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ABSTRACT

Radiobiological analysis of the reef fishes of Rongelap and Ailinginae Atolls indicated that a recontamination of the area occurred in 1956. Gross levels of beta activity in muscle tissue ranged from 0.016 to 0.038 uc/kg wet weight. The levels of radioactivity in bone and muscle tissues of fish collected during 1957 were about the same as the levels for similar tissues collected in 1955. Gamma spectra analysis and ion-exchange methods revealed the presence of Zn^{65}, Co^{57}, Co^{58}, Co^{60}, Mn^{54}, and Fe^{55}. Radiostrontium was found only in small amounts (about .0014 uc/kg wet weight) in the bone of fish from Kabelle Island, Rongelap Atoll. Approximately 40 per cent of the total radioactivity in the reef fishes was due to Zn^{65}, 28 per cent to cobalt, 26 per cent to Fe^{55}, and 6 per cent to other radionuclides.

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Introduction

During July 1957 collections of fish for radiobiological analysis were made at Ailinginae and Rongelap Atolls. The data from these collections represent part of the information from a continuing program of radiobiological studies which was begun on March 26, 1954, soon after the first radiological contamination of Rongelap and Ailinginae Atolls. Subsequent collections were made on July 16, 1954, January 29, 1955, and October 10, 1955. All of these investigations have been reported by Donaldson, et al. (1955). Data from the investigations in the Rongelap area by this Laboratory and other organizations have been summarized and coordinated by Dunning (1957). Results of the analyses of additional material collected August 3, 1956 are included in this report.

Materials and Methods

Fish were collected at Enibuk Island, Ailinginae Atoll, on July 11, 1957, by poisoning an area of the inner reef. One large grouper also was taken by hook and line in Mogiri Pass. On July 17, 1957, a collection was made in the lagoon in front of the village on Rongelap Island, Rongelap Atoll, and

on July 18, 1957, a collection was made in the channel off the northwest end of Kabelle Island, Rongelap Atoll. All fish were obtained in water 15 feet or less in depth and the collections were made in localities almost identical to those of the 1954, 1955 and 1956 surveys. Locality, date of collection, common names, genera, species and number of specimens for the 1956 and 1957 collections are listed in the appendix.

The fish were placed on ice in insulated containers within two hours of capture and transported to the Eniwetok Marine Biological Laboratory where they were frozen. There the fish were identified and dissected, except in the case of fish collected in 1956 when the frozen fish were shipped to the base Laboratory at the University of Washington for dissection and subsequent radiological analysis. Tissues used for analysis were muscle, bone, liver and stomach contents or viscera. Specimens which were too small to dissect were processed as whole fish.

Partly because of the omnivorous food habits of the Marshallese natives and partly because of variations in the samples, it is advisable to analyze many specimens of a variety of species to obtain reliable estimates of levels of radioactivity (Welander, 1957). Consequently, two-gram samples of muscle tissue were taken from each fish and the aggregate was homogenized in a Waring Blendor. Plates were made of aliquots of this homogenate and the remainder dried for radiochemical analysis. All samples were dried at 100° C and the plated samples ashed at temperatures up to 540° C, cooled, slurried, dried and counted in

internal methane gas-flow counting chambers at the Laboratory of Radiation Biology in Seattle. Counts per plate were converted to disintegrations per minute per gram of wet tissue by correcting for sample weight, geometry, backscatter and self-absorption. For a more complete discussion of these procedures see Donaldson et al. (1953)

Other tissues were treated similarly, with the exception of liver, in which case the whole organ was removed from each specimen. If a sufficient number of specimens of a single species was obtained, the tissues were treated separately as in the case of goatfish and halfbeak from Kabelle Island (see Table 1).

Decay rates for radioactivity of tissues of fish collected in 1956 were calculated because there were indications that Rongelap Atoll was contaminated during the Redwing operation.

Gamma spectra and total gamma counts were made on dried or ashed samples in a single channel, 50-position, automatic advance, gamma spectrometer using a two-inch, well-type sodium iodide crystal. Chemical analyses were made by ion-exchange resin column and radiochemical precipitation techniques. The radioactive isotopes contained in the separate fractions were identified by determination of the gamma energies, and by beta mass absorption studies using aluminum foil. Correction factors for converting beta and gamma counts to disintegrations per minute were calculated by the use of standards of known energies. Details of the procedures used are given by Lowman et al. (1957)

Table 1. Gross levels of beta radioactivity in reef fishes collected at Rongelap and Ailinginae Atolls, July 1957, expressed as uc/gm wet tissue*

Collection date and Locality	Common name	Number of specimens	Muscle	Bone	Liver	Stomach content	Whole fish
7/11/57 Ailinginae Atoll Enibuk I.	Reef fish	32	.038		.163		
	Reef fish	51					.030
	Grouper (Plectropomus leopardus)	1	.036	.100			
7/17/57 Rongelap Atoll Rongelap I.	Reef fish (carnivores)	26	.016	.022	.059	.026	
	Reef fish (omnivores)	24	.018	.020	.068	.063	
	Reef fish	73					.028
7/18/57 Rongelap Atoll Kabelle I.	Reef fish	11	.027	.102	.276	.125	
	Reef fish	36					.049
	Goatfish (Mulloidichthys samoensis)	14	.036		.727	.370	
	Halfbeak (Hyporhamphus laticeps)	50	.016		.080	.038	

*Counts were made during August 1957.

