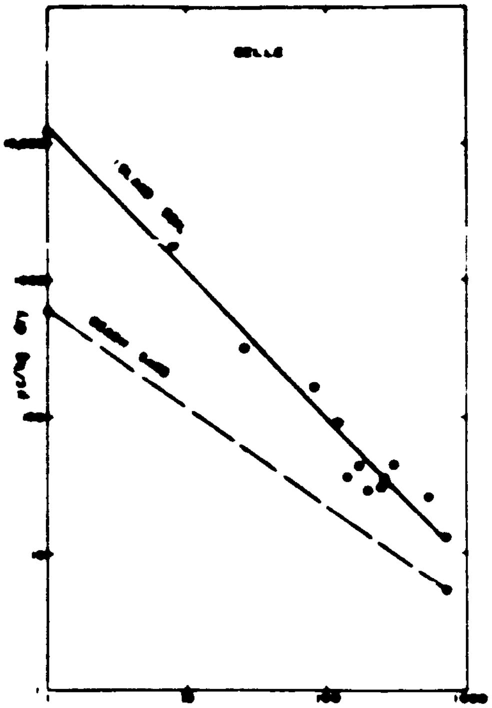

Fig. 4

Figure 5 shows the decay of samples of island soil from Belle (plate 7542) and from Edna (plate 9170), and of intertidal beach sand from Henry (plate 9711A). A slope of -1.2 is included for comparison.

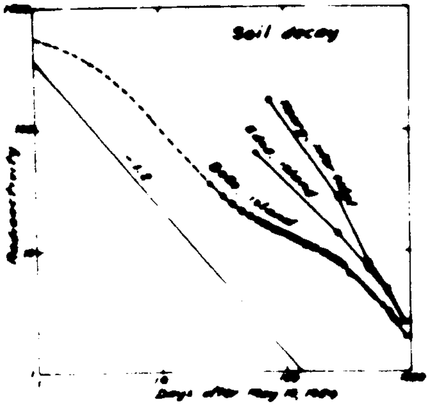

Fig. 5

The Belle island soil decay curve is for plate number 7542 which served as the basis for computation of the decay correction factors for converting values back to date of collection. The same factors were used for all types of material except rats collected post-Nectar at Eniwetok Atoll. The dashed, early portion of the curve is not a straight line because it was originally extrapolated on semi-log paper.

For comparison, Figure 6 shows the decay of the sample of lagoon bottom sand dredged November 7, 1952 off Tilda (northwest of Vera). This decay was used for calculation of decay correction factors for the collections following the Mike test in 1952 (Donaldson 1953:25), and for 20-1000 days its similarity to the theoretical curve of Figure 2 is striking. It was practically uninfluenced by residues from previous detonations. The more pronounced flexures in the curve for Belle island soil, as well as its generally more gradual slope are the result of the influence of the Mike test residues superimposed upon the Nectar test effect.

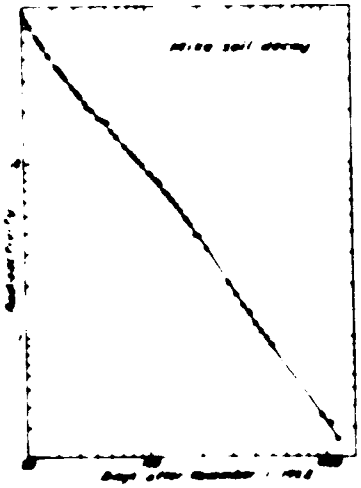

Fig. 6

Figure 7 shows island soil decline slopes at sites other than Belle. Pre-Nectar levels are indicated by short horizontal bars at the left edges of the graphs. Except at Bruce and Elmer, the points are widely scattered and the trends poorly defined. Variations in exact location of sample taking, changes of personnel, and the use of single samples contributed to this variability.

Levels of radioactivity were much higher at the northern than at the southern localities.

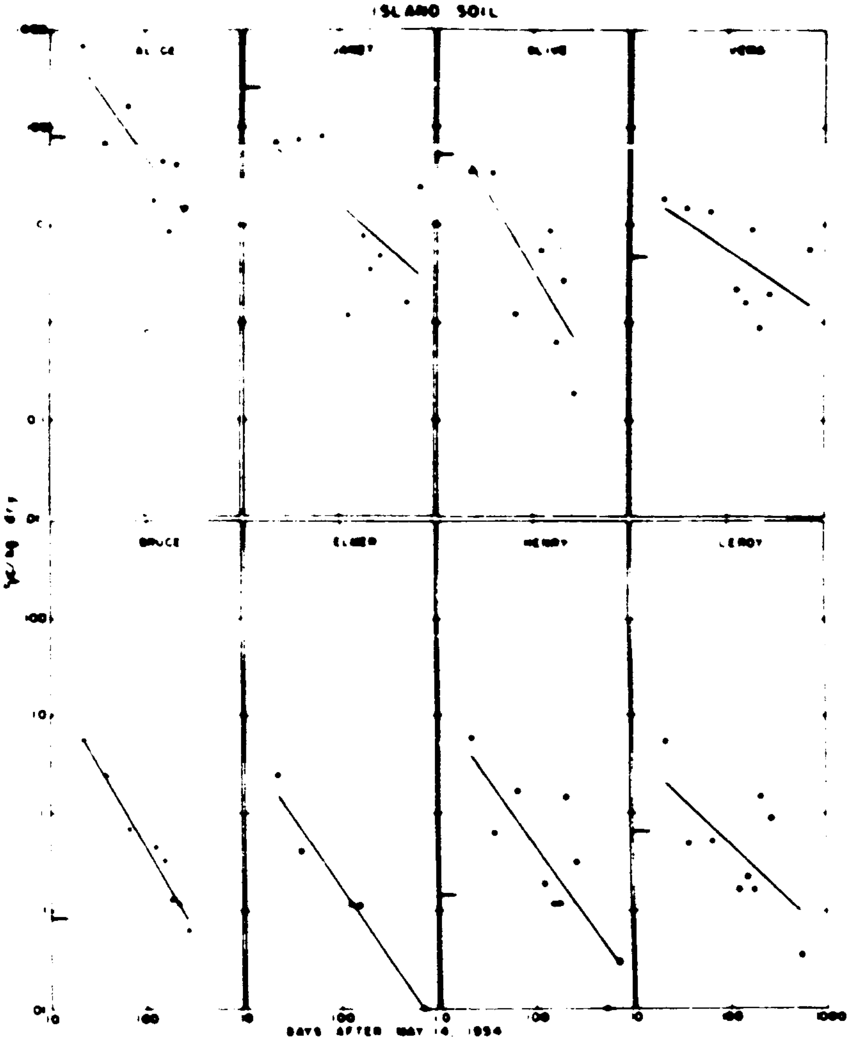

Fig. 7

Table 3 gives decay slopes of island soil samples from various islands over a time span of from one or two months to more than two years. Slopes ranged from -0.6 to -1.3, averaging -0.9 ± 0.02.

Since the five soil decay curves with more than two points are fairly straight lines, 2-point slopes were used to expand the scope of observations. The period of time covered by the decays is close to that of the declines. Table 3 shows that declines were steeper than decays except at Janet where decays were steeper, and at Vera where decay and decline were equal.

Table 3. Island soil decay rates with decline rates for comparison.

Locality	Plate number	Date of collection	Days after May 14, 1954, range	No. of times plate counted	Slope, negative		
					Decay		Decline from Table 1
					Plate	Locality, mean	
Alice	7597	6-3-54	50-540	2	.85	.9	1.4
"	7597A	"	50-540	2	1.05		
"	7597B	"	50-540	2	1.01		
Belle	7542	5-15-54	25-910	70	.7	.7	1.36
"	7543	"	49-870	4	.64		
"	9189	6-19-54	49-440	2	.62		
Edna	9170	6-7-54	49-910	5	1.2	1.2	
Janet	7595	6-3-54	49-870	2	1.27	1.3	.87
Olive	7593A	6-3-54	49-870	2	1.21	1.2	1.6
"	7593B	"	48-870	2	1.28		
Vere	7591B	6-3-54	48-870	2	.60	.6	.64
"	7591	"	49-870	2	.68		
Bruce	7587	"	50-870	2	.90	1.0	1.69
"	9196A	6-21-54	75-870	2	1.03		
"	9196B	"	75-870	2	1.21		
Elmer	9153	6-3-54	49-870	2	.78	.8	1.47
Henry	9151	"	49-870	3	.90	.9	1.44
Leroy	7599	"	48-870	4	.62	.6	.92
"	7599A	"	48-870	2	.57		

Table 4. Decay rates of intertidal beach sand, with declines from Table 1 for comparison.

Locality	Plate number	Date of collection	Days after May 14, 1954, range	No. of times plate counted	Slope, negative		
					Decay		Decline from Table 1
					Plate	Locality, mean	
Alice	9707A	6-21-54	76-870	2	.88	.9	.84
"	9707	"	"	2	.92		
Belle	7541	5-15-54	48-870	2	1.13	1.2	.7
"	7541A	"	47-870	2	1.14		
"	7541B	"	57-870	2	1.29		
Janet	9705	6-21-54	76-870	2	.80	.8	.79
Olive	9703B	"	74-870	2	1.16	.8	.84
"	7594	6-3-54	49-540	2	.96		
"	7594A	"	48-540	2	.65		
"	7594B	"	49-540	2	.55		
Vere	7592	6-3-54	49-540	2	.80	.9	.60
"	7592A	"	48-540	2	.40		
"	7592B	"	48-540	2	.70		
"	9701	6-21-54	76-870	2	.76		
"	9701A	"	75-870	2	1.23		
"	9701B	"	75-870	2	1.28		
Bruce	7588	6-3-54	49-540	2	1.00	1.5	1.36
"	7588B	"	48-540	2	.83		
"	9197	6-21-54	75-870	2	2.1		
"	9197A	"	75-870	2	2.2		
"	9197B	"	75-870	2	2.0		
Henry	9711A	6-21-54	78-910	5	1.7	1.7	1.88
Leroy	9709	"	76-870	2	2.2	2.2	1.39
"	9709A	"	76-870	2	[illegible]		

Beach sand

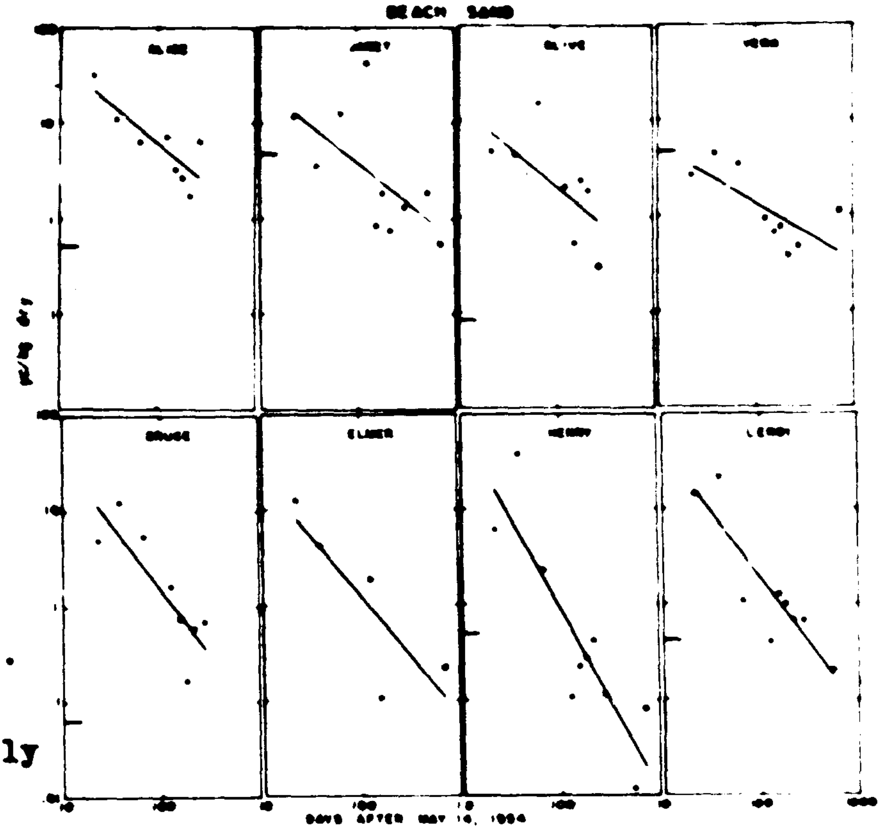

Fig. 8

Intertidal beach sand at Belle was sampled only twice, at the first and the last of the experimental period (Fig. 4). These sparse data suggest a considerably lower initial level than for island soil, and a somewhat lower decline rate of -0.7.

Figure 8 shows beach sand declines for eight islands, and pre-Nectar levels except at Elmer. As with island soil there was great variability, possibly because of the continual shifting of the sand. The northern islands were only slightly more radioactive than the southern islands, but the declines at the southern islands, especially Henry and Leroy, tended to be steeper than at the northern islands.

The slower decline at northern than at southern islands is probably caused by a greater residue of radioactivity from previous detonations (higher pre-Nectar levels) at northern localities, possibly associated with the water currents.

The decays for beach sand are given in Table 4, page 13. Except for Henry (Fig. 5), these are based upon only two points. Beach sand decays were appreciably steeper at the southern than at the northern islands. The relationship between the slopes of declines and decays was inconsistent. At Henry decline slightly exceeded decay. At Leroy decays were steeper than declines, and at other localities differences were negligible. In general, decays were steeper than declines, although not convincingly so.

Sea water

Sea water sampling was most extensive at Belle as Table 5 shows. Data from plankton stations at Belle, lagoon reef, and ocean reef are presented separately, while at other localities all of the data for an island are combined.

Table 5. Radioactivity of sea water samples expressed as disintegrations per minute per milliliter (d/m/ml). The value indicates two samples except where the number of samples follows the parenthesis.

Day	Date	Belle			Alice	Edna	Flora crater	Janet	Olive	Vera	Bruce	Deep Entr.	Wide Pass.	Henry	Leroy
		Plankton station	Lagoon reef	Ocean reef											
1	5/15/54			2600											
2	16			590											
3	17			500											
4	18			123(1											
5	19	25,000		117			3400								16,000
7	21			540											
8	22			2800											
12	26			170											
14	28			130											
18	6/1/54			430											
21	4			95											
24	7			137											
26	9	273					170			86			380		610
28	11			72											
31	14											120(4			
36	19			380											
38	21				21			21	27	36	67			57	66
42	25		54												
48	7/1/54		50												
50	3					360(4									
53	6	57								62		7.2	46		60
56	9		53												
60	13					80(8									
62	15		46												
74	27	24								22		5.4	10		26
76	29		40												
88	8/10/54		3.7												
116	9/7/54		14												
140	10/1/54	18								16		20	18		16
[illegible]	6			17											
[illegible]	[illegible]							2.1							
172	11/2/54			7.6(1											
176	6	3.1								3.6		3.4	2.8		2.2
187	17				2.5			1.1	2.8	1.4	3.1			3.1	2.0
[illegible]	12/3/54	1.7										1.4	1.7		2.2
217	17	2.0			1.0			.85	2.6	.43(4	2.5	2.3	2.3	1.7	1.5(6
274	2/12/55	5.0(1	.41(1	2.6(1		10			1.2	.54(3	1.2	.30(1	.50(1	3.6	.66(3
311	3/21/55	1.1(1	.57(1	.37(1				2.2		2.2(1		-.54(1	.55(1		.65(1
536	11/1/55		.081												
713	4/26/56			.075				.082		.063	.12	.078			

Additional data: 6/21/54, Yvonne, 21, and Elmer, 60; 7/14/54, Daisy, 88(6.

