UNCLASSIFIED

UWFL-90

GAMMA-EMITTING RADIONUCLIDES IN TUNA SAMPLES FROM THE TOKYO CENTRAL FISH MARKET, 1962

By
Allyn H. Seymour

September 5, 1963

Laboratory of Radiation Biology
University of Washington
Seattle, Washington

UNITED STATES ATOMIC ENERGY COMMISSION • DIVISION OF TECHNICAL INFORMATION

UNCLASSIFIED

This report has been reproduced directly from the best available copy.

Printed in USA. Price $2.00. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Va.

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

UWFL-90
BIOLOGY AND MEDICINE
(TID-4500, 39th Ed.)

GAMMA-EMITTING RADIONUCLIDES IN TUNA SAMPLES FROM THE TOKYO CENTRAL FISH MARKET, 1962

Allyn H. Seymour

Laboratory of Radiation Biology
University of Washington
Seattle, Washington

Lauren R. Donaldson
Director

September 5, 1963

Operated by the University of Washington
under Contract No. AT(45-1)1385 with the
United States Atomic Energy Commission

GAMMA-EMITTING RADIONUCLIDES IN TUNA SAMPLES FROM THE TOKYO CENTRAL FISH MARKET, 1962

INTRODUCTION

Samples of tuna were obtained from the Tokyo Central Fish Market for radiological analyses during the period from May 2 to October 31, 1962. The fish were caught in the Western Pacific Ocean by Japanese commercial fishermen before, during and after the United States program, in 1962, of testing nuclear devices near Christmas Island in the Central Pacific. The samples were obtained by inspectors from the Tokyo Metropolitan Food Inspection Office of the Tokyo Central Wholesale Market as the fish were unloaded from the fishing vessels. Each sample was divided: one half was retained by the National Institute of Health, Tokyo, and the other half, after drying, was sent to the Laboratory of Radiation Biology, University of Washington. The arrangements for obtaining these samples, as well as similar samples in 1958, were made by L.R. Donaldson, Director of the Laboratory of Radiation Biology, and T. Kawabata of the Department of Food Control, National Institute of Health, Tokyo.

The kinds and amounts of gamma-emitting nuclides in these samples are reported here. The gross-beta and the gross-gamma radioactivity of the duplicate samples has been reported by Kawabata, Muira and Shimanuki (1963).

Table 1. Fishing records and species of "tuna" from which samples for gamma spectrum analyses were obtained.

Grouping* Month	Fish no.	Dates landed, 1962	Dates of catch, 1962	Big-eye	Yellow-fin	Sword-fish	Total
Eviscerated tuna							
1. May	1-20	May 2-13	Feb. 20-April 27	16	4		20
2. June	23-84	May 14-June 24	Mar. 2-June 13	55	5	2	62
3. July	85-162	June 27-July 25	April 15-July 10	44	28	6	78
4. August	163-272	July 25-Aug. 30	April 27-Aug. 16	56	54		110
5. September	273-369	Aug. 30-Sept. 28	June 26-Sept. 13	46	51		97
6. October	370-448	Sept. 28-Oct. 31	July 29-Oct. 19	13	66		79
			Total	230	208	8	446
Whole tuna						Skip-jack	
	M2-M12	June 12-Sept. 14	April 20-Sept. 1	2	2	7	11
							457

*Grouping as used by Kawabata, Muira and Shimanuki, 1963.

second, to determine the distribution of these seven gamma-emitting radionuclides in many tissues from each of the 11 whole tuna; and third, to determine the presence of iron-55 (Fe^{55}) in the tissue samples from the whole tuna with the greatest gamma radioactivity.

The six fallout radionuclides above were selected, based upon past experience, as the nuclides most likely to be present in the samples. Cerium-141 (Ce^{141}) and Ce^{144} also might be expected to be present, but because of the difficulty of obtaining reliable estimates of small quantities of low-energy (< 0.2 Mev), gamma-emitting nuclides by gamma-spectrum analysis, Ce^{141} and Ce^{144} were not included in the list of nuclides that were determined routinely. If the gamma spectrum had suggested the presence of significant quantities of cerium or other radionuclides, additional analyses would have been made.