Results

Gross Beta Radioactivity

Table 1 shows gross levels of beta radioactivity in the fishes during July 1957. Of the three islands visited the highest levels were found in the fish liver tissue from Kabelle Island. In all cases, for comparable tissues the least radioactivity was found in fish collected near Rongelap Island. Radioactivity in muscle tissue of fish from Enibuk Island, Ailinginae Atoll, was as great or greater than that of Kabelle Island.

Comparatively minor differences are seen in the levels of radioactivity in similar tissues of omnivorous and carnivorous fishes from Rongelap Island, except for stomach contents. The presence of algae in the stomachs of many omnivorous fish would account for the higher levels in these fishes.

Two species, the goatfish and the halfbeak, were taken in sufficient quantities for separate analyses. The goatfish feeds on small invertebrates, principally crustacea, of the sandy bottom areas. Levels of radioactivity in the stomach contents and liver of these fish were much higher than in other fish of the same area; however, radioactivity in muscle tissue was not much higher. The halfbeaks from Kabelle Island had about the same amount of radioactivity as fish from Rongelap, reflecting, perhaps, a different feeding habit than that of other fish of Kabelle Island. The halfbeak normally feeds at the surface on macroplankton,

which includes small fish, invertebrates and algae.

Table 2 contains data on the rate of decline of the beta radioactivity in reef fish collected at Rongelap and Ailinginae Atolls between March 26, 1954 and July 18, 1957. The rates of decline in liver, bone and muscle tissue of fish from Kabelle Island are given in Figure 1. The decline rates are similar for all three tissues, especially during the first two years. Recontamination by other nuclear devices during the summer of 1956 is indicated by the increase of radioactivity in muscle and bone and a temporary decrease in rate of decline in liver tissue. At present, the radioactivity in liver tissue appears to be declining at a more rapid rate than in bone or muscle, while the radioactivity in the viscera or stomach contents has declined more rapidly than that of other tissues (Table 2). It has been suggested (Welander, 1957) that some of the long-lived isotopes may be accumulating in the bone and muscle of fish, whereas the radioactivity in liver tissue is similar to that in the stomach, bearing out the fact that the liver is an organ for the temporary storage and passage of food and waste products. It is of interest to note that the levels of radioactivity in the bone and muscle are about the same as those of the 1955 samples.

Data on radioactive decay were obtained from bone and liver tissue of groupers (Epinephalus merra) from Kabelle and Rongelap Islands, and from homogenized muscle tissues from 13 species of reef fish. The decay rates of muscle and bone (Figure 1) are more rapid than decline rates for the

Table 2. Gross levels of beta radioactivity in the reef fish collected at Rongelap and Ailinginae Atolls, 1954 through 1957, expressed as uc/kg wet tissue

Locality	Date of collection	Number of specimens	Muscle	Bone	Liver	Viscera or stomach contents	Whole fish
Rongelap Atoll							
Rongelap I.	1/25/55	22	0.034	0.30	2.0	1.6	
	10/22/55	33	0.009	0.070	0.60		
	8/3 /56	19	0.059	0.15	0.71		
	7/17/57	50	0.017	0.021	0.064	0.044	
		73					0.028
Kabelle I.	3/26/54	12	2.7	13.0	200.0	510.0	
	7/16/54	32	0.50	2.9	22.0	36.0	
	1/29/55	27	0.083	0.49	3.2	3.6	
	10/21/55	34	0.026	0.12	1.6		
	8/3 /56	15	0.030	0.21	1.3		
	7/18/57	11	0.027	0.10	0.28	0.12	
		36					0.049
Ailinginae Atoll							
Enibuk I.	10/23/55	28	0.015	0.039	0.27		
	7/11/57	32	0.038		0.16		
		51					0.030