Figure 9 shows the declines for sea water at 12 localities. Variability was moderate except for the low values of early points for the ocean reef at Belle. The slopes were steeper than for meter readings, soil, or beach sand at most localities. At Belle, omitting the early ocean reef collections, the slopes were as steep as at Leroy, in contrast to the declines for sea cucumbers, beach sand, and algae, which were much steeper at Leroy.

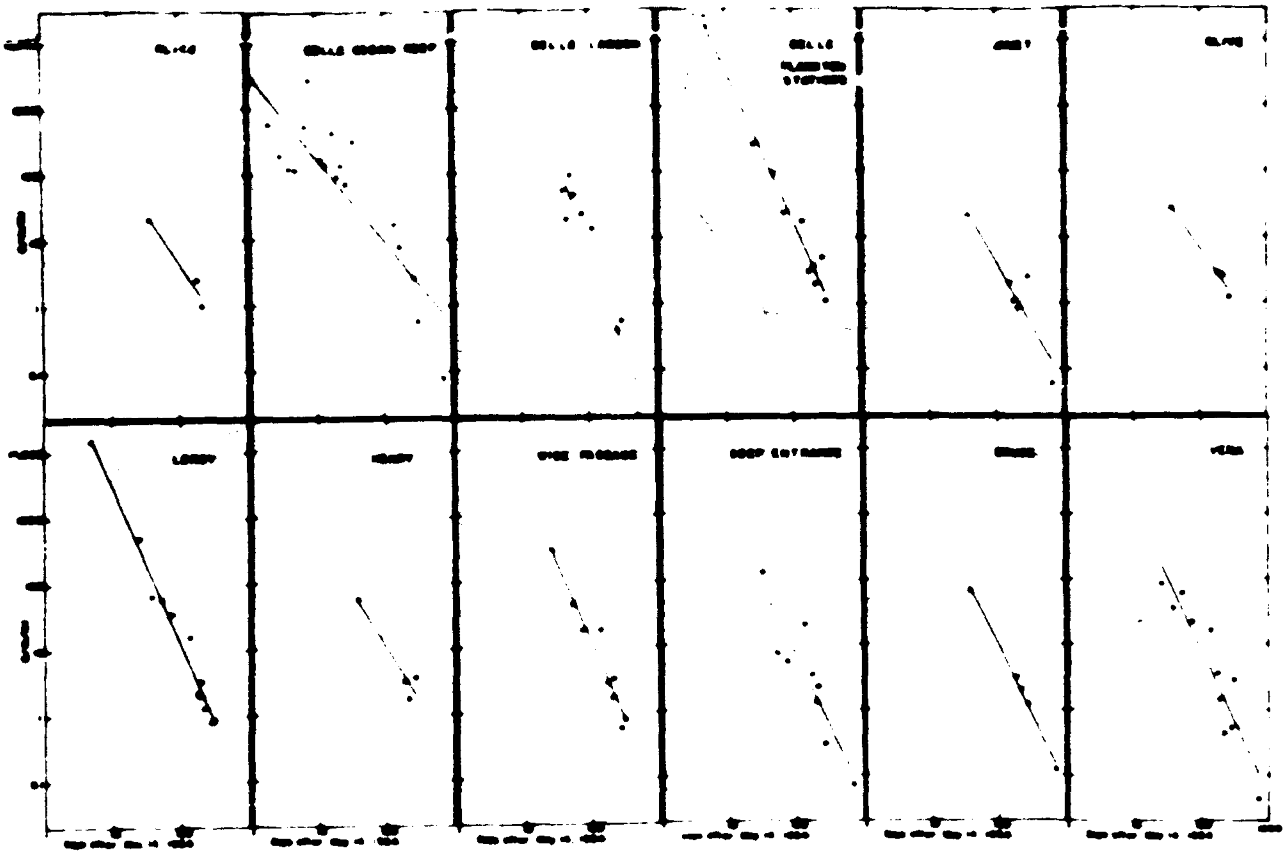

Fig. 9

Figure 10 is a scatter diagram of the sea water decline data of Table 5. The "Belle, outer" regression line is the same as that of Figure 9, Belle ocean reef. The regression for all data combined is shown as well as the steepest line for all data other than that of Belle, outer. The data for the sea water sampling at Eniwetok Atoll exclusive of Belle ocean reef give a decline slope of about -2.2.

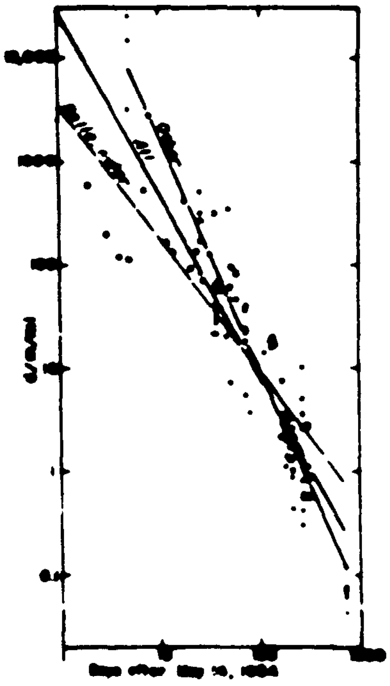

Fig. 10

The decays for sea water are given in Table 6 and Figure 11. Counting errors were large because of the low levels of nearly all of the later counts. The contribution to the radioactivity by K^{40} was compensated for by subtracting 1 from each count per minute per 5 milliliter plate. One count per minute per plate was equivalent to 3 d/m/plate, because the correction factor for geometry, back scatter, and self absorption was approximately 3.

Table 6. Decay rates of sea water samples collected at Eniwetok Atoll in May, June, and July 1954, with corresponding decline rates from Table 1 for comparison. Data for Fig. 11.

Curve number	Plate numbers	Locality	Time span in days after 5/14/54, of decay slope	Slope, negative Decay	Slope, negative Decline, from Table 1
1	7567-68	Belle, ocean side	33-630	1.3	1.88
2	7569-70	" " "	33-630	1.5	1.88
3	7575-76	" plankton station	55-910	1.3	2.30
4	7585-86	" ocean side	39-630	1.5	1.88
5	9803-04	" lagoon side	100-800	1.0	2.91
6	9793-94	Wide Passage	100-300	1.2	2.40
7	7572	Leroy plankton sta.	55-940	1.5	2.41
8	9161	" " "	49-940	1.5	2.41
9	9795-96	" " "	100-300	1.4	2.41

The data of Table 6 for the 9 sea water decays are graphed in Figure 11. With the exception of Belle, ocean side (curves 1, 2, and 4) where decline was unusually gradual because of low early values, declines were steeper than decays.

The decay curves tend to level terminally, even after subtraction of the activity due to K^{40}.

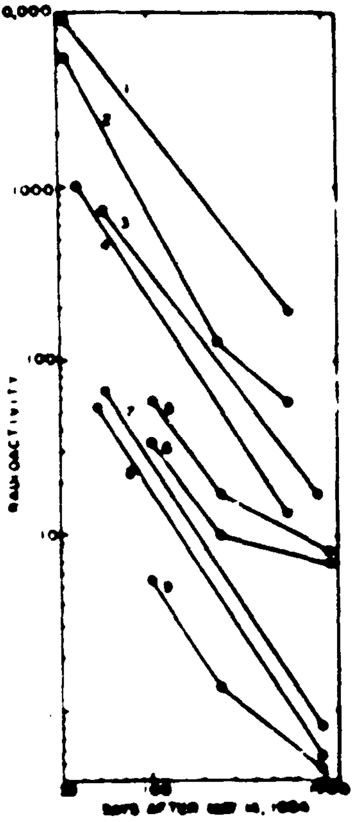

Fig. 11

Plankton

Amounts of radioactivity per unit of wet weight of plankton in samples from each tow appear in Table 7, and on the basis of ash weight, in Table 8. This dual analysis is intended to evaluate the appropriateness of the wet basis as compared to the ash basis in considering the radioactivity of plankton. Where simultaneous fine and coarse mesh tows

Table 7. Gross beta radioactivity of plankton samples in thousands of d/m/g of wet weight at Eniwetok Atoll in 1954-56.

Date	Belle			Mike crater			Vera			Deep Entrance			Wide Passage			Leroy		
	Net mesh			Net mesh			Net mesh			Net mesh			Net mesh			Net mesh		
	#6	?	#20	#6	?	#20	#6	?	#20	#6	?	#20	#6	?	#20	#6	?	#20
5/6&7/54		12.5			13.0			8.2									2.3	
5/19/54	10900		12900	8170		12800										5000		5500
6/9/54	802		2990	670		1360	900		400				220			660		370
6/16/54											186							
7/6/54	270		287				3.1		15	16.0		38	41		42	54		49
7/27/54		148						3.2			211			123			113	
		84						6.0			54			190			62	
9/1/54	82		58				33		9.1	19.5		33	63		39	30		2.5
10/1&8/54	12		33				1.1		32	4.2		7.6	77		12	17		2.8
11/6/54	46		150				105		250	234		216	8.7		6.3	28		21
11/26/54				121		163				5.6		6.1						
				60		180												
11/27/54				61		72				38		30						
				220		121				53		56						
12/3/54	12.7		30							6.6		5.8	.84		1.01	11.5		6.2
12/17/54	15.6		105				24		67	65		58	21		2.8	2.3		10.8
2/12/55	3.6						4.7			2.3			.34			.52		
3/16/55													.27			.37		
3/21/55	7.0						7.6			12.6								
	10						32			25								
10/29/55		.85						.55			.47						.091	
		3.4						2.2			.32						.22	
											.11							
											.41							
4/27/56										.034	.083							

Additional "? mesh": on 5/6–8/54, Janet 9.6, Yvonne 1.8, Bruce 2.0, Elmer 2.5, and Henry 3.4; on 4/27/56, Bruce 0.73 and 0.49.

Table 8. Gross beta radioactivity of plankton samples in thousands of d/m/g of ash weight at Eniwetok Atoll in 1954-56.

Date	Belle			Mike crater			Vera			Deep Entrance			Wide Passage			Leroy		
	Net mesh			Net mesh			Net mesh			Net mesh			Net mesh			Net mesh		
	#6	?	#20	#6	?	#20	#6	?	#20	#6	?	#20	#6	?	#20	#6	?	#20
5/6&7/54		97			54			101									13.5	
5/19/54	140000		99000	58900		107000										76000		58000
6/9/54	6300		13000	8400		6800	10100		4230				6860			3600		2430
6/16/54											3920							
7/6/54	7700		8000				125		496	574		863	1200		1080	1420		1680
7/27/54		8400						95			350			2240			770	
7/27/54		2100						147			1070			4000			1060	
9/1/54	1830		1580				797		217	584		745	1100		623	434		78
10/1&8/54	830		1120				87		861	167		210	1840		630	380		223
11/6/54	1400		900				2540		3660	3210		3600	364		2.5	437		332
11/26/54				1170		1310				300		144						
11/26/54				738		1200												
11/27/54				2180		3410				2170		986						
11/27/54				5860		1250				2000		1270						
12/3/54	810		1340							444		284	44		111	640		325
12/17/54	760		840				604		542	1380		779	508		77	151		149
2/12/55	118						188			164			13.8			80		
3/16/55													12.8			4.4		
3/21/55	280						128			468								
3/21/55	186						438			307								
10/29/55		41						30			21.5						5.0	
10/29/55		153						11.8			10.6						10.6	
10/29/55											2.78							
10/29/55											8.34							
4/27/56										.7	[illegible]							

Additional "? mesh": on 5/6–8/54, Janet 58, Yvonne 50, Bruce 78, Elmer 78, and Henry 26; on 4/27/56, Bruce 1.36.

permitted comparison, the data are shown separately, and other data appear in columns headed with question marks for mesh, usually either No. 6 of 74/inch or No. 20 of 173/inch.

Table 9 shows for the paired tows the ratio of the activity per unit weight in coarse mesh to that in fine (No.6/No.20 on both a wet and ash weight basis.

Table 9 Ratio of radioactivity in tows with coarse mesh to fine mesh (#6/#20) on wet and ash weight bases. Data from Tables 7 and 8.

Date	Belle		Mike Crater		Yoro		Deep Entrance		Wide Passage		Leroy	
1954	Wet	Ash	Wet	Ash	Wet	Ash	Wet	Ash	Wet	Ash	Wet	Ash
5/19	.84	1.41	.33	.55							.77	2.00
6/9	.27	.48	.49	1.23	2 25	2.39					1.78	3.95
7/6	.95	.96			.21	.25	.49	.67	.98	1.11	1.14	.86
9/1	1.39	1.18			3.62	3.67	.59	.70	1.61	1.77	12.0	6.21
10/1&2	.36	.47			.034	.78	.55	.80	6.41	2.98	6.8	1.43
11/6	.31	1.56			.41	.71	1.09	.89	1.38	1.65	1.38	1.32
11/26			.74	.89			.95	1.39				
11/26			.33	.61								
11/27			.85	.62			1.26	2.20				
11/27			1.82	4.21			.95	1.57				
12/3	.42	.60					1.13	1.68	.83	.44	1.85	1.97
12/17	.18	.90			.36	1.11	1.32	1.69	7.50	6.56	.21	1.01

Between the northern localities of Belle Island and the Mike crater and the southern localities of Wide Passage and Leroy Island, there was a difference using the t test, significant at the 2% level on the ash basis. The reason is not apparent for this association of high counts with fine mesh nets at northern, and with coarse at the southern and western localities.

Whereas, in 1952 (WT-616) significantly higher radioactivity occurred in fine mesh net hauls than in coarse, the present data show wide variation. On the wet basis the coarse mesh was higher in 18 pairs and the fine mesh in 25 pairs, while on the ash basis the figures were reversed, the coarse mesh was higher in 25 pairs and the fine mesh in 18 pairs. Thus, neither wet nor ash basis showed a significant difference due to mesh size.

Assuming, as these results indicate, that activities in coarse and fine meshes do not differ, the ratio of coarse to fine should be unity. The ratios in Table 9 were used to determine variability on the wet as opposed to the ash basis. On the ash basis, variance was only half as great as on the wet basis, thus, ash is considered the better basis. Conversion to logarithms was necessary to normalize the skewed (with peak toward the left) frequency distribution of the two arrays of ratios.

Figure 12 shows the decline for plankton samples at 6 localities on a wet weight basis using the data of Table 7, with the two values for paired tows averaged.

Except at the Mike crater and Vera the declines were steep, ranging from -1.8 to -2.61 as seen from Table 1, with an average for all localities combined of -1.96, wet basis, and -1.74 on the ash basis. The gradual decline (-1.0) at the Mike crater could be the result of continuous leaching of radioisotopes, from the crater into the water, thereby maintaining the activity of the plankton. At Vera the trend is too poorly defined (P > 10%) to permit comparisons.