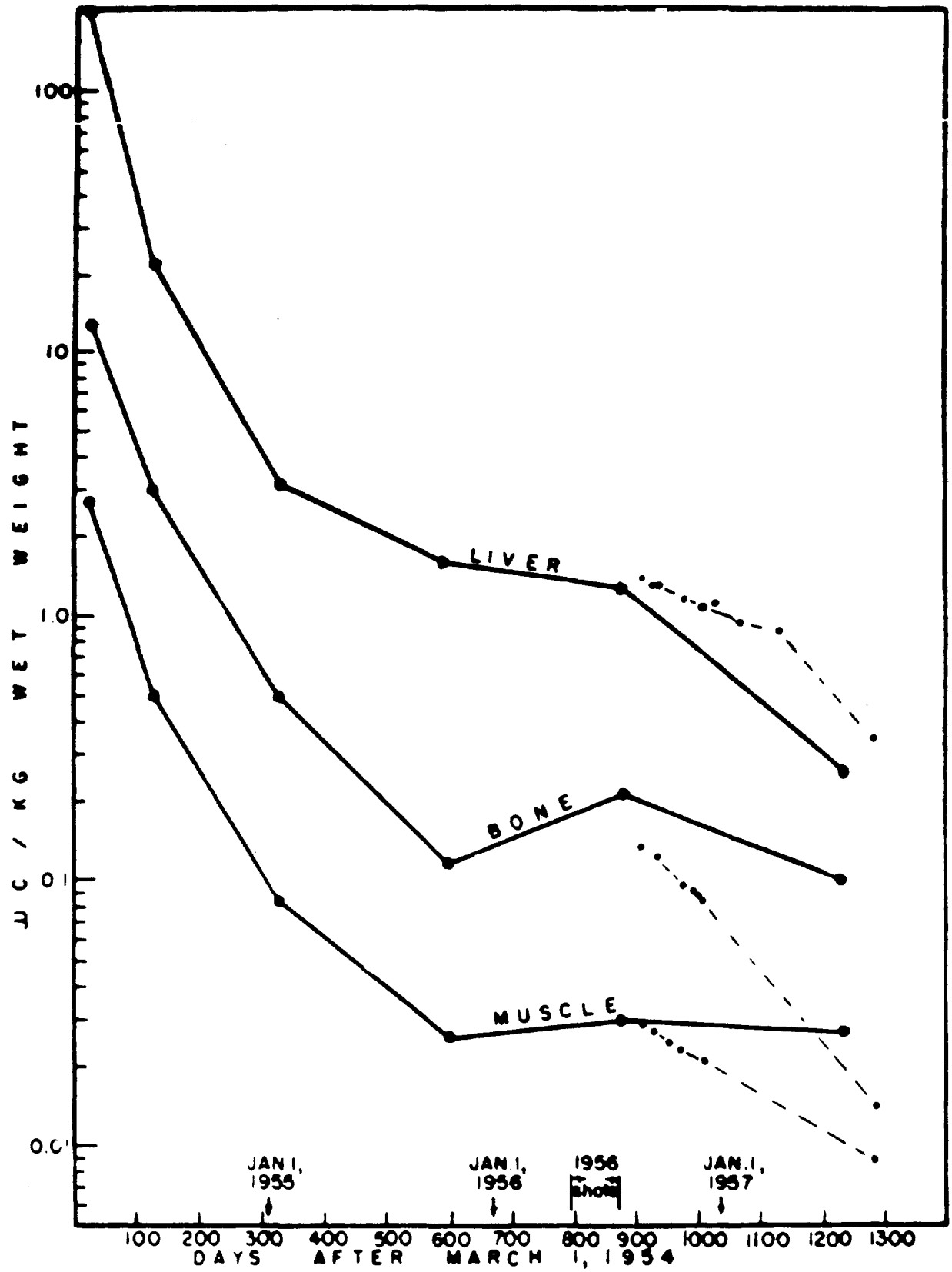

Fig. 1. Rate of decline (solid line) of radioactivity in reef fish collected at Kabelle Island, Rongelap Atoll between March 26, 1954 and July 18, 1957. Broken lines indicate decay in tissue of fish collected August 3, 1956.

same period; however, liver tissue decay and decline rates are similar. The differences in rate of decay and decline in both bone and muscle may indicate greater retention as well as continued uptake of long-lived radioactive materials in these tissues.

Figure 2 illustrates the rate of decline in the tissues of fish from Rongelap Island between January 25, 1955 and July 17, 1957. Again it will be noted that the rate of decline of radioactivity is somewhat greater in the liver tissue than in bone or muscle. All tissues show a definite increase in radioactivity after the summer of 1956, reaching a relatively higher level than for the same tissues in fish from Kabelle Island, but declining at a more rapid rate after 1956.

Decay and decline rates of radioactivity of muscle and bone tissue from fish from Rongelap Island are approximately the same, decay being slightly more rapid. The radioactivity in liver tissue declines at a more rapid rate than it decays.

Gross Gamma Radioactivity, 1957

Table 3 contains data on gross levels of gamma radioactivity in the homogenate of many reef fishes collected at Rongelap and Ailinginae Atolls. As with the beta radioactivity, Rongelap Island fish generally had less gamma radioactivity than fish from either Enibuk or Kabelle Islands. Also differences were not great between similar species from different islands. A markedly higher amount of radioactivity was noted again in the liver of