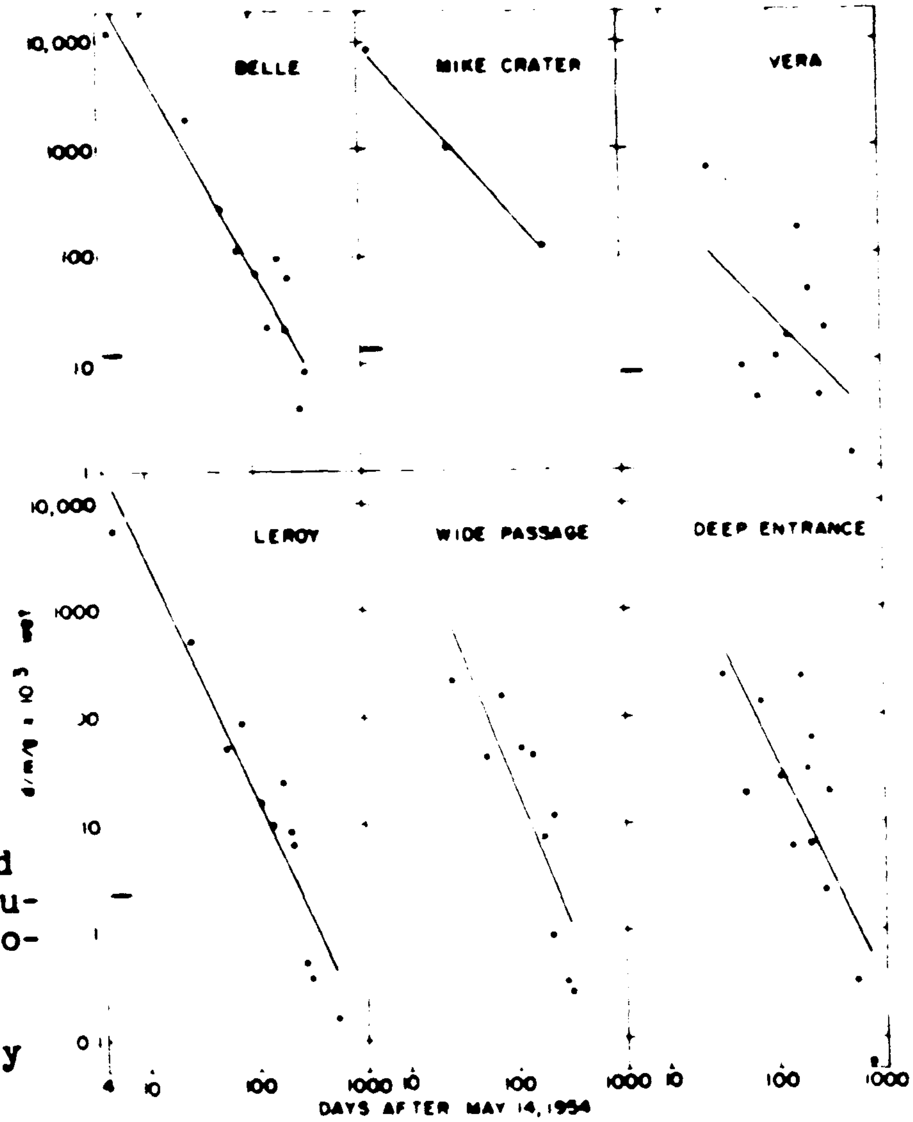

Fig. 12

Plankton decays were unusually uniform, as shown in Figure 13 and Table 10. The mean and standard error of the slopes of these 18 decays are -1.39 ± .02. This average for the decays is less steep than the decline of -1.74, ash basis.

At Belle Island, the Deep Entrance, the Wide Passage, and Leroy Island, the declines greatly exceeded the decays in steepness. At Vera the scatter of decline points is so great that the slope is highly uncertain. At the Mike crater the unusually gradual decline (-1.04) due to contributions from the crater itself, accounts for one of the rare instances of decay exceeding decline. In general, plankton declines were steeper than decays.

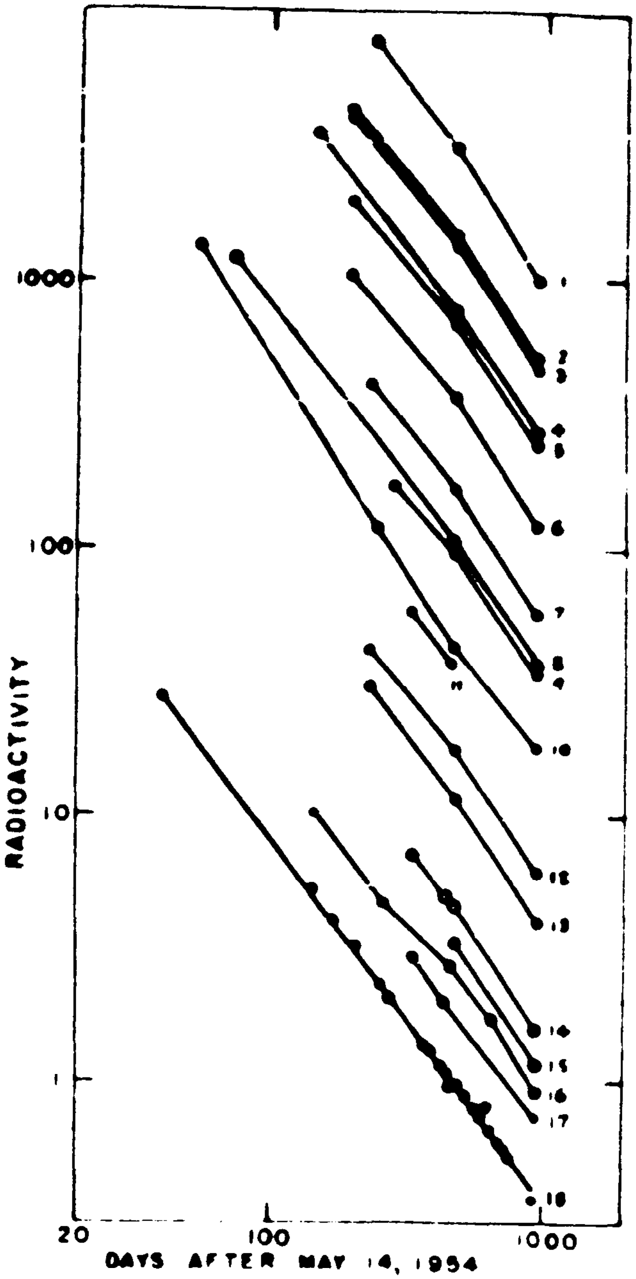

Fig. 13

Table 10. Data for plankton decay curves of Fig. 13.

Curve no.	Plate no.	Locality	Date of collection	Days after May 14, 1954, range	Slope, negative Decay	Slope, negative Decline, ash basis, Table 1.
1	19014	Belle	12/27/54	230-950	1.46	1.52
2	8277	Belle	11/6/54	195-940	1.36	1.52
3	8264	Wide Passage	10/1/54	195-940	1.38	2.37
4	8258	Belle	9/1/54	147-940	1.37	1.52
5	8267	Belle	10/1/54	196-940	1.32	1.52
6	8282	Deep Entrance	11/6/54	196-940	1.36	1.93
7	19017	Deep Entrance	12/17/54	240-940	1.40	1.93
8	8234	Belle	6/6/54	134-940	1.34	1.52
9	19034	Belle	2 /12/55	186-940	1.35	1.52
10	8220	Leroy	6/9/54	55-940	1.51	1.90
11	19058	Belle	3/21/55	330-460	1.39	1.52
12	8294	Mike crater	11/27/54	238-940	1.37	1.00
13	8293	Mike crater	11/27/54	238-940	1.45	1.00
14	19057	Belle	3/21/55	340-940	1.46	1.52
15	8292	Mike crater	11/27/54	480-940	1.55	1.00
16	8253	Wide Passage	9/1/54	146-940	1.28	2.37
17	19066	Leroy	3/16/55	330-940	1.34	1.90
18	8217	Belle	5/16/54	41-930	1.36	1.52

Halimeda

The calcareous alga, Halimeda, was the one most commonly sampled at the various islands. Figure 14 shows that the absolute levels of radioactivity were nearly uniform from island to island. The highest levels and the steepest decline were found in samples taken at Leroy. Variability was low because nearly every point is an average of several samples.

At Belle the points fall in a curve, nearly level at first, steepening to a maximum at 100 to 200 days, and then again leveling. This is the most frequently observed pattern of deviation from linearity noted throughout the survey.

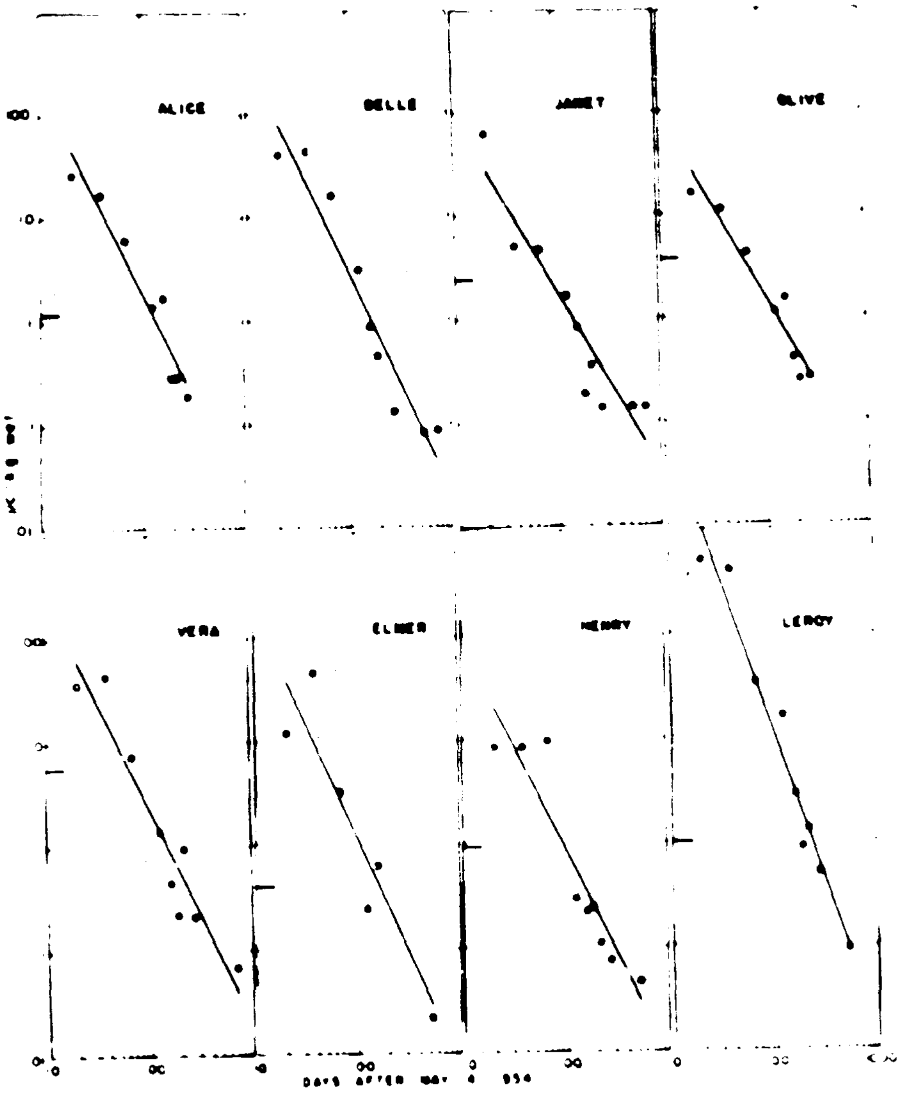

Fig. 14

Figure 15 and Table 11 give decays for 9 localities. In addition, five later samples (plates 6969-73 from Belle on July 22, 1954) counted 84 and 1106 days post-Nectar gave slopes ranging from -1.31 to -1.36.

Thus, at each locality, declines were appreciably steeper than decays. _Halimeda_ decay curves resemble those of sea water and plankton in being nearly straight for a long period.

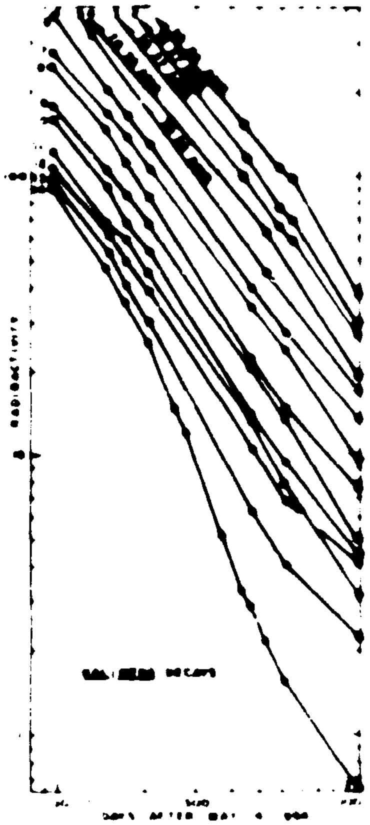

Fig. 15

Table 11. Decay rates of samples of _Halimeda_ at nine localities. Data for Figure 15.

Curve number	Plate number	Locality	Date of collection	Negative slope to 600 days
1	6322	Belle	5/15/54	1.1
2	[illegible]	"	"	1.3
3	[illegible]	"	"	1.3
4	[illegible]	"	6/7/54	1.2
5	[illegible]	"	"	1.4
6	[illegible]	Alice	7/20/54	1.2
7	[illegible]	Janet	"	1.2
8	[illegible]	Olive	"	1.4
9	[illegible]	Vera	"	1.3
10	[illegible]	Yvonne	"	1.5
11	[illegible]	Bruce	"	1.6
12	[illegible]	Elmer	"	1.6
13	[illegible]	Henry	"	1.7
14	[illegible]	Leroy	"	2.2

The last three curves, representing the southern islands, Elmer, Henry, and Leroy, become less steep at about 600 days, while at islands farther north the rate does not change, suggesting a difference in isotopic constitution in the two regions.

Land plants

The green leaves of land plants at Belle were selected to show the trend of activity in terrestrial vegetation. Figure 16 shows the decline of individual plate values as a scatter diagram upon which are superimposed the calculated regression line of slope -1.63 from Table 1, and a curve fitted by inspection to the crosses representing the arithmetic means of values of radioactivity grouped by logarithmically equal intervals of time.

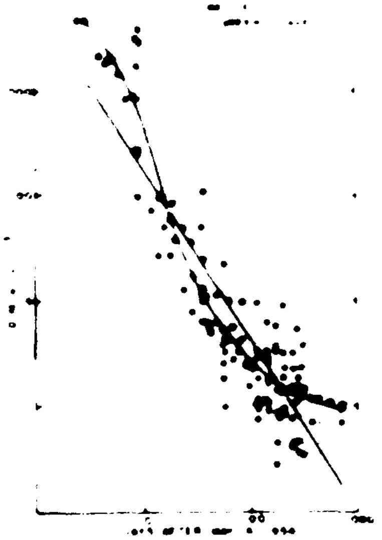

Fig. 16

The latter curve resembles the trend noted for Halimeda at Belle, in that it increases in steepness at first, and then decreases. It differs in being steepest at 20, instead of 100, days as with Halimeda.

Comparison of decay with decline for leaves taken at Belle is complicated by the scatter of the decline values in the period from 150 to 600 days. Slopes of 13 decay curves appear in Figure 17 and Table 12. Over the 150 to 600-day period the slopes averaged -.54.

Decline for this period lies between the slope of the regression line, -1.63, and the slope (-0.45) of the curved line of Figure 16 between 150 and 600 days.

Since the decay rate of -0.54 falls far short of the maximum decline rate of -1.63, and is only slightly greater than the minimum of -0.45, the rate of decline is considered to exceed the rate of decay.

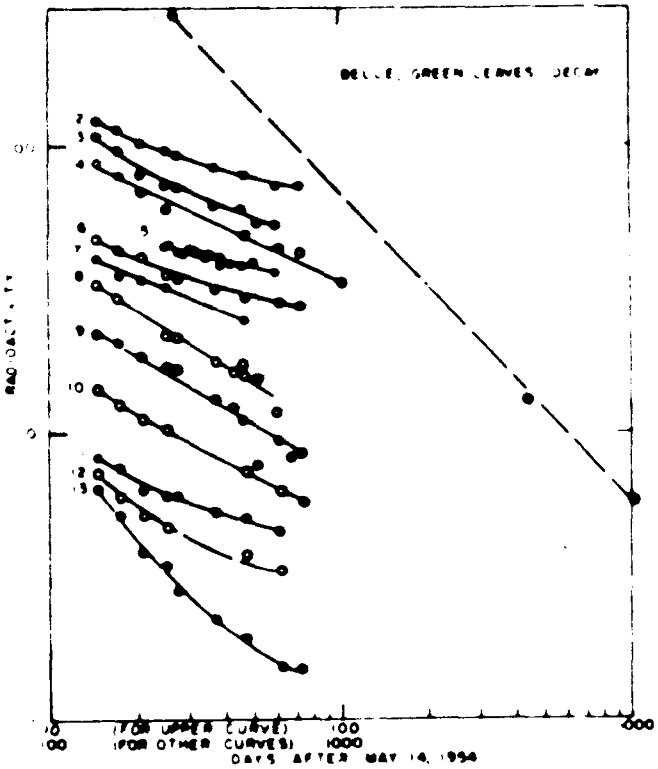

Fig. 17

Table 12. Decay rates of samples of green leaves from land plants at Belle.