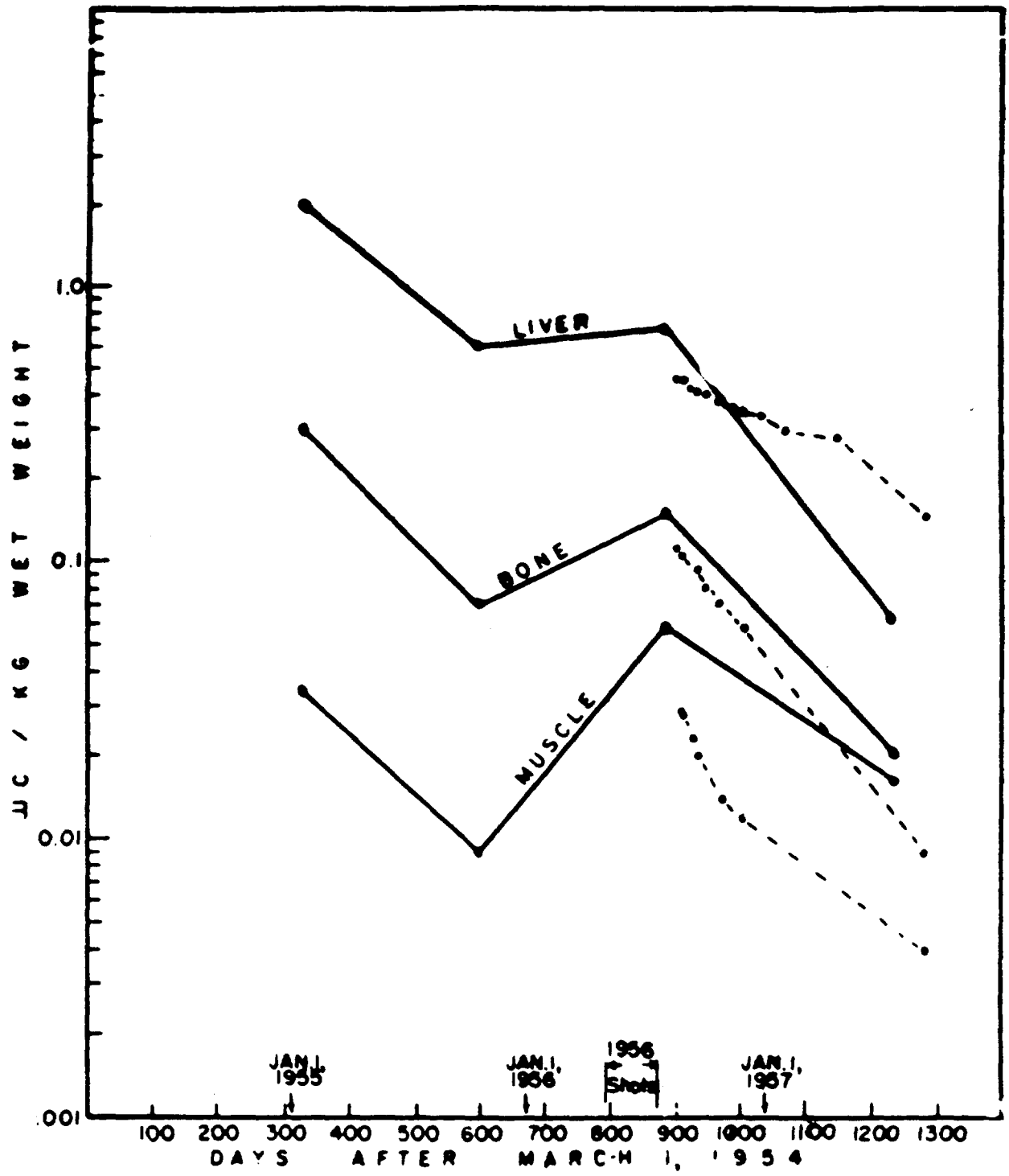

Fig. 2. Rate of decline (solid line) of radioactivity in reef fish collected at Rongelap Island, Rongelap Atoll between January 25, 1955 and July 17, 1957. Broken lines indicate decay in tissues of fish collected August 3, 1956.

Table 3. Gross levels of gamma radioactivity in reef fishes collected at Rongelap and Ailinginae Atolls, July 1957, expressed as c/m/g wet tissue *

Collection date and Locality	Common name	Number of specimens	Muscle	Bone	Liver	Stomach content
7/11/57 Ailinginae Atoll Enibuk I.	Reef fish	32	33		105	
7/17/57 Rongelap Atoll Rongelap I.	Reef fish (carnivores)	26	20	34	111	
	Reef fish (omnivores)	24	19	22	64	
7/13/57 Rongelap Atoll Kabelle I.	Reef fish	11	36	54	75	48
	Goatfish	14	28		413	683
	Halfbeak	50	14		64	

*Tissues were counted for radioactivity during September 1957.

goatfish caught at Kabelle Island. The radioactivity in muscle tissue was generally about the same in Kabelle and Enibuk reef fish.

Gamma radioactivity in the muscle averaged about 26 per cent that of the liver with variation of from 7 to 48 per cent. Beta activity was slightly lower, the muscle to liver ratio averaging about 19 per cent, with a range of from 5 to 27 per cent. The greatest difference in the amounts of both gamma and beta radioactivity between liver and muscle was found in the goatfish.

Gamma Spectra

Gamma spectra were made on dried samples of tissue to determine if gamma peaks other than those from expected fission products were present. The gamma spectrum curves obtained from various fish tissues are compared with spikes of radioactive cobalt and radioactive zinc in Figure 3 (top, center panel)

The gamma spectra (made in October 1957) on whole samples exhibited certain common characteristics with peaks at several positions as follows:

0.12 MEV considered to be from Co^{57}

0.51 MEV " " " " Zn^{65}

0.84 MEV " " " " Mn^{54}

1.12 MEV " " " " Zn^{65}

1.33 MEV " " " " Co^{60}

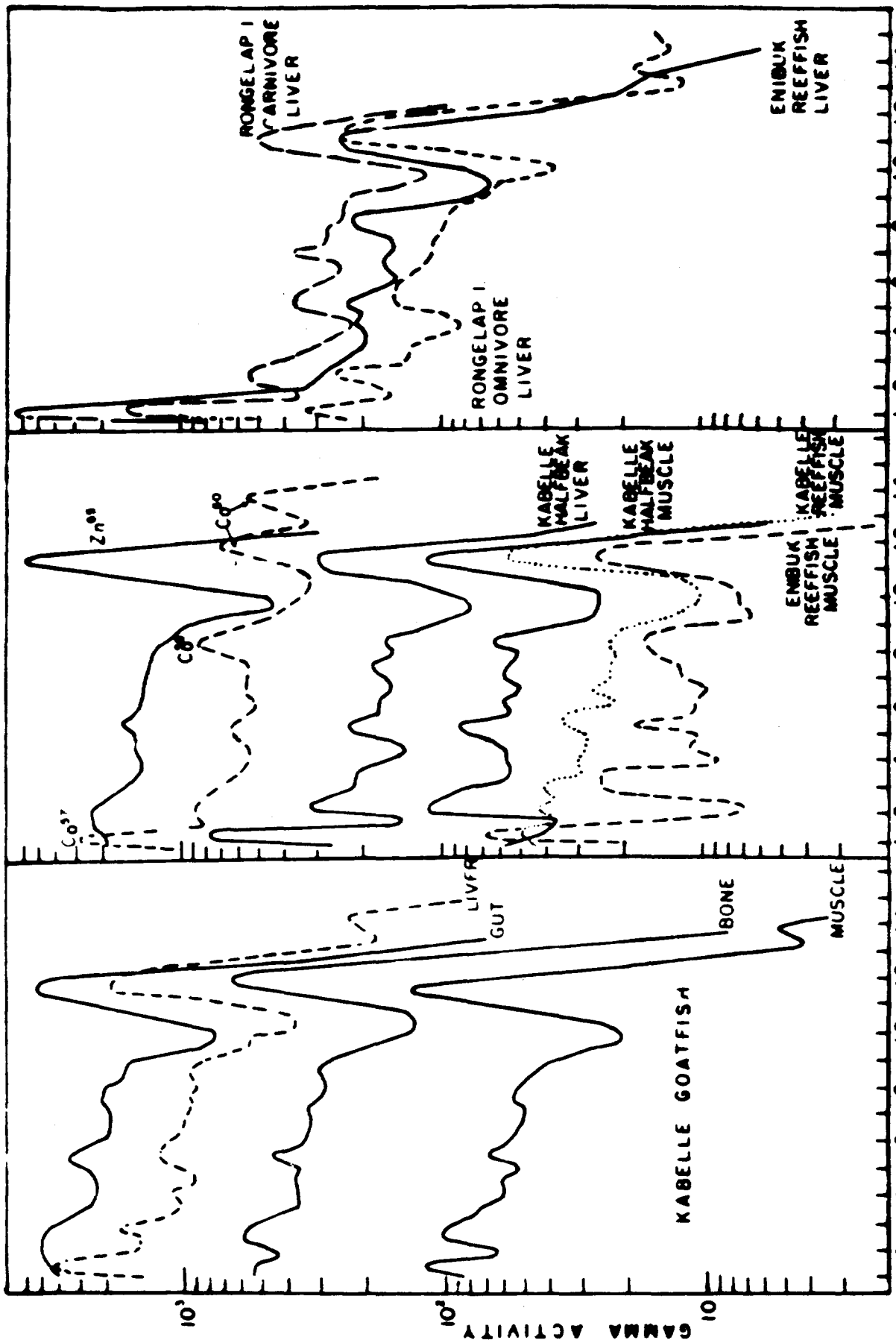

Fig. 3. Gamma spectrum curves on whole samples of fish tissue from Rongelap and Ailinginae Atolls, July 1957, compared with gamma spectrum curves of Zn^{65} and Co^{57}, Co^{58} and Co^{60} (top, center).

The Zn^{65} peak at 1.12 MEV occurred in every tissue sample tested, indicating the common occurrence of this isotope compared with other gamma emitters. This radioisotope has been observed in fish tissues by many authors, as summarized by Lowman et al. (1957). Additional data from this Laboratory are given in Table 4.

The Co^{57} peak of 0.12 MEV was present in the liver of all fish tested, however, it appears to be rather low in the liver tissue of omnivorous fish taken at Rongelap Island. This radioisotope was not detected in goatfish gut or goatfish bone, but occurred in small amounts in goatfish muscle. No distinct peak at 0.12 MEV appeared in the muscle tissue of reef fish or in halfbeaks taken at Kabelle Island.

The peak of Mn^{54}, at 0.84 MEV, was partially obscured by the Co^{58} peak at 0.81 MEV. One or both of these radioisotopes appeared to be present in the muscle and liver of reef fish from Enibuk Island, in the muscle and liver of halfbeaks from Kabelle Island, and possibly were present in the muscle of reef fish from Kabelle Island. Verification of the presence of both of these isotopes in Enibuk reef fish liver was later obtained by ion-exchange resin column analysis (see below).

The Co^{60} peak at 1.17 MEV was obscured by the Zn^{65} peak at 1.12 MEV; however, the Co^{60} peak at 1.33 MEV was observed in the liver and muscle of Kabelle goatfish and in the liver of Rongelap omnivorous fish. The presence of Co^{60} was also later verified by ion-exchange analysis of Enibuk reef fish liver.

Table 4. Summary of the data from gamma spectrum curves on whole samples of fish tissues from Rongelap and Ailinginae Atolls collected in 1955, 1956, and 1957

Collection site and Date		Specimen	Co^{57}	Mn^{54}	Fe^{59}	Co^{60}	Fe^{55}
Rongelap I.	10/21/55	Dogtooth tuna muscle	?			?	
Kabelle I.	"	Grouper muscle	present	present			
Rongelap I.	"	Mullet muscle	?				
Rongelap I.	7/23/56	Reef fish bone	?	present		present	
"	"	Reef fish liver		present			
Kabelle I.	7/24/56	Goatfish liver			trace		?
"	7/18/57	Goatfish liver	present	?		present	
"	"	Goatfish muscle	present			present	
"	"	Goatfish bone		?			
"	"	Halfbeak muscle		?			
"	"	Halfbeak liver	present	?			
"	"	Reef fish muscle	?	present			
"	"	Reef fish gut	?	?			
Rongelap I.	7/17/57	Reef fish liver (carnivores)	present			?	
"	"	Reef fish liver (omnivores)	present			present	
Enibuk I.	7/11/57	Reef fish liver	present	present			present
"	"	Reef fish muscle	present	present			

*A strong Zn^{65} peak was seen in almost all of the curves.

In general, the gamma spectra of the fish tissues from different areas have definite similarities, even when compared to results obtained from other atolls (Lowman et al 1957) Differences in gamma spectra appear to be greater between different organs of the same fish than between the same organs of fish from different islands or atolls.