Curve number	Plate number	Species	Kind of green leaf	Month and day collected, 1954	Negative slope to 600 days
1	6348	Scaevola	young	May 15	1.1
2	10220	"	sprout	Sept. 7	.36
3	10219	"	apical	" 7	.50
4	10218	"	old	" 7	.46
5	[illegible]	"	apical	Nov. 30	[illegible]
6	[illegible]	Messerschmidia	sprout	Sept. 7	.33
7	[illegible]		apical	" 7	.60
8	10237	Lepturus	leaves	" 7	[illegible]
9	[illegible]	Triumfetta	buds	" 7	[illegible]
10	[illegible]		old	" 7	[illegible]
11	[illegible]	Portulaca	leaves	" 7	.41
12	[illegible]	Boerhaavia	leaves	" 7	[illegible]
13	[illegible]	Coconut	leaves	" "	1.0

Coral

Acropora was the most common coral in the collections. Trends in levels of activity of three other genera of corals were similar to Acropora, and absolute levels differed, but not significantly. Considering Acropora levels as unity, other genera had these values: Heliopora 2.6, Porites 1.3, and Pocillopora 0.7. Samples at Vera and Olive showed significantly greater activity in Porites than in Pocillopora.

Figure 18 shows that a fairly rapid and uniform rate of decline prevailed from 36 to 710 days post-Nectar. Table 1 gives -2.23 as the slope. From 1 to 8 (average 3.6 ± 0.5) plates were the basis for each point on the graph.

The decline data of Figure 18 could also be considered as a sinusoidal curve similar to that of Belle Halimeda, but not so markedly leveling terminally. Projection of the decline curve into the future would be of special interest because of the basic role of corals in the atolls.

Decays, also, appear in Figure 18. Slopes on the same day are in general agreement, with the exception of curve 15. When decline and decay slopes are compared over identical periods decays are seen to be appreciably less steep than declines. Table 13 gives data pertinent to the decays. Only the early portion of curve 5 exceeds the decline curve in steepness.

Fig. 18

Table 13. Decay rates of Acropora samples from Belle. Data for Figure 18.

Curve number	Plate number	Collecting date	Negative slope, first to last points
1	[illegible]	[illegible]	1.7[illegible]
2	[illegible]	"	1.[illegible]
3	[illegible]	"	1.[illegible]
4	[illegible]	9/7/56	1.[illegible]
5	[illegible]		1.[illegible]
6	[illegible]	"	1.3
7	[illegible]	"	1.0[illegible]
8	[illegible]	11/30/56	.[illegible]
9	[illegible]	"	.[illegible]
10	[illegible]	"	.[illegible]
11	[illegible]	[illegible]	.[illegible]
12	[illegible]	[illegible]	.9
13	[illegible]	"	1.0[illegible]
14	[illegible]	"	1.0
15	[illegible]	[illegible]	1.[illegible]
16	[illegible]	"	.[illegible]
17	[illegible]	"	.[illegible]

Clam

Tridacnid clams, mostly Tridacna crocea, were sampled at Belle over a longer period than other invertebrates except crabs. Numbers of specimens used on each collecting date ranged from 1 to 5, averaging 2.1 ± 0.2.

Figure 19 shows the declines for clam tissues at Belle. The early ranking of the tissues from most to least radioactive, was visceral mass, kidney, gill, shell, mantle, and muscle. The more gradual decline rate (-0.71) for kidney than for other tissues brought kidney to first place at the end of the 2-year period, while other tissues retained their ranking.

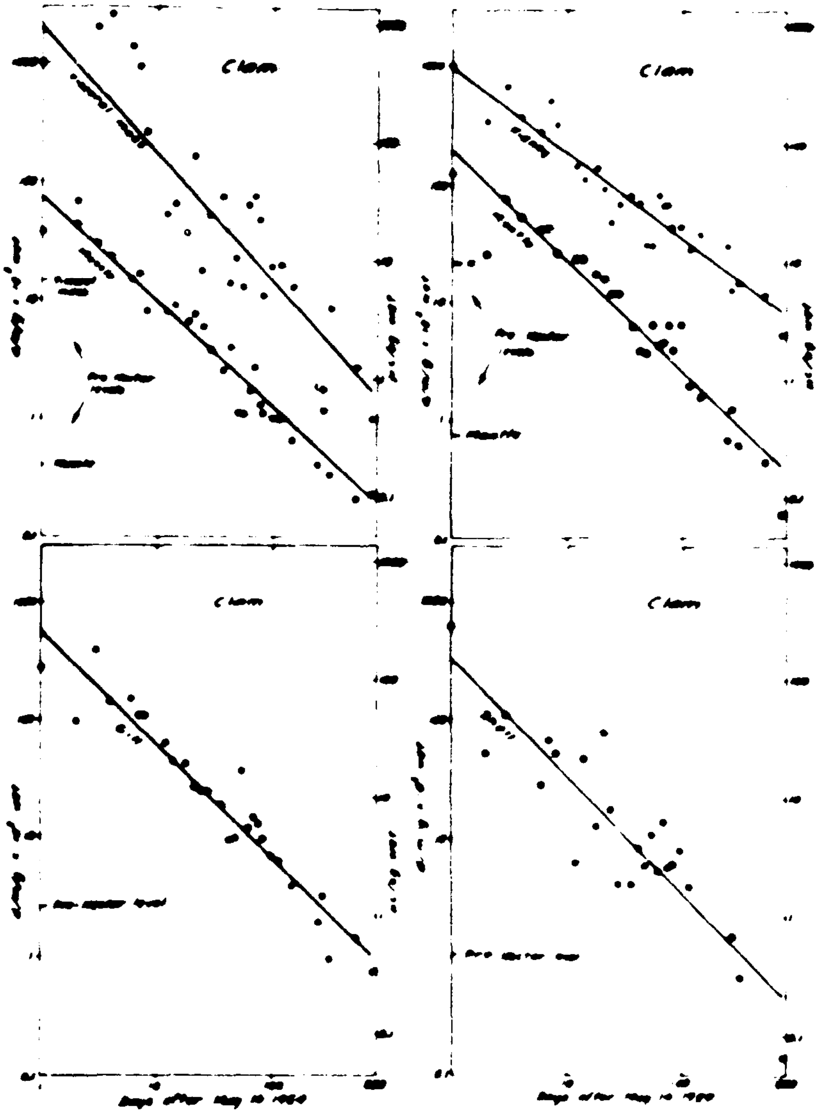

Fig. 19

Early absolute levels ranged from 20 to 1000 uc/kg for muscle and visceral mass, respectively. Two years later the range was from 0.1 to 4 uc/kg for muscle and kidney, respectively.

Figure 20 and Table 14 give the decay data. Kidney decay, like kidney decline, was comparatively gradual, indicating the uptake of longer-lived radioisotopes by this, than by other clam tissues. The comparison of decay and decline in the last two columns of Table 14 shows that decay and decline were approximately equal.

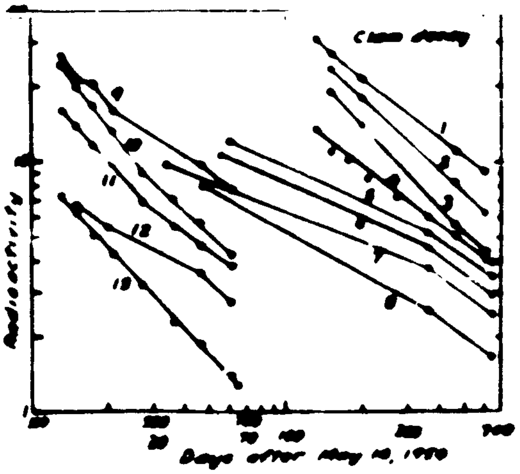

Fig. 20

Table 14. Decay rates for tridacnid clam tissues from Belle. Data for Figure 20

Curve number	Plate number	Tissue	Date of collection	Negative slope, first to last points: Decay	Decline
1	11400	muscle	9/7/54	.8	.90
2	11403	visceral mass	9/7/54	.98	1.07
3	11401	gill	9/7/54	1.1	.96
4	11316	kidney	8/19/54	.77	.71
5	[illegible]	kidney	6/1/54	.8	.71
6	8614	kidney	5/26/54	.8	.71
7	[illegible]	kidney	5/18/54	.8	.71
8	[illegible]	kidney	5/18/54	.8	.71
9	11313	mantle	8/19/54	.8	.96
10	11315	gill	8/19/54	1.1	.96
11	11314	muscle	8/19/54	.9	.90
12	11402	kidney	9/7/54	.8	.71
13	11317	visceral mass	8/19/54	1.1	1.07

The equality of decline and decay rates is further substantiated by a method used by Held (1957) on samples of hermit crab carapace. If samples collected soon after detonation decay to the same levels observed for samples collected at later dates, then the rate of decl'ne would be equal to the rate of decay; in fact, decline could be accounted for solely on the basis of physical decay. Such an equality was demonstrated by recounting clam kidney samples in October 1957, 2 to 3 years after they were collected. When the 39 available plates of clam kidney collected 6 to 536 days after Nectar were thus recounted in October 1957 the levels of radioactivity were randomly scattered from 2,000 to 10,000 without any trend that could be related to date of collection. That is, the early samples were neither higher nor lower than the later samples, in a statistical sense. The correlation coefficient of log activity related to log days after May 14, 1954 was .05, which, for 37 degrees of freedom falls short of even the 10% level of P. Results were similar to recounts of samples of snails and sea cucumbers which are graphed in Figures 24 and 30 respectively. Clam kidney resembled snail tissues in that early and later samples were alike when recounted in 1957, while for most sea cucumber tissues the early samples tended to be more radioactive than later samples when all were recounted in 1957.

Pre-Nectar samples of clam kidney collected April 15, 1954 when recounted in 1957 contained almost (70%) as much radioactivity as the post-Nectar samples, indicating that much more radioactivity was contributed by the Mike test, November 1, 1952, than by later detonations, chiefly Nectar.

Microscopic examination of kidney smears of Tridacna shows a profusion of highly refractive granular inclusions which are assumed to be responsible for some unusual properties of this tissue, in addition to its dark brown color. The specific gravity and ash content of kidney are high, the level of radioactivity is high, and the decline and decay rates are slow.

Lowman, et al. (1957:36) showed by resin column analysis on December 18-24, 1956 of a sample (plates 1282 and 1284) of clam kidney collected at Belle on September 22, 1956, the following radioisotopic composition:

Fe^{55} --------74%
Co^{57} -------- 9.6%
Co^{58} -------- 9.2%
Y^{91} -------- 2.6%
Mn^{54} -------- 2.2%
Co^{60} ---------1.8%
Ru^{106}-Rh^{106} -- .74%
Zr^{95}-Nb^{95} ---- .15%
Fe^{59} --------- .15%

The preponderance of Fe^{55} is missed in end-window beta or in gamma counting because of the low energy of its emission (70 KV X-rays). At the same time gamma spectrometry of the sample above as well as two other analyses of kidney samples collected at Belle in June-July, 1954 and March-November, 1955 showed only Ru^{106}-Rh^{106}, Mn^{54}, Co^{60}, and Co^{57}. It is probable that Fe^{55} would have been detected by resin column analysis of the 1954-55 material.

X-ray spectrometric analysis on December 19, 1957 of the ash of kidney from a 12-inch tridacnid clam (Hippopus), collected May 12, 1956 at Leroy Island, showed the most abundant non-radioactive heavy elements to be bromine, strontium, and zinc, with a small amount of iron.

Snail

The spider snail, Lambis, was sampled at Belle once before Nectar and ten times after Nectar with the results shown in Figure 21. Each point is based on 1 to 4 (average 2.3 ± 0.5) samples. Liver, at > 1000 uc[illegible], was the most radioactive tissue sampled, followed by gut, visceral mass (not shown), mantle, shell, and muscle. Visceral mass, collected 116 to 311 days post-Nectar, was similar to gut in absolute level and in trend over this period.

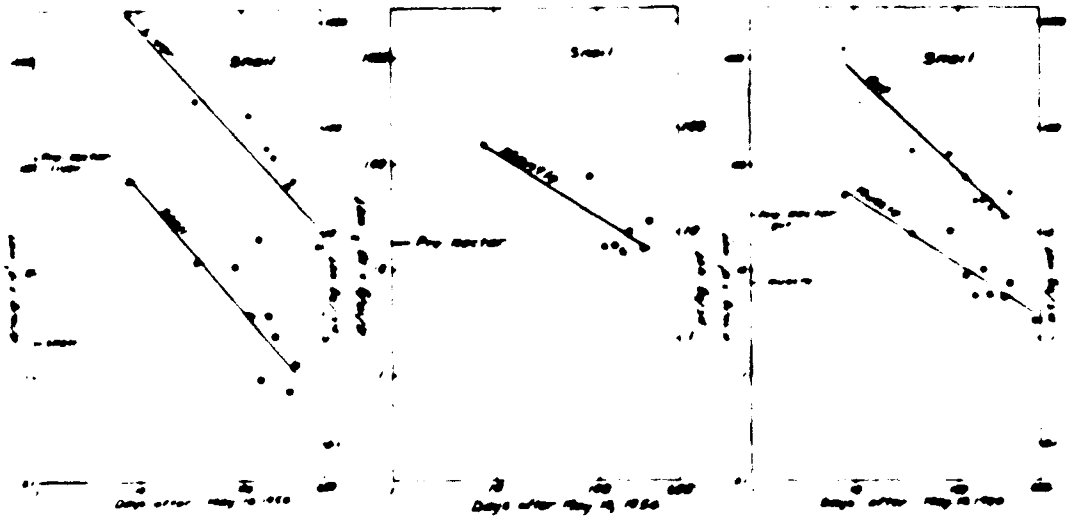

Fig. 21

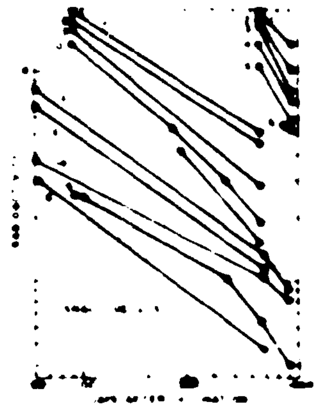

Fig. 22

Absolute levels of snail tissues were higher than for clams. Snail liver and clam visceral mass were highest of the invertebrate tissues sampled. Snail muscle was significantly higher than clam muscle, but shells of snail and clam were about equal.

Figure 22 and Table 15 show decay data for snails at Belle. Curves 1 to 6 are pre-Nectar and are shown related to Mike, November 1, 1952, as origin, which accounts for their steepness. Other decays are related to Nectar.

Snail post-Nectar decays almost equalled the declines. For liver and shell the declines were slightly steeper than decays, while for mantle, gut, and muscle the declines and decays were approximately equal.

Table 15. Decay rates for Lambis at Belle. Data for Figure 22.

Curve number	Plate number	Tissue	Date of collection	Date of origin to which referred	Slope, negative: Decay, to about 700 days	Slope, negative: Decline
1	5659	shell	4/18/54	11/1/52	.[illegible]	1.16
2	5660	liver	"	"	1.61	1.10
3	5661	muscle	"	"	2.03	.[illegible]
4	5662	gut	"	"	1.77	.[illegible]
5	5663	mantle	"	"	1.70	.[illegible]
6	5664	shell	"	"	.80	1.10
7	8121	mantle	3/22/55	5/14/54	.44	.[illegible]
8	8122	muscle	"	"	.87	.[illegible]
9	81[illegible]	liver	"	"	.[illegible]	1.10
10	[illegible]	gut	"	"	.[illegible]	.[illegible]
11	81[illegible]	shell	"	"	[illegible]	1.10
12	5797	liver	6/10/55	"	.74	1.10
13	5798	gut	"	"	.[illegible]	.93
14	5799	shell	"	"	.[illegible]	1.10
15	5800	muscle	"	"	.70	.[illegible]
16	5801	gonad	"	"	.77	--

The possibility that the detonation on March 1, 1954 at Bikini contributed the greatest amount of the activity in snail tissues, was examined by means of the decays. Decay rates themselves furnish a clue to the date of origin, if it is assumed that a constancy exists in rate of decay from one test to another. For any one tissue the slope of the pre-Nectar curves when related to the appropriate origin might be expected to agree with the slope of post-Nectar curves during the corresponding interval after Nectar.

Using the Mike test as origin, the counting period of the first five pre-Nectar samples would be 650 to 930 days post-Mike, and the slopes in Figure 22 of curves 1 to 3 (shell, liver, and muscle) would be -.98, -1.61, and -2.03, respectively. The corresponding slopes for the post-Nectar shell, liver, and muscle samples (curves 14, 12, and 15) during the interval 700 to 900 days post-Nectar were -.92, -1.36, and -1.55.

This agreement between Mike-derived and Nectar-derived slopes is satisfactory, especially if allowance is made for some carry-over of long-lived products from Mike into the post-Nectar material. According to this hypothesis, no great proportion of the radioactivity of pre-Nectar snail samples could have been contributed by the detonation of March 1, 1954 at Bikini, since relating curves 1 to 6 to this date gives slopes of -.36, -.57, -.75, -.68, -.62, and -.28, which are not steep enough to correspond with slopes of the post-Nectar samples. Therefore, curves 1 to 6 in Figure 22 are referred to the Mike test as origin, and the remainder to Nectar.

The decay curves of Figure 22 are unusual in that they tend to steepen with time rather than to level out. This variation suggests that their semi-log plots might be linear. Therefore, these and other curves are shown on semi-, instead of log-log plot in Figure 23, and the data appear in Table 16. Several of the curves do approach linearity indicating a single half life.

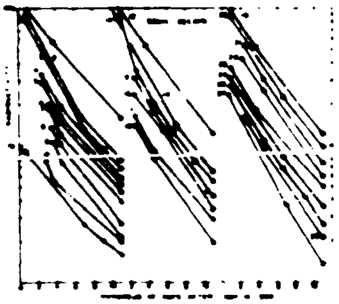

Fig. 23

Table 16. Half-lives of radioactivity remaining in samples of tissues of [illegible] from Jello, two to three years after Nectar. Data for Figure 23.

Curve number	Plate number	Date of collection	Tissue	Day half-life determination starts (to 1100 days)	Half-life in days: Per plate	Half-life in days: Per tissue, including 2-point slopes
1	[illegible]	4/15/56	liver	370	400	370
2	9108	5/22/56	"	[illegible]	405	"
3	9797	6/19/56	"	[illegible]	420	"
4	17000	11/3 56	"	480	380	"
5	17045	11/30/56	"	430	[illegible]	"
6	17333	[illegible]	"	430	390	"
7	17340	[illegible]	"	440	400	"
8	[illegible]	3/21/57	"	420	360	"
9	17008	11/30/56	shell	400	380	437
10	[illegible]	4/15/56	"	370	500	"
11	9790	6/19/56	"	700	340	"
12	[illegible]	4/15/56	gut	100	330	381
13	9106	5/22/56	"	670	380	"
14	9798	6/19/56	"	730	380	"
15	17020	11/30/56	"	400	310	"
16	[illegible]	11/30/56	"	[illegible]	[illegible]	"
17	[illegible]	11/30/56	visceral mass	480	370	[illegible]
18	17011	11/30/56	"	480	470	"
19	[illegible]	4/15/56	muscle	370	320	320
20	[illegible]	[illegible]	"	670	460	"
21	17007	11/30/56	"	480	380	"
22	[illegible]	11/30/56	"	[illegible]	[illegible]	"
23	[illegible]	4/15/56	muscle	370	300	[illegible]
24	[illegible]	[illegible]	"	670	[illegible]	"
25	[illegible]	6/19/56	"	400	315	"
26	[illegible]	11/30/56	"	480	310	"
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2-point slopes, not graphed:						
	[illegible]	3/21/57	shell	360	[illegible]	
	[illegible]	3/21/57	liver	360	[illegible]	
	[illegible]	3/21/57	visceral mass	360	[illegible]	
	[illegible]	3/21/57	muscle	360	[illegible]	
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	[illegible]	[illegible]	gut	[illegible]	[illegible]	
	[illegible]	[illegible]	muscle	[illegible]	[illegible]	
	[illegible]	11/30/56	visceral mass	[illegible]	[illegible]	
	[illegible]	[illegible]	shell	[illegible]	[illegible]	
	[illegible]	11/30/56	liver	[illegible]	[illegible]	
	[illegible]	11/30/56	gut	[illegible]	[illegible]	
	[illegible]	11/30/56	muscle	[illegible]	[illegible]	
	[illegible]	11/30/56	shell	[illegible]	[illegible]	
	[illegible]	11/30/56	muscle	[illegible]	[illegible]	
	[illegible]	11/30/56	shell	[illegible]	[illegible]	

Table 16 indicates that during the time interval from about 500 to 1100 days post-Nectar, half lives of about one year predominated even among samples collected before Nectar. The one-year half life is substantiated by gamma spectrometric analysis on May 10, 1957 of plate 5797 (Fig. 23, curve 3) by Lowman *et al*. (1957:34), which showed the radioisotopic constituents to be primarily Ru^{106}-Rh^{106} of 1-year half life, Mn^{54} 300-day, Co^{57} 267-day, and small amounts of Co^{60} 5.2-year. Using the t test, the average half life for liver was significantly longer than for mantle (P = 0.2%), gut (P = 1%), and muscle (P about 5%), but not significantly longer than for visceral mass or gonad, or shorter than for shell.

The high levels of radioactivity of Belle snails made it practical to observe radioactive decay over as long a period as three years. Nearly all (109) of the snail samples collected in 1954-55 were recounted on May 21, 1957.

Figure 24 shows as log-log plots, the radioactivity of snail samples from Belle on May 21, 1957 related to date of collection. Little or no correlation exists. The amount of activity remaining in May 1957 was about the same in samples collected on April 15, 1954 (shortly before Nectar), shortly after Nectar, and long (540 days) after Nectar, thus supporting the observation that decline and decay do not differ.

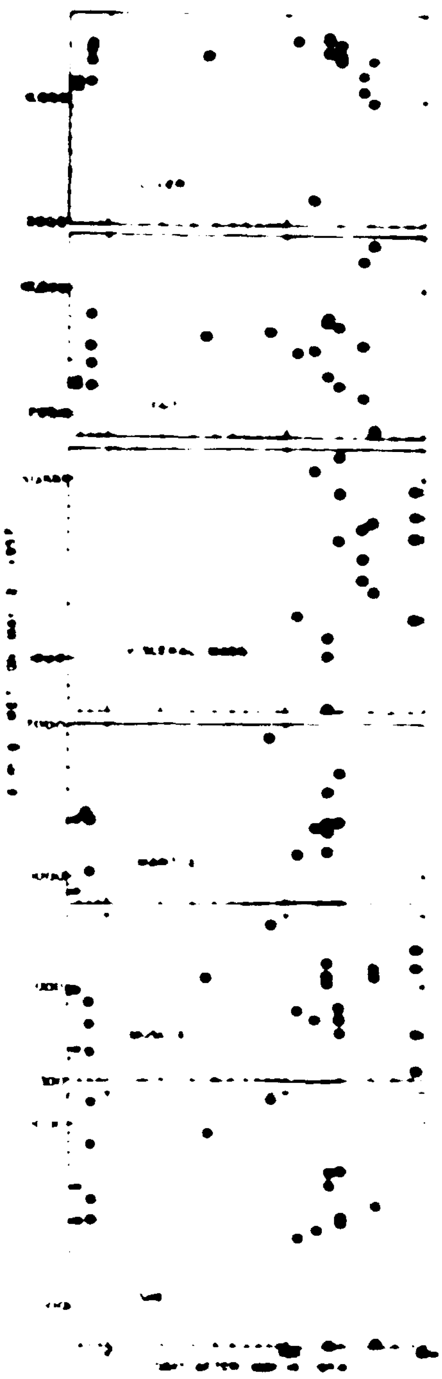

Fig. 24

The land hermit crab, Coenobita, has been reported upon by Held (1957), primarily from the standpoint of its sensitivity as an indicator of radiostrontium. Individual sample values were given in appendix form showing d/m/g based on the usual decay correction factors except for carapace, which was based upon the decay rate of Sr^{89} and Sr^{90}-Y^{90}. Declines were shown semi-log in order to relate them to half life, and to accentuate fluctuations in the later trends of the curves.

For purposes of comparison with other organisms, this section presents, in the form used throughout the paper, the same crab data tabulated by Held, (1957: 26). In addition, the observations on April 26, 1956, just before the next series of tests, are shown as the last points on the muscle and carapace graphs. However, instead of decay factors based only upon strontium, the usual decay factors employed in the present paper were used for carapace. Numbers of specimens on each collecting date ranged from 1 to 5, averaging 2.9 ± 0.2.

Figure 25 shows the declines for five crab tissues. Alignment of points was good in the cases of liver and gill. Rates of decline ranged from -.95 to -1.46. A dip shortly after 100 days in all of the curves appears to be followed by a leveling tendency.

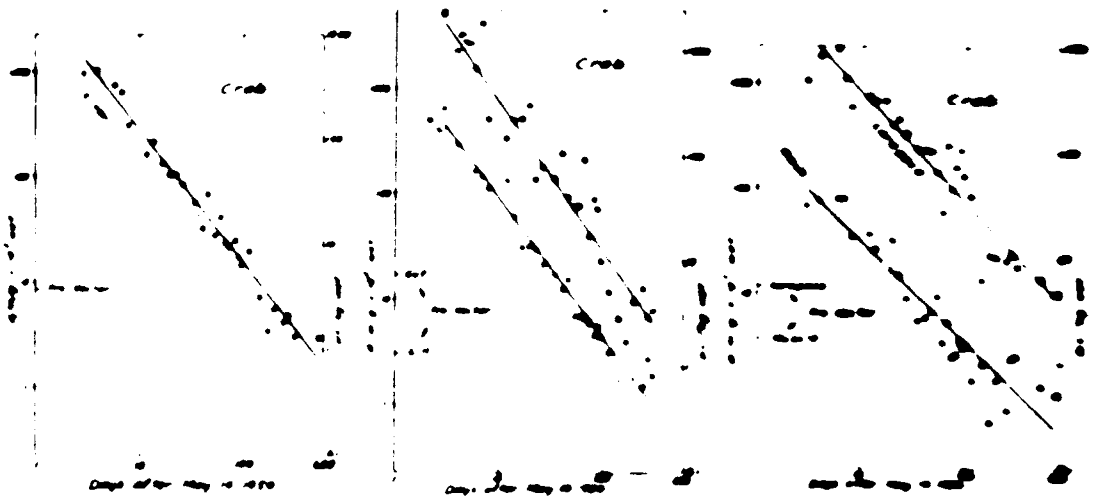

Fig. 25

The decline curve for carapace differs from that shown by Held, who used decay correction factors based solely on strontium, in that it extends through a vertical range of about 2.3 orders of magnitude, while his extends through only about 1.3 orders of magnitude, possibly because in the present paper short-lived products in the sand-derived decay factors were included, while in Held's consideration these possible short-lived products were excluded.

Figure 26 and Table 17 show crab decays. Carapace of Coenobita is emphasized, but other tissues are included, as well as a curve for carapace of the ghost crab, Ocypode, for comparison.

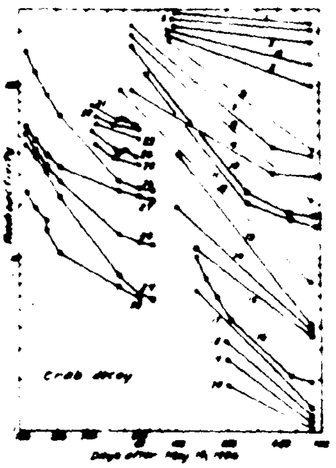

Fig. 26

There is a pronounced leveling with time, indicating an unusually high content of long-lived isotopes. The two-point slopes define limits within which intermediate points must have occurred, following the pattern of corresponding multi-point curves, and which are included to show the transition from the slow decay of pre-Nectar samples to the more rapid decay of later samples. An uptake period of 1 to 2 weeks for the isotopes remaining at the time of counting the decays in Figure 26 is suggested by the increase in slope of successive curves with time of collection after Nectar.

Carapace of Coenobita and Ocypode showed similar decay patterns as may be seen by comparing curves 16 and 26.

Paucity of decay data in the first 100 days precludes adequate comparison with the early portion of the decline curves. After 100 days post-Nectar the variability in the decline curves is too great to permit of definite conclusions, but decline and decay appear to be about equal. No significant difference can be shown between decline and decay using the available data.

Held (1957:8) showed that recounts in February 1956 of all samples of carapace where all of the activity was due to Sr90-Y90 gave uniform values of d/m/g regardless of date of collection. He concluded that equilibrium in the uptake-excretion process had been reached. The same phenomenon was noted above for clam kidney and for all snail samples.

Table 17. Rates of radioactive decay referred to Nectar, of samples of crabs at [illegible]. Data for Figure 26.

Curve no.	Plate no.	Organism and tissue		Date of collection	Negative slope, first to last points
1	[illegible]	Coenobita	carapace	[illegible]	.1
2	[illegible]	"	"	"	.1
3	[illegible]	"	"	"	.1
4	[illegible]	"	"	[illegible]	.2
5	[illegible]	"	"	"	.3
6	[illegible]	"	"	"	.7
7	[illegible]	"	"	[illegible]	.7
8	[illegible]	"	"	"	.5
9	[illegible]	"	"	[illegible]	.6
10	[illegible]	"	"	"	.9
11	[illegible]	"	"	7/1/56	.8
12	[illegible]	"	"	[illegible]	1.0
13	11281	"	"	[illegible]	1.3
14	[illegible]	"	"	"	.8
15	11301	"	"	[illegible]	.6
16	11308	"	"	"	1.1
17	[illegible]	"	"	[illegible]	1.0
18	[illegible]	"	"	[illegible]	.8
19	[illegible]	"	"	"	.7
20	[illegible]	"	"	"	.6
21	[illegible]	"	"	[illegible]	.6
22	[illegible]	"	"	[illegible]	.3
23	[illegible]	"	"	"	.3
24	[illegible]	"	"	[illegible]	.5
25	[illegible]	"	"	[illegible]	.4
26	[illegible]	Ocypode	"	[illegible]	1.1
27	[illegible]	Coenobita	muscle	[illegible]	.6
28	[illegible]		gill	"	.5
29	[illegible]	"	gut	"	1.3
30	[illegible]	"	liver	"	.8

Sea cucumber

The only animals regularly sampled for the distributional study (Fig. 1) were sea cucumbers. Three specimens were usually taken on each collecting date.