Separation and Identification of the Nuclides by Ion-exchange Techniques

To identify the various radionuclides contained in the reef fish liver samples collected at Enibuk Island, Ailinginae Atoll, July 11, 1957, the samples were pooled and the ash (0.384 grams) dissolved in 0.2 N HCl. This solution, after filtering, was passed through an ion-exchange cationic resin column of Dowex 50. The anions and HCl wash fractions of the sample were combined and later passed through an ion-exchange column of Dowex 1 anionic resin to further separate the fractions and to obtain the excess of the nuclides resulting from overloading the cationic resin The radioassay of the fractions obtained from both columns is summarized in Table 5. Details of these procedures have been reported by Lowman et al (1957). The methods generally follow those developed by Tompkins et al. (1947), Kraus and Moore (1953), Kimura et al (1956), Takanobu et al. (1956), and Ishibashi et al. (1956).

The identification of Fe^{55} in the oxalate fractions was made by mass absorption technique in a windowless methane gas-flow beta counter. One-ml plates of several fractions totaled 39 c/m after drying under an

Table 5. Summary of the radioassay by ion-exchange analysis of liver tissue of reef fish from Enibuk Island, July 11, 1957 * (Counts made in October 1957)

Dowex 50 separation Fractions in order of elution	Isotope	d/m ash sample	d/m/g wet weight
0.5% oxalic acid	Fe^{55}	11,872	516
5% ammonium citrate pH 3.5, b-m	Zn^{65}	6,187	269
" " "	Co^{57}	5,902	257
" " "	Co^{58}	1,102	48
" " "	Co^{60}	489	21
pH 3.5, o,p and pH 4.1, a-i	Mn^{54}	108	5
pH 5.1, b-k	Sr^{90}	0	0
Dowex 1 separation** Fractions in order of elution			
6 M HCl	Mn^{54}	458	20
4 and 2.5 M HCl	Co^{57}	3,968	172
" " " " "	Co^{58}	485	21
" " " " "	Co^{60}	756	33
0.005 M HCl	Zn^{65}	11,898	517

* Ash weight of sample 0.384 grams.

**These fractions contained considerable amounts of manganese, cobalt, and zinc, indicating an overloading of the Dowex 50 cationic resin.

infrared heat lamp, 110 c/m after flaming and 4 c/m after covering with aluminum foil 4.7 mg/cm^2 in weight. A total correction factor of 112 was used (based on a secondary Fe^{55} standard obtained from Dr. C. A. Finch, University of Washington) to convert to disintegrations per minute.

The radioisotopes of zinc, cobalt and manganese were identified by their gamma energies and the disintegrations per minute were calculated from the gamma spectrum curves of the different fractions.

Radiostrontium was not detected in the citrate fractions where it would be expected to occur.

Radiochemical precipitation determinations revealed the presence of small amounts of radiostrontium in the bone of fish collected at Kabelle Island. No radiostrontium was detected either in the liver or muscle of any of the fish taken at Ailinginae or Rongelap Atolls or in the bone of fish from Enibuk Island or Rongelap Island. Table 6 contains data on the Sr^{90} content in fish tissues collected during and since 1954 at Rongelap Atoll by this Laboratory. Except for traces of Sr^{90} in goatfish and reef fish bone from the Kabelle Island 1957 collections and in bonito bone from the 1955 collections at Labaredj, no radiostrontium has been detected in the fish tissues.

A summary of the data on the radioisotopes obtained from the liver tissue sample of reef fish from Enibuk Island is contained in Table 7. In total radioactivity, Zn^{65} contributed about 40 per cent, Co^{57}, Co^{58},

Table 6. Radiostrontium in fish tissues collected at Rongelap and Ailinginae Atolls, 1954 through 1957*

Island	Date collected	Species	Tissue	Total beta activity d/m/g wet weight	Sr^{90} d/m/g wet weight	Sunshine units
Rongelap	July 1957	Reef fish	Bone	46	0	0
Kabelle	" "	" "	"	220	3.2 ± 0.2	23
"	" "	Goatfish	"	44	2.5 ± 0.4	14
"	" "	"	Liver	1,600	0	0
"	" "	"	Muscle	80	0	0
"	" "	Reef fish	"	60	0	0
Enibuk	" "	Grouper	Bone	220	0	0
Rongelap	July 1956	Reef fish	Muscle	73	0	0
"	" "	" "	"	316	0	0
Kabelle	" "	" "	"	82	0	0
"	" "	" "	"	137	0	0
Kabelle	Jan. 1955	Mullet	Muscle	300	0	0
"	Oct. "	Grouper	"	31	0	0
"	" "	"	Liver	5,500	0	0
"	" "	Goatfish	Muscle	42	0	0
Labaredj	" "	Bonito	"	150	0	0
"	" "	"	Liver	1,700	0	0
"	" "	"	Bone	390	2.3	11
Mellu	Dec. 1954	Dogtooth tuna	Muscle	22	0	0

*Data obtained from radiochemical precipitation analyses made by Miss Dorothy South.