Figure 27 shows the decline at Belle, and Figure 28, at other localities. Pre-Nectar levels were highest at Belle, Alice, Janet, and Vera (about 1 to 10 uc/kg), and about one order of magnitude lower at Olive, Bruce, Elmer, and Henry; Leroy was not sampled. Early post-Nectar levels were about 50 to 100 times higher than the pre-Nectar levels. At Belle the first value, on the 8th day, was too low to align with later values, except for gut which is really mostly sand. To show the

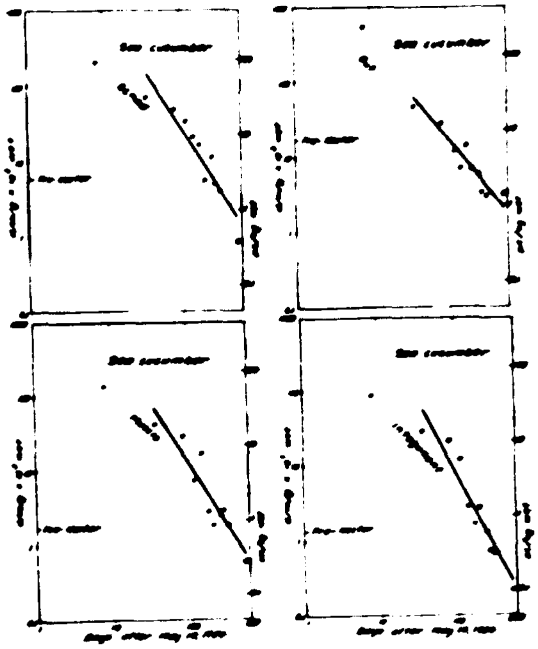

Fig. 27

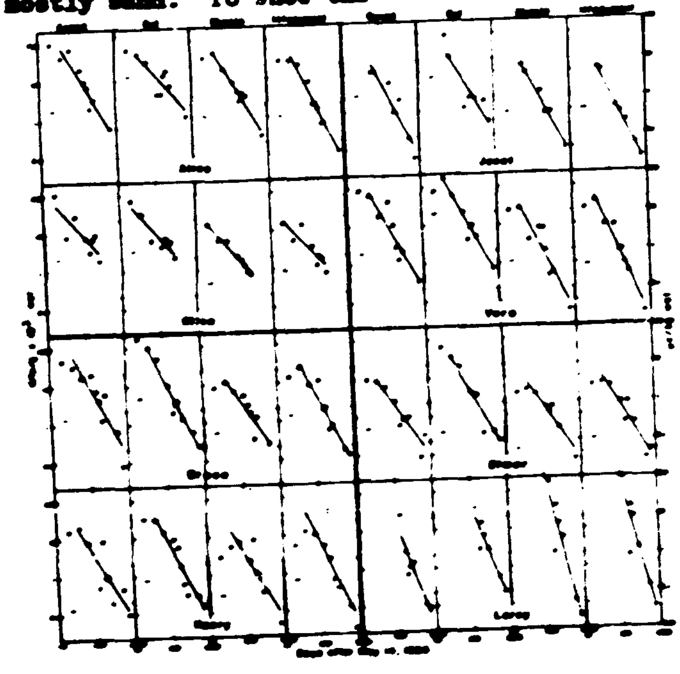

Fig. 28

trend over the
line was calcul
and the same fo
was reached at
first made on t

It is infe
levels in line
of approximatel
radioisotopes
constituents o
occurred withi

The devia
seems not to f
curve for gut
land plant lea
(Fig. 25), [illegible]
days (see

Figure 29
curves for sea
include Belle,
other islands
usually straig
50 days to 110
are typical of
cays. The slo
from -1.1 to -
-1.6 occurred
Leroy where th
steep. At 70
moderated, ap
the other cur

Declines
the decays (c
cucumbers, th
rapid than de

[illegible]

Curve no.	Plate no.	Localit
1	[illegible]	[illegible]
2	[illegible]	Belle
3	[illegible]	"
4	[illegible]	"
5	[illegible]	"
6	[illegible]	"
7	[illegible]	"
8	[illegible]	"
9	[illegible]	Janet
10	[illegible]	"
11	[illegible]	Vera
12	[illegible]	[illegible]
13	[illegible]	[illegible]
14	[illegible]	[illegible]
15	[illegible]	Leroy
16	[illegible]	Leroy

[illegible] with respect to the regression line. In trend over the major portion of the survey period, the regression line was calculated starting on about the 36th day post-Nectar, and the same for other islands except Olive, where the maximum was reached at 20 days, and at Leroy, where collections were first made on the 124th day.

It is inferred from the failure of early samples to attain levels in line with later samples on log-log plots, that a period of approximately 30 days was generally required for the uptake of radioisotopes to reach equilibrium with the non-radioactive constituents of the tissues, although at Olive this had apparently occurred within 20 days.

The deviation of the decline points from log-log linearity seems not to follow a pattern but to be random. Only the decline curve for gut at Henry resembles that of Belle *Halimeda* (Fig. 14), land plant leaves (Fig. 16), *Acropora* (Fig. 18), and crab carapace (Fig. 25), [illegible] sinusoidal with point of inflection about 150 days (see Discussion, p. 40).

Figure 29 and Table 18 show decay curves for sea cucumbers selected to include Belle, Leroy, and Henry, and other islands randomly. They are unusually straight lines from as early as 50 days to 1100 days post-Nectar, and are typical of other sea cucumber decays. The slopes to 700 days ranged from -1.1 to -3.4. Slopes steeper than -1.6 occurred only at Henry, and at Leroy where they were particularly steep. At 700 days the steepest slopes moderated, approaching the slopes of the other curves.

Declines exceeded all but two of the decays (curves 1 and 5). For sea cucumbers, then, declines were more rapid than decays.

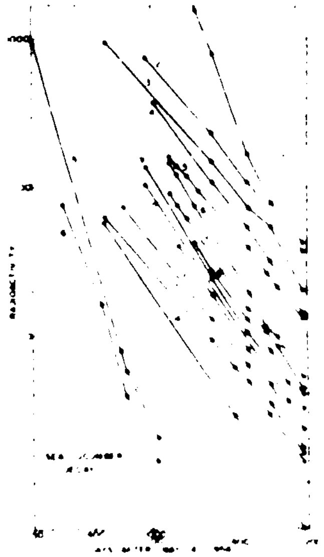

Fig. 29

Table 18. Rates of radioactive decay, referred to Nectar, of samples of sea cucumbers. Data for Figure 29.

Curve no.	Plate no.	Locality	Date of collection, 1954	Tissue	Slope, negative: Decay, to 700 days	Slope, negative: Decline, from Table 1
1	11787	Henry	Oct. 21	gonad	2.6	1.7
2	[illegible]	Belle	May 22	integument	1.2	2.0
3	[illegible]	"	June 10	gut	1.1	1.8
4	[illegible]	"	Aug. 8	gonad	1.3	1.8
5	[illegible]	"	Sep. 7	gut	1.2	1.8
6	[illegible]	"	Sep. 7	integument	1.6	2.0
7	[illegible]	"	Sep. 7	gonad	1.6	1.6
8	[illegible]	"	Oct. 8	integument	1.6	2.0
9	[illegible]	Janet	June 20	integument	1.5	2.0
10	[illegible]	"	June 20	integument	1.5	[illegible]
11	[illegible]	Vera	Sep. 18	gonad	1.5	1.8
12	[illegible]	Yvonne	June 22	muscle	1.3	-
13	[illegible]	Elmer	June 8	gonad	1.2	[illegible]
14	[illegible]	Henry	June 1	integument	1.6	[illegible]
15	[illegible]	Leroy	Sep. 18	integument	3.4	3.7
16	[illegible]	Leroy	Jan. 17	integument	[illegible]	3.7

Figure 30 shows for the Belle sea cucumber collections the amount of radioactivity remaining when the samples were recounted in May-June, 1957, related to time of collection of the samples. Log-log regressions were calculated excluding the collections at 8 days, as was done for declines on the basis that uptake of activity had not yet reached equilibrium. For time, t, of collection of sample in days after May 14, 1954, the regressions for gonad, muscle, and integument, respectively, were:

$d/m/g$ in 1957 = 5290 $t^{-0.395}$
$d/m/g$ in 1957 = 2720 $t^{-0.405}$
$d/m/g$ in 1957 = 4280 $t^{-0.612}$

with correlation coefficient significance, $P = 1\%$, $P < 1\%$, and $P << 1\%$, respectively.

Fig. 30

Thus, the trends for gonad, muscle, and integument were downward, while for gut there was no distinct ($P >> 10\%$) upward or downward trend. The slope of the line reflects the difference between decline and decay, being steepest when decline differs most from decay, and horizontal when the two are equal. That this difference was true in a general way for sea cucumbers at Belle may be seen by comparing the rates of decline and decay in Table 18. Decline exceeded decay most in the case of integument, and less for the other tissues.

For sea cucumber integument where the decline slope was -2.0 and the decay slope about -1.4, the slope of the log of the recount in 1957, related to the log of day of collection after assumed detonation, was -0.6, practically accounting for the difference between decline and decay slopes.

While widely varying spectra of half lives are possible, resulting in unpredictable relationships between decline and decay, it is important to note that a fairly constant relationship does exist as shown by these recounts which are in harmony with the relationship of decline to decay, especially evident in the case of integument.

Pre-Nectar collections retained until 1957 about 10% of the activity measured when first counted, while samples taken June-August, 1954, retained only 2% to 5%. The highest levels of activity tended to occur more than 36 days after Nectar.

<u>Fish</u>

Figure 3
the declines
tissues of re
from Belle.
figure includ
data shown by
(1957:Fig.2)
log plot, for
his Table 1 g
regarding nu
specimens and
Values from t
cated numbers
were averaged
point. In ad
Welander's da
31 shows the
one plate of
two plates of
small fish fr
lection made
26, 1956.

For each
initial peri
of nearly tw
followed by a
regular decli
in slope from
liver to -1.9
(Table 1). A
levels were c
those of inve

Fish

Figure 31 shows the declines of five tissues of reef fish from Belle. This figure includes the data shown by Welander (1957:Fig.2) in semi-log plot, for which his Table 1 gives data regarding numbers of specimens and plates. Values from the indicated numbers of plates were averaged for each point. In addition to Welander's data, Figure 31 shows the levels for one plate of liver and two plates of muscle for small fish from a collection made on April 26, 1956.

For each tissue an initial period of uptake of nearly two weeks was followed by a fairly regular decline ranging in slope from -1.2 for liver to -1.9 for skin (Table 1). Absolute levels were comparable to those of invertebrates.

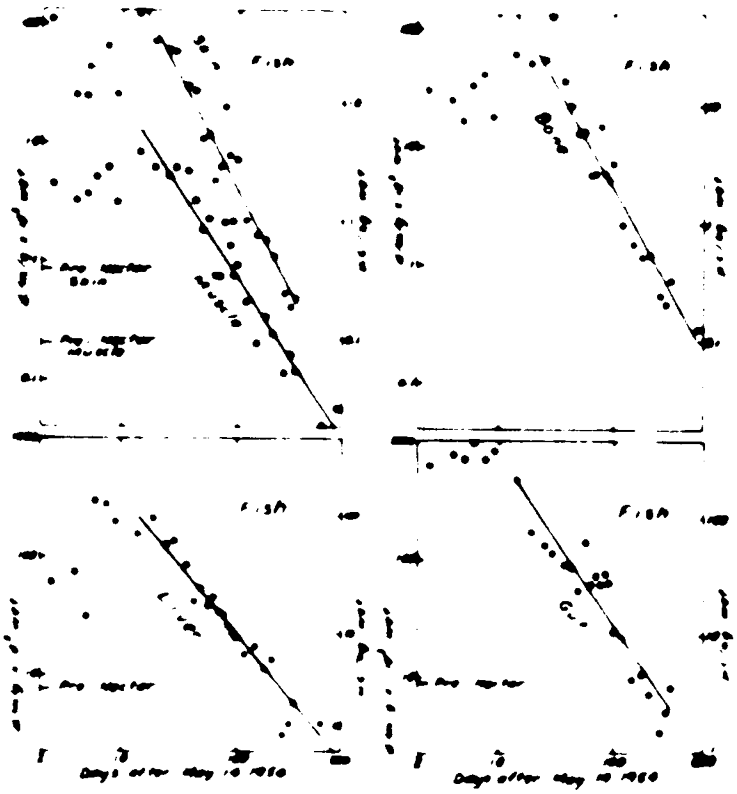

Fig. 31

Figure 32 and Table 19 show the decay of samples of muscle, bone, and liver of Belle reef fish. Variability was moderate. Even within a single species as with the decays from the two goatfish taken May 21, curves 4, 12, and 21 show longer-lived products than do curves 5, 13, and 22.

Although some parts of certain decay curves may be steeper than the corresponding decline, the declines in general are significantly steeper than the decays.

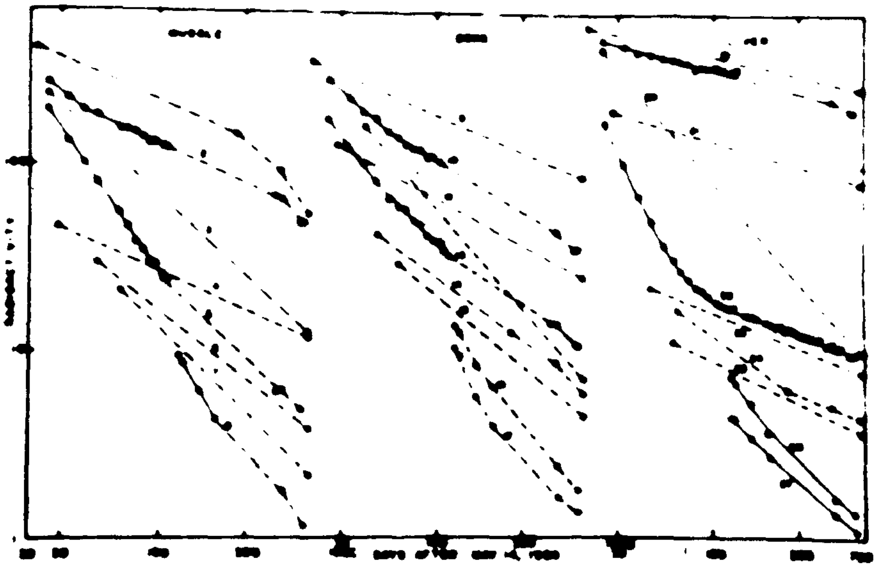

Fig. 32

Table 19. Rates of radioactive decay, referred to Nectar, of samples of reef fish from Belle. Data for Figure 31.

Curve no.	Plate no.	Tissue	Species	Date of collection, 1958	Slope, negative: Decay, first to last points: Per plate	Slope, negative: Decay, first to last points: Per tissue, mean	Slope, negative: Decline, from Table 1
1	[illegible]	muscle	wrasse	May 17	.60	.96	1.49
2	7067	"	mullet	May 18	.52	"	"
3	7067	"	goatfish	May 19	.98	"	"
4	8082	"	"	May 21	.43	"	"
5	8077	"	"	May 21	1.17	"	"
6	8137	"	wrasse	May 22	.78	"	"
7	[illegible]	"	goatfish	July 1	.97	"	"
8	12062	"	shark	Aug. 12	1.38	"	"
9	7066	bone	wrasse	May 17	.48	.96	1.77
10	7066	"	mullet	May 18	.66	"	"
11	7068	"	goatfish	May 19	1.11	"	"
12	8063	"	"	May 21	.61	"	"
13	8078	"	"	May 21	.98	"	"
14	8136	"	wrasse	May 22	.75	"	"
15	[illegible]	"	goatfish	July 1	.78	"	"
16	12063	"	shark	Aug. 12	1.30	"	"
17	12063	"	surgeon	Aug. 19	1.30	"	"
18	7067	liver	wrasse	May 17	.82	.70	1.18
19	7068	"	mullet	May 18	.89	"	"
20	7068	"	goatfish	May 19	1.15	"	"
21	8084	"	"	May 21	.89	"	"
22	8079	"	"	May 21	.90	"	"
23	8139	"	wrasse	May 22	.40	"	"
24	8814	"	rouper	June 28	.56	"	"
25	8824	"	goatfish	July 1	.48	"	"
26	12064	"	shark	Aug. 12	1.08	"	"
27	12064	"	surgeon	Aug. 19	.90	"	"

Birds

The fairy terns, rarely the sooty or noddy tern, were the birds sampled at Belle. The number of samples on each collecting date ranged from 1 to 3 averaging 2.25 ± 0.15. Results appear in Table 1 and Figure 33. The points shown for the individual tissues were averaged arithmetically to give the data for all tissues combined.

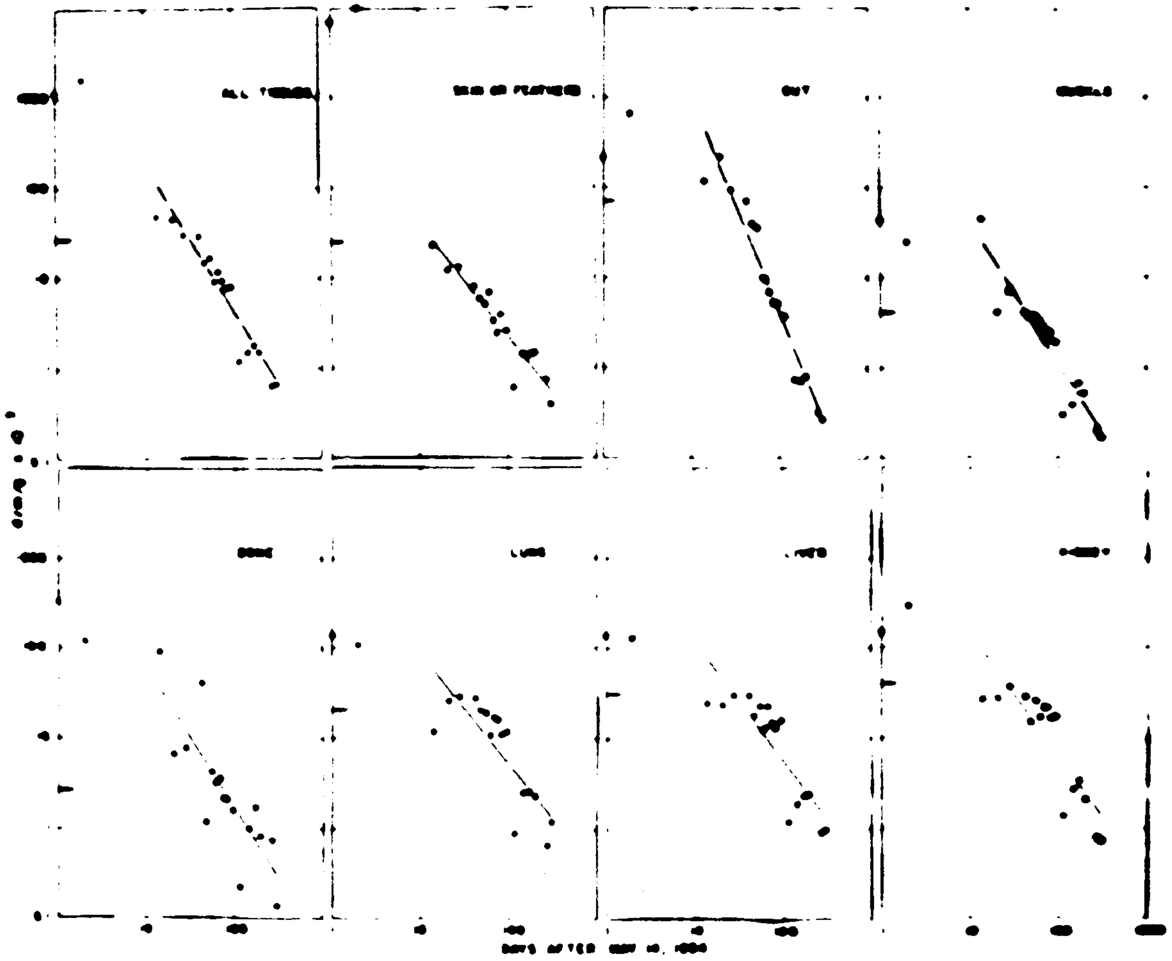

Fig. 33

Declines were calculated starting two weeks after Nectar in order to avoid the first two days when uptake was rapid. The decline for tern gut was outstandingly steep, -2.4. For other tissues it ranged from -1.2 to -1.6 without significant differences.

Figure 34 shows decays for the tissues of two fairy terns collected at Belle on August 19, 1954. Except for one skin and one bone sample, the curves become more nearly level as time proceeds. In order of increasing steepness of decay slopes between 150 and 300 days, the tissues ranked as follows: kidney, liver, gut, lung, muscle, skin, and bone, ranging from -2.6 to -0.8.

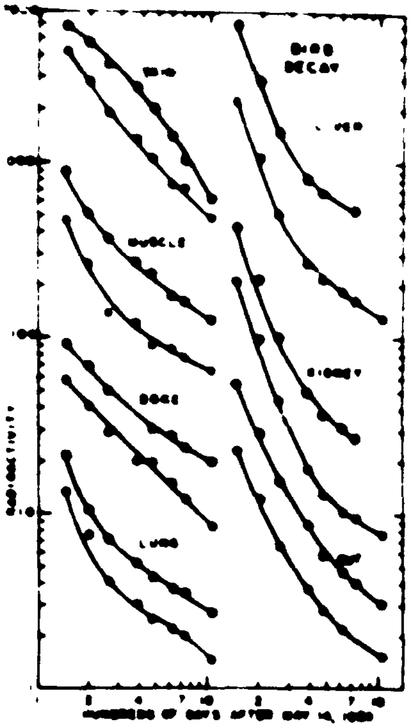

Fig. 34

Decline data extend only to 310 days, so that comparison with the decays is possible only from 150 days, when decays were started, to 310 days post-Nectar. Because of the curvature in the decays and the variability in this short section of the time scale for the decline data, comparisons cannot be made.

Rat

Janet was the site of collection of rats, rather than Belle where rats were virtually absent. Table 20 shows number of specimens and average amounts of radioactivity in the tissues on various collecting dates.

Table 20. Radioactivity expressed in thousands of d/m/g of wet tissue of rats from Janet, Eniwetok Atoll, in 1954-56.

Date	No. rats	Skin	Muscle	Bone	Liver	Lung	Kidney	Gut
4/[illegible]-4/30	3	--	1.27	10.7	.87	[illegible]	1.32	[illegible]
5/16	2	--	2.08	14.3	2.00	2.64	7.42	20.8
5/21	7	--	2.64	17.3	14.7	7.10	14.6	44.3
6/30	4	1.13	.787	17.1	.862	.640	[illegible]	6.70
7/7-1[illegible]	4	1.38	1.27	12.[illegible]	1.[illegible]	.716	1.33	2.06
7/21	8	.971	1.[illegible]	[illegible].16	1.18	.646	1.35	1.92
7/2[illegible]	4-5	[illegible]	[illegible]	[illegible]	1.23	[illegible]	1.17	1.71
8/11	3	.588	1.08	5.3[illegible]	.645	.608	.670	.680
8/18	3	.634	.762	4.45	.507	.540	[illegible]	1.38
9/[illegible]	[illegible]	.336	1.2[illegible]	7.72	1.60	.872	1.38	.615
10/26	3	.179	[illegible]	[illegible].74	1.[illegible]	[illegible]	1.27	[illegible]
11/[illegible]	4	.41[illegible]	1.36	4.76	1.05	.780	1.46	[illegible]
12/16	3	.338	1.24	[illegible]	[illegible]	[illegible]	2.13	1.16
1/17/55	5	.712	.651	[illegible]	1.56	[illegible]	1.04	.876
2/14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.499	[illegible]
3/[illegible]	3	.219	.311	1.16	.651	.163	.77	.639
3/15	5	.349	.201	[illegible]	[illegible]	.241	[illegible]	[illegible]
10/17&29	11-12	--	.872	[illegible]	[illegible]	--	[illegible]	--

The high pre-Nectar level for gut and a consideration of declines for all tissues suggest that the activity originated primarily from Bikini on March 1, 1954, and less from earlier detonations and from Nectar. Accordingly, Figure 35 and Table 1 show declines for the tissues of rats on Janet related to March 1, 1954 as origin.

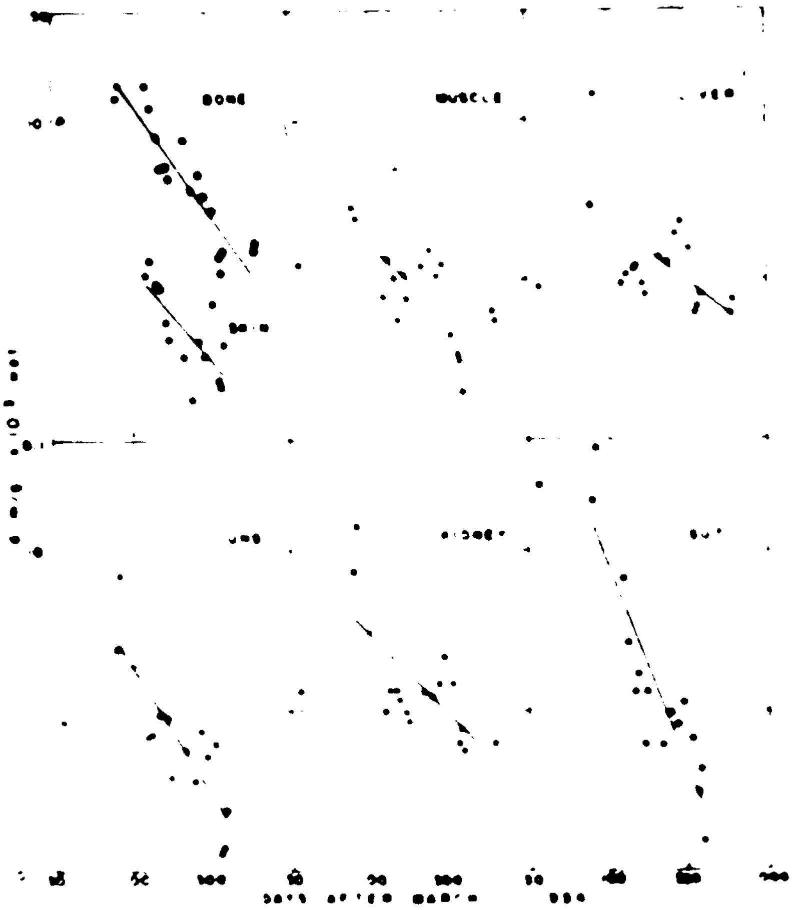

Fig. 35

If referred to Nectar as origin, the decline curves become much less steep, with the following slopes: skin -.75, muscle -.37, bone -.51, liver -.34, lung -.58, kidney -.49, and gut -.97.

Decays were started 220 days post-Nectar. Table 21 and Figure 36 show the radioactive decay of tissues from three rats collected August 18, 1954 at Janet and referred to March 1, 1954 as origin. From 220 to 600 days post-detonation, muscle, liver, kidney, and lung decayed very slowly, while bone, skin, and gut decayed appreciably faster. After about 600 days, even some of the bone, skin, and gut samples decayed extremely slowly, approaching the relatively uniform decay rate of the other tissues.

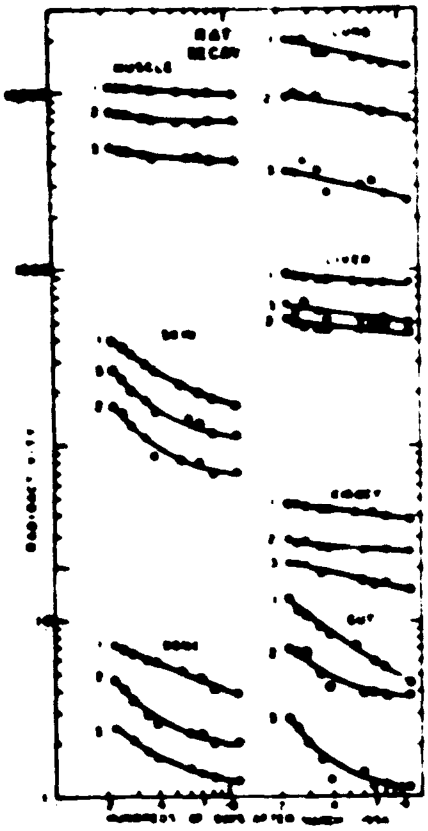

Fig. 36

Table 21. Rates of radioactive decay, referred to the detonation of March 1, 1954 at Bikini, of samples of tissues from three rats collected August 18, 1954 at Janet. Data for Figure 35.

Tissue	Curve no.	Plate no.	Slope, negative decay, 220-600 days		Decline, entire period, from Table 1
			For plate	For tissue, average, rounded	
muscle	1	13120	.26	.1	.90
"	2	13107	.20	"	"
"	3	13114	.13	"	"
skin	1	13099	.50	.7	1.15
"	2	13106	.74	"	"
"	3	13113	.70	"	"
bone	1	13101	.60	.6	1.40
"	2	13109	.78	"	"
"	3	13115	.56	"	"
lung	1	13102	.22	.2	1.30
"	2	13100	.16	"	"
"	3	13116	.20	"	"
liver	1	13103	.06	.1	.76
"	2	13110	.08	"	"
"	3	13117	.11	"	"
kidney	1	13104	.12	.1	1.12
"	2	13111	.27	"	"
"	3	13118	.21	"	"
gut	1	13105	.72	.7	2.56
"	2	13112	.58	"	"
"	3	13119	.76	"	"

Comparison of decline and decay rates is precluded by the paucity of simultaneous data and the variability in the terminal portion of the decline curves.

Variability

In view of the variety of conditions of locality, time, and personnel involved in the study, considerable variability in the results is to be expected. The statistical nature of the variability in algae, invertebrates, and fish is dealt with in another report (Bonham, 1956). For invertebrates, the coefficients of variation of the values of radioactivity for a tissue in a collection appear in Table 22.

Table 22. Mean coefficient of variation in percent, of values of radioactivity in tissues of invertebrates collected in 1954 at Belle after Nectar.

Tissue	Invertebrate			
	Tridacnid clam	Spider snail	Land hermit crab	Sea cucumber
Muscle	30	28	33	43
Gut or visceral mass	56	61	56	42
Integument	--	--	44	23
Liver	--	27	36	--
Mantle	29	37	--	--
Gill	33	--	39	--
Shell or carapace	61	46	30	--
Gonad	--	--	--	46

These mean coefficients are averages of 7 to 30 individual coefficients of variation calculated from the few (2 to 10, average 2.8) values for a tissue in each collection that involved more than one sample. Approximately 300 coefficients were averaged for Table 22. These ranged from 3% to 125% and were distributed asymmetrically with the peak strongly toward the left at about 20% to 30%, and the mean at 40%.

Coefficients of variation were highest (42% to 61%) for gut and shell, and markedly lower (28% to 43%) for muscle.

For the declines, the variability of the points about the regression lines is measured by the correlation coefficient in the last two columns of Table 1. The correlation is best where the data are most numerous.