Table 7. Summary of the radioassay of liver tissue from reef fish collected at Enibuk Island, Ailinginae Atoll, July 11, 1957

Isotope	Beta-gamma activity, d/m/g wet weight	Beta+ activity,* d/m/g wet weight	uc/kg wet weight	Per cent total beta-gamma activity
Zn^{65}	786	24	.357	39.5
Co^{57}	429	138	.195	21.6
Co^{58}	69	22	.031	3.5
Co^{60}	54	19	.024	2.7
Fe^{55}	516	0	.234	25.9
Mn^{54}	25	0	.011	1.2
Sr^{90}	0	0	0	0
Unidentified	111**	111**	.050	5.6
Totals	1,988	314	.902	100.0

* Beta+ activity for Zn^{65} is 2.5 per cent of the total radioactivity. Self-absorption corrections for beta activity in cobalt were made by using standards and spikes in 5 per cent citrate dried on 1½-inch plates and counted in the methane gas-flow Nucleometer (Lowman et al., 1957).

** Unidentified radioactivity was estimated by subtracting the calculated beta activity in Zn^{65}, Co^{57}, Co^{58} and Co^{60} from the beta activity (314 d/m/g wet weight) counted in the methane gas-flow counter.

and Co^{60} about 28 per cent, and Fe^{55} about 26 per cent. The radioisotope Mn^{54} was detected in only minor amounts and unidentified radioisotopes amounted to about 6 per cent of the total radioactivity. It was presumed that the unidentified radioactivity was due to beta particles which penetrated the aluminum shield of the sodium iodide crystal. However, these totals may be conservative, due in part to sample loss and partly because all of the gamma activity was not accounted for.

It will be observed that almost all, if not all, of the radioactivity is due to non-fission products (Table 7). It is also of interest to note that since the discovery of Zn^{65} in tissues of fish from the Pacific area by Kawabata (1954), this radioisotope has consistently been found in fish tissues, usually as the dominant radioisotope (Rinehart et al., 1955; Donaldson et al., 1955; Yamada et al., 1955; Saeki, Okano, and Mori, 1955; Mori and Saiki, 1956; Yoshii, 1956; Nagasawa et al, 1956; Lowman et al., 1957).

There are additional similarities in the kinds and amounts of radioisotopes found in fish tissues. Most investigators have found little or no radiostrontium, even in the bones of fishes. Radioisotopes of cobalt have been found in tissues of fish from Bikini and Eniwetok Atolls (Lowman et al., 1957) as well as in fish of the open sea (Kawabata, 1954). Co^{57}, Co^{58} and Co^{60}, together, comprise as much as 28 per cent of the radioactivity in the fish tissues of the Rongelap area. Fe^{55} and Mn^{54} have both been found by previous investigators (Lowman et al., 1957). Apparently

Fe^{55} is the dominant radioisotope in tissues of fish from Eniwetok and Bikini Atolls. Mn^{54} is often present in fish tissues but only in small amounts.

Some differences in radioisotopic content of certain organs in the same fish have become evident. Bone, for example, differs from most other tissues in lacking Co^{57}, Co^{58}, and Co^{60}, although considerable amounts may be present in the muscle and liver of the same fish.

If the radioisotopes in Table 7 are used and the half lives weighted by either the per cent of total activity or the d/m/g wet weight, the estimated generalized decay of the radioactivity in the sample indicates an approximate 380-day half life for the period between the summer of 1957 and the summer of 1958.

An estimation of the biological half life of the radiosotopes in the fish of the Rongelap area would be even more speculative. However, if the comparisons of the decline and decay in Figures 1 and 2 are indicative, it would appear that the biological half life is longer than that estimated for physical decay in the previous paragraph. It would be of value to know the biological half life of each of the radioisotopes in the Rongelap environment.

Summary

This report contains data and a discussion of the analysis of the radioactivity in the fish collected at Rongelap and Ailinginae Atolls during the summers of 1956 and 1957, as well as comparisons with previous radiobiological studies.

Gross levels of beta radioactivity in muscle tissue ranged from .016 to .038 uc/kg wet weight; bone from .020 to .102 uc/kg wet weight; and liver tissue from .059 to .727 uc/kg wet weight.

Decline in radioactivity in the various tissues, as determined from data obtained from collections of fish made in 1954, 1955, 1956 and 1957, indicates recontamination from the nuclear tests of 1956. The levels of radioactivity in bone and muscle tissues during the summer of 1957 were approximately the same as they were in the summer of 1955.

Data on gross gamma radioactivity indicated that about the same relative amount was present in the tissues of fish and in fish from different areas as was observed with gross levels of beta activity. Both gamma and beta radioactivity were higher in the liver tissue than in other tissues of the same fish, muscle tissue being the lowest of the materials tested. The radioactivity in the fish was lower at Rongelap Island than at either Enibuk Island, Ailinginae Atoll, or Kabelle Island, on the northeast rim of Rongelap Atoll. Of the three areas, Kabelle Island had fish with the greatest amount of radioactivity.

Gamma spectrometry on ashed samples revealed that certain radioisotopes such as Zn^{65}, Co^{57}, Co^{60} and Mn^{54} were common in all soft tissues examined, while only Zn^{65} and Mn^{54} were found in the bone. The similarities between these gamma spectra and those obtained from fish tissues of other areas of the Pacific are pointed out.

Chemical separations by ion-exchange resin column techniques were made on fish liver samples from Ailinginae Atoll. These samples exhibited the characteristic gamma spectrum of fish tissues from the three areas. The presence of the radioisotopes mentioned above was verified and quantitative estimates of the radioactivity of each isotope in the sample were made. In addition Fe^{55} was found using mass absorption techniques. About 40 per cent of the total radioactivity was due to Zn^{65}; 28 per cent to Co^{57}, Co^{58}, and Co^{60}; 26 per cent to Fe^{55}; and about 6 per cent to unidentified radioisotopes.