Radiochemical analysis

In February 1956, Miss Dorothy South analyzed radiochemically some of the invertebrates collected at Belle in February and March, 1955, using procedures designed for the determination of fission products. Miss South is reporting the study more fully elsewhere. Ce^{144}-Pr^{144} accounted for 52-61% of the radioactivity in samples of spider snail muscle and mantle, and sea cucumber gonad; for only 10% in clam kidney; and for less than 1% in land hermit crab muscle and carapace. Sr^{90} constituted approximately 50% of the activity in hermit crab carapace, 5% in its muscle, and 0.1% in clam kidney. Ca^{45} constituted 2-4% of the activity in clam kidney. Because of the late date of analysis, Sr^{89} was not found in any of the samples mentioned here. The proportion of radioactivity due to Cs137 in March 1956 for land hermit crabs collected November 1, 1955 at Belle was 88% in muscle and 81% in liver.

At Belle the slow rates of decay and decline for spider snail muscle and mantle, and for sea cucumber gonad, relative to other tissues of the same animals, are presumably due to the large proportion of the radioactivity contributed by these particular long-lived products, but they do not explain the slow rate of clam kidney.

DISCUSSION

Decline and decay compared

The foregoing results show the decline trends for a period up to two years following detonations. It is important to be able to predict the future course of declines more than two years after the cessation of testing. Since prediction of radioactive decay of samples is possible on the basis of their radioisotopic content as determined by radiochemistry, spectrometry, etc., an understanding of the relationship between decline and decay will help in extrapolating future declines.

Decline rate was clearly steeper than decay rate for the alga Halimeda, the coral Acropora, and for most samples of sea water, plankton, and sea cucumbers. Decline and decay were nearly equal for island soil, most beach sand samples, clam, snail, and reef fish. The data were insufficient for comparison of the green leaves of land plants, crabs, terns, and rats. The slight indication of a steeper average decay than decline for beach sand at Leroy, if valid, might be caused by a continuing influx of activity from some reservoir, such as the crater, after the collection of the decay samples.

In a few cases decay rates were steeper than decline, probably because of uncertainty as to the decline rate: island soil at Janet, beach sand at Belle and Vera, sea water on the ocean side of Belle. The steeper decays of plankton at the Mike crater and of beach sand at Leroy appear to have more validity. However, all of these cases could occur by chance in the process of making as many comparisons as are represented in this paper. Clearly the balance is on the side of steeper declines than decays.

Decays tended to become more nearly level as time progressed for Acropora, Coenobita, tern, and rat, while for snail the decays became steeper instead of less steep, and for plankton, Halimeda, clams, and sea cucumbers the decays continued as essentially straight lines in log-log plot.

The declines showing the most pronounced tendency toward leveling near the end of the observation period were Halimeda at Belle, Janet, and Henry; leaves of land plants, Acropora, and Coenobita carapace at Belle; and sea cucumber gut at Henry. In some of these cases at least, the noted trend is simply a vagary of sampling.

That the tendency toward terminal leveling is not the general rule among the decline data is suggested by the position of the terminal point with respect to the regression line. In 63 of the graphs the last point fell below the line and in 53 cases, above. The position of the last decline point was predominantly above the decline regression line for beach sand, Belle land hermit crabs, reef fish, and Janet rats. It might be suspected that for these organisms declines were leveling. The terminal points were predominantly below the lines for sea water, plankton, clam, sea cucumber, and tern.

Assuming a constant, linear, log-log decay rate, and an equal rate of decline, all samples regardless of whether collected shortly or a long time after detonation should give the same level of activity when counted simultaneously, since the early samples would have decayed to the level of the later samples.

If the linear log-log decay and decline rates differ, then the early and late samples should yield different values when counted at the same time. When analogous samples taken on different dates were counted simultaneously, their levels reflected the relationship between decline and decay. This relationship was evident for Belle sea cucumber integument where the decline slope of -2.0 differed from the decay slope of about -1.4 by the amount of the recount slope, -0.6 (p. 33).

For Belle spider snails and the carapace of the land hermit crab no difference was apparent between decline and decay, nor was there a trend in the recounts (p. 28 and Held).

Rapid decline and decay at Leroy

The steepest decline and decay slopes for marine organisms, represented by Halimeda and sea cucumbers, were at Leroy. Rapid decline might be caused by dilution from ocean currents that are relatively free from radioactivity, but this factor would not influence decays.

In view of the correspondence between decline and decay, the rapid decline at Leroy undoubtedly reflects the isotopic composition of the samples rather than any diluting effect of ocean currents. However, some selective transporting mechanism, probably the water currents of the lagoon, must have been responsible for bringing shorter-lived products to Leroy or removing long-lived products.

That the Nectar-derived short-lived products at Leroy were not contributed by fallout is confirmed by the slow rate of decay of soil from the island proper.

The interval of 20 days after Nectar, before the first Leroy collections of *Halimeda*, would allow time for the currents in the lagoon to transport products of the detonation to the vicinity of Leroy. From earlier, unpublished data on the decay curves for collections of marine crabs, snails, coral, and sea cucumbers from Leroy on November 5, 1952, four days after the Mike shot, it was clear that decay slopes were no steeper at Leroy than at other islands.

Assuming similar spectra of half-lives from Mike and from Nectar, this four-day interval is believed to have permitted fallout, but to have been insufficient to allow such selective transporting by water, of short-lived products to, or of long-lived products from Leroy as may have occurred by the 20th day following Nectar.

Through some unknown mechanism the long-lived residual products from earlier detonations tended to remain in the marine life close to the site of detonation at the northern islands, while shorter-lived products tended to dominate in marine organisms at the greater distances represented by the southern islands within the confines of the atoll.

The distribution and uptake of short-lived materials at Leroy should be made the subject of further study because of their bearing upon the duration of radioactive contamination of marine habitats.

SUMMARY

Trends with time in the beta radioactivity of invertebrates and other organisms and substances were traced over a period of about two years, from shortly before Nectar (May 14, 1954) to April 1956. Extensive observations at one locality, Belle, were supplemented by study at several other localities around the atoll.

Absolute levels of radioactivity are summarized in Table 23. Outstanding values expressed in disintegrations per minute per gram (d/m/g) of wet tissue were: for pre-Nectar collections on April 15, 1954, high values, tern feathers $3x10^5$, clam kidney $2x10^5$, and snail liver 10^5; low values, fish muscle 200, and the branching coral Acropora 600.

Maximum levels of 10^7 occurred within one week post-Nectar in plankton at Belle and Leroy, and in tern feathers at Belle. Post-Nectar levels were low for rat skin and muscle at Janet, 2 to $3x10^3$ and for fish muscle at Belle, 7000. Acropora was intermediate at $3x10^5$.

By 700 days post-Nectar, the levels had decreased to maxima of 10^4 for clam kidney and Coenobita (land hermit crab) carapace, and minima of 100 for Acropora and estimated 30 to 40 for tern gut and muscle.

The decrease in amount of radioactivity in a certain substance at a locality with the passage of time after detonation, has been termed decline to distinguish it from the physical decay of individual samples.

The declines and decays were plotted logarithmically for comparison with the approximate theoretical decay rate, $t^{-1.2}$, for mixed fission products. Correlation coefficients at or beyond the 1% level of P were demonstrated for the relationship of log of activity to log of time after detonation in the cases of survey meter readings, some island soils and beach sands, most sea water samples, some plankton, most Halimeda (algae), land plant leaves, Acropora, tridacnid clams, most spider snail tissues, land hermit crabs, sea cucumbers, reef fish, tern, and most rat tissues.

Levels of activity in the first few days were in some cases too low to align with later points in logarithmic plot, suggesting that a preliminary period of build up is required in these organisms, particularly coral, sea cucumber, fish, and tern, for the radioisotopes to attain equilibrium with the non-radioactive constituents of the tissues.

Table 23. Levels of radioactivity in representative materials and organisms at Eniwetok Atoll before, and up to two years after, Nectar detonation, May 14, 1954. Data from decline graphs.

Substance or tissue	Locality	d/m/g wet, or as indicated		
		Pre-Nectar, April 5-15, 1954	Post-Nectar	
			Maximum observed	At 700 days*
Survey meter, open	Belle	--	400 mr/hr	1 mr/hr
Island soil	"	--	30,000,000	30,000
Beach sand	"	--	1,000,000	10,000
Sea water	"	--	30,000	1-.01
Plankton	"	10,000	10,000,000	2,000
"	Leroy	20,000	5,000,000	200
<u>Halimeda</u> (alga)	Belle	--	100,000	200
"	Leroy	2,000	1,000,000	100
Green leaves	Belle	--	5,000,000	1,000
<u>Acropora</u> (coral)	"	600	300,000	100
Clam visceral mass	"	20,000	2,000,000	1,000
" muscle	"	400	40,000	200
" kidney	"	20,000	1,000,000	10,000
Snail liver	"	100,000	3,000,000	20,000
" muscle	"	7,000	50,000	3,000
<u>Coenobita</u> (crab) liver	"	8,000	1,000,000	2,000
" carapace	"	10,000	2,000,000	10,000
" muscle	"	4,00	80,000	1,000
" gut	"	20,000	6,000,000	2,000
Sea cucumber gonad	"	6,000	200,000	1,000
" " gut	"	20,000	500,000	2,000
" " muscle	"	2,000	100,000	400
" " integument	"	1,000	100,000	200
" " gonad	Leroy	--	30,000	70
" " gut	"	--	30,000	200
" " muscle	"	--	200,000	50
" " integument	"	--	200,000	80
Fish (reef) skin	Belle	800	100,000	70
" " muscle	"	200	7,000	40
" " bone	"	--	100,000	200
" " liver	"	8,000	300,000	3,000
" " gut	"	9,000	1,000,000	2,000
Tern feathers & skin	"	30,000	10,000,000	200
" gut	"	70,000	600,000	30
" muscle	"	4,000	40,000	40
" bone	"	3,000	300,000	100
" lung	"	20,000	200,000	600
" liver	"	30,000	200,000	500
" kidney	"	40,000	300,000	600
Rat skin	Janet	--	2,000	100
" muscle	"	1,000	3,000	200
" liver	"	900	10,000	500
" lung	"	800	6,000	70
" kidney	"	1,000	10,000	300
" gut	"	30,000	80,000	50
" bone	"	10,000	20,000	600

*From regression. By extrapolation if necessary.

Decline rates were calculated on a logarithmic basis by the method of least squares using the Nectar test as origin except for rats, whose radioactivity was referred to the March 1, 1954 detonation at Bikini as origin. The most rapid declines with a slope of about -4 were for sea cucumber muscle and integument at Leroy. At Belle the decline rates of sea cucumber integument and muscle were about -2. Lagoon water and plankton near Belle declined at rates of -2.6 and -1.8, respectively, Halimeda -2.1, green leaves of land plants -1.6, Acropora after one month -2.2, clam tissues about -1.0, spider snail tissues -0.6 to -1.2, land hermit crab tissues -1 to -1.5, sea cucumber tissues -1.6 to -2, fish tissues -1.2 to -1.9, tern tissues -1.2 to -2.4 (gut), and rat tissues related to March 1, 1954, -0.8 to -2.6 (gut).

The residual long-lived products from earlier detonations, particularly Mike on November 1, 1952, are considered to have had an appreciable leveling influence on the decline and decay slopes. Even so, with the exception of clams, snails, and crabs, the observed decline rates were steeper than the -1.2 rate for mixed fission products.

Decay rates of certain samples were compared with the declines over simultaneous periods. Decline rate was steeper than decay for Halimeda, Acropora, and for most samples of sea water, plankton, and sea cucumbers. Declines approximately equalled decays for island soil, beach sand, clam, snail, and reef fishes. Simultaneous data were inadequate for comparison of decline and decay for the green leaves of land plants, crabs, terns, and rats. Only with beach sand was the decay somewhat steeper than decline.

The diluting influence of rain and of the surrounding ocean upon the radioactivity in the vicinity of the testing areas is considered to be responsible for the cases of more rapid decline than decay.

When samples of sea cucumber tissues collected in 1954-55 at Belle were recounted nearly simultaneously in 1957, the early samples tended to be more radioactive than the later samples, as would be expected when decline is more rapid than decay. Similar simultaneous recounting of samples of clam kidney and spider snail tissues from Belle, where decline and decay were equal, showed no significant difference between early and late samples.

Declines and decays of Halimeda and sea cucumbers were more rapid at Leroy than at more northern and eastern localities.

Lagoon currents are considered to be responsible for the tendency of marine, shallow water organisms to contain shorter-lived radioisotopes in the vicinity of the southern islands, and especially at Leroy, than at the northern islands where longer-lived products predominated. Soil from Leroy Island proper, which could not be affected by currents, on the other hand, exhibited as long a radioactive life as that from the northern islands.

Radiochemical analyses made in February 1956 by Miss South, in which methods designed for the detection of fission products were used, showed that 52-61% of the radioactivity in samples of spider snail muscle and mantle and in sea cucumber gut, and 10% in clam kidney was due to Ce^{144}-Pr^{144}. About 50% of the activity in carapace and 5% in muscle of the land hermit crab was due to Sr^{90}.

Gamma spectrometric analyses made in December 1956-May 1957 by Lowman, et al. of kidney and snail liver collected in 1954-55 at Belle demonstrated the presence of Ru^{106}-Rh^{106}, Mn^{54}, Co^{57} and Co^{60}. Resin column analyses, by the same authors, in December 1956 of a September 1956 sample of Belle clam kidney showed Fe^{55} to account for 74% of the activity, Co^{57}--9.6%, Co^{58}--9.2%, Co^{60}--1.8%, Y^{91}--2.6%, Mn^{54}--2.2%, and Ru^{106}-Rh^{106}, Zr^{95}-Nb^{95}, and Fe^{59}, together, --1%.

REFERENCES

Applied Fisheries Laboratory, University of Washington. 1955. Radiobiological resurvey of Rongelap and Ailinginae Atolls, Marshall Islands, October-November, 1955. U. S. Atomic Energy Commission report UWFL-43.

Bonham, K. 1956. Statistical variability in radioactivity of field samples of biological materials at Belle Island in 1954-55. (Manuscript)

Donaldson, L. R. 1953. Radiobiological studies at Eniwetok before and after Mike shot. U. S. Atomic Energy Commission report WT-616 (UWFL-33). (Confidential)

Donaldson, L. R. 1955. A radiological study of Rongelap Atoll, Marshall Islands, during 1954-1955. U. S. Atomic Energy Commission report UWFL-42.

Donaldson, L. R., et al. 1956. Survey of radioactivity in the sea near Bikini and Eniwetok Atolls June 11-12, 1956. U. S. Atomic Energy Commission report UWFL-46.

Held, Edward E. 1957. Land crabs and radioactive fallout at Eniwetok Atoll. U. S. Atomic Energy Commission report UWFL-50.

Hunter, H. F. and Ballou, N. E. Fission-product decay rates. Nucleonics, v. 9. no. 5, C-2-C-7, November 1951.

Lowman, F. G., R. F. Palumbo, and D. J. South. 1957. The occurrence and distribution of radioactive non-fission products in plants and animals of the Pacific Proving Ground. U. S. Atomic Energy Commission report UWFL-51.

Olson, P. R. and A. D. Welander. Radioactivity in roving carnivorous fishes at Eniwetok Atoll, April 1954 to October 1955. (Manuscript)

Palumbo, R. F. Radioactivity of the algae at Eniwetok Atoll in 1954-55. (Manuscript)

South, D. J. Radiochemical studies of materials from the Pacific Proving Ground in 1954-55. (Manuscript)

Welander, A. D. 1957. Radioactivity in the reef fishes of Belle Island, Eniwetok Atoll, from April 1954 to November 1955. U. S. Atomic Energy Commission report UWFL-49.

END

UNCLASSIFIED

UWFL

53

2OF2