Ion-exchange resin column methods failed to reveal the presence of radiostrontium in the liver of Enibuk reef fish. This radioisotope has been reported occasionally in fish bone of the Rongelap region but only in very small amounts.

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APPENDIX

Appendix Table 1. Common name, genus, species and number of specimens collected at Rongelap and Ailinginae Atolls during July 1957

Locality and date	Common name	Genus and species	Number of specimens
Enibuk I. Ailinginae Atoll 7/11/57	Grouper	Epinephalus merra	11
	Goatfish	Upeneus bifasciatus	3
	"	Mulloidichthys samoensis	3
	Squirrelfish	Holocentrus sammara	3
	Damselfish	Abudefduf biocellatus	10
	"	Dascyllus aruanus	5
	Surgeonfish	Acanthurus elongatus	12
	Hawkfish	Amblycirrhitus arcatus	4
	Lizard fish	Synodus variegatus	3
	Reefsmelt	Parapercis montillae	5
	Eel	Gymnothorax picta	1
	Halfbeak	Hyporhamphus laticeps	1
	Wrasse	Halichoeres trimaculatus	7
	Cardinal fish	Apogon sp.	5
Rongelap I. Rongelap Atoll 7/17/57	Grouper	Epinephalus merra	27
	"	Anyperodon leucogrammicus	2
	"	Cephalopholis leopardus	2
	Squirrelfish	Holocentrus spinifer	2
	"	" diadema	8
	Jack	Caranx sp.	6
	Lizard fish	Synodus variegatus	8
	Damselfish	Pomacentrus lenkensi	30
	Surgeonfish	Ctenochaetus striatus	5
	"	Zebrasoma flavescens	1
	Butterfly fish	Chaetodon citrinellus	5
	"	" lunula	1
	Wrasse	Halichoeres trimaculatus	13
	Goatfish	Mulloidichthys samoensis	5
	Snapper	Lutianus sp.	1
	Parrot	Scarus sp.	5
	Cardinal fish	Apogon snyderi	1
	Goby	Amblygobius phalaena	1
	Flatfish	Bothus mancus	1
Kabelle I. Rongelap Atoll 7/13/57	Goatfish	Mulloidichthys samoensis	14
	"	Upeneus bifasciatus	1
	Grouper	Epinephalus merra	4
	"	" fuscoguttatus	1
	Surgeonfish	Acanthurus olivaceus	1
	"	" elongatus	11

Appendix Table 1. (continued)

Locality and date	Common name	Genus and species	Number of specimens
Kabelle I. Rongelap Atoll 7/18/57	Squirrelfish	Myripristis murdjan	1
	"	Holocentrus diadema	1
	Damselfish	Pomacentrus lenkensi	3
	"	Dascyllus aruanus	9
	Wrasse	Halichoeres trimaculatus	6
	Parrot	Scarus sp.	3
	Eel	Gymnothorax buroensis	4
	Reef fish	Pseudochromis tapeinosoma	2
	Halfbeak	Hyporhamphus laticeps	50

Appendix Table 2. Radioactivity in fish from Rongelap Island, Rongelap Atoll, collected July 23, 1957 (Values expressed in uc/kg)

Common name	Genus and species	Muscle	Bone	Liver
Surgeonfish	Acanthurus nigricans	0.341	0.199	0.590
Squirrelfish	Holocentrus diadema	.028	.058	.285
		.043	.353	6.090
Butterfly fish	Chaetodon citrinellus	.024	.091	.178
Grouper	Epinephalus merra	.019	.112	.468
Grouper	Cephalopholis leopardus	.021	.121	1.400
Grouper	C. urodelus	.014	.068	.482
Damselfish	Pomacentrus melas	.087	.134	.309
		.027	.104	.222
Goatfish	Mulloidichthys samoensis	.018	.069	.189
		.021	.131	.178
		.012	.222	.224
Goatfish	Upenaus berberinus	.145	.106	.168
Lizard fish	Synodus variegatus	.038	.205	.454
Threadfish	Polydactylus sexfilis	.164	.273	1.040
		.013	.173	.375
		.055	.213	.473
Jack	Caranxoides ferdau	.029	.094	.295
Wrasse	Halichoeres trimaculatus	.014	.079	.084
Homogenized muscle tissue from 13 species (above) 19 specimens (1 gram tissue from each). Three plates made from aggregate.		.029		
		.043		
		.122		

Appendix Table 3. Radioactivity in fish from Kabelle Island, Rongelap Atoll, collected July 24, 1956

Common name	Genus and species	Muscle	Bone	Liver
Butterfly fish	Chaetodon citrinellus	0.056	0.196	1.520
Damselfish	Pomacentrus nigricans	.043	.384	.208
Surgeonfish	Acanthurus elongatus	.035	.306	1.390
Parrotfish	Scarus purpureus	.030	.340	.814
Flatfish	Bothus mancus	.035	.224	.444
Grouper	Epinephalus merra	.017	.135	1.400
Grouper	E. fuscoguttatus	.035	.079	.886
Snapper	Gnathodentex aurolineatus	.024	.173	.477
Goatfish	Mulloidichthys samoensis	.038 .028	.314 .294	1.460 2.820
Lizard fish	Synodus variegatus	.019	.116	.113
Squirrelfish	Holocentrus sammara	.026	.124	4.170
Squirrelfish	Myripristis pralinius	.020	.127	.318
Wrasse	Cheilinus fasciatus	.026 .021	.170 .124	2.470 .736
Homogenized muscle tissue from 13 species (above), 15 specimens (1 gram tissue from each). Three plates made from aggregate.		.027 .030 .048		

END