The gamma nuclides were measured in a detector system with four pi geometry. The detector consisted of an eight-inch well and a three-inch solid sodium iodide crystal. In practice, a sample is placed on the three-inch solid crystal which is raised into the three-inch well of the large crystal, thereby completely surrounding the sample with at least 2-1/2 inches of crystal. The counting efficiency of this system was about ten times greater than the efficiency of the system with the single, three-inch, solid crystal. Counting time was 30 minutes per sample. The output data from the 256-channel analyzer were processed by an IBM Model 709 computer.

All values were corrected for decay of the radionuclide during the period between the estimated date of catching the fish and the date of counting the sample. The date of catch was arbitrarily assumed to be the mid-point between the first and last days of fishing for the vessel from which the sample was obtained. "Month of catch" rather than "month of landing" would be another logical way of grouping the data, but the error in estimating the date of catch did not warrant changing the original method of grouping the data as established by Kawabata et al. (1963).

In accumulating the data on the radioactivity of the samples three variables were recognized: month of landing, tissue and radionuclide. Species and area were recognized only for special analyses; there was little species difference and segregation by area was unwarranted because of the widely scattered fishing areas and the migratory habits of the fish. The samples in the first group, identified as "May", were from fish caught before the initiation of the 1962 program at Christmas Island and therefore can be considered to be "pretest" samples.

The average values for each of seven gamma-emitting radionuclides in four tissues of eviscerated tuna--light muscle, dark muscle, skin and bone--by date of sampling, are given in Table 2. The total number of samples analyzed was 1,775, rather than 1,784 (446 fish x 4 tissues), as nine samples were eliminated for various reasons. The standard deviation for these values has little meaning and is not given in Table 2 because of the large number of zero values and the non-random distribution of the positive values. Instead, the maximum values, as a measure of range, and the number of samples with positive values, as an indication of distribution, are given in Appendix Table 1. Data from Table 2 for "light muscle" and for "dark muscle" are presented graphically in Figure 1.

Although few tuna were caught near Christmas Island, the amount of Ru^{103} in dark muscle of tuna from this area landed in October (the nuclide, tissue and month with the largest radioactivity values) was plotted by area of catch to determine if a distribution pattern was evident. No pattern was evident from the 79 values plotted by areas 10 degrees square, as shown in Figure 2, although the greatest values were in samples from the area nearest Christmas Island. To explore further the levels of radioactivity in tuna caught near the test site, the average nuclide values, by tissue and month of landing, for 40 tuna caught within 700 miles of Christmas Island are presented in Table 3. By comparison with similar data in Table 2 for tuna from all areas, the only values in Table 3 that are consistently greater are the October Ru^{103} values.

Table 2. Average values by tissue and by month of landing for seven gamma-emitting radionuclides in samples from 446 eviscerated tuna landed at Tokyo between May and October, 1962. Values in picocuries per gram of wet tissue.

Light Muscle

Month of landing	n*	K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	20	3.34	.01	.03	.12	.02	.00	.03
June	62	2.59	.01	.02	.13	.01	.05	.03
July	77	2.60	.01	.02	.09	.02	.13	.03
August	110	1.70	.01	.05	.05	.08	.07	.02
September	97	2.00	.03	.02	.11	.60	.19	.03
October	77	2.24	.04	.08	.10	1.42	1.85	.03
Average		2.412	.018	.037	.100			.028

Dark Muscle

Month of landing	n*	K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	20	5.21	.04	.00	.92	.07	.00	.10
June	62	2.06	.01	.03	.63	.06	.05	.03
July	78	2.24	.01	.06	.27	.03	.45	.04
August	110	0.97	.02	.10	.28	.16	.30	.03
September	97	1.60	.04	.28	.33	1.78	.59	.03
October	79	2.68	.11	.15	.42	4.94	10.8	.06
Average		2.460	.038	.103	.475			.048

Skin

Month of landing	n*	K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	20	4.14	.03	.05	.38	.10	.00	.08
June	62	1.12	.02	.06	.37	.03	.20	.05
July	78	1.75	.03	.04	.15	.05	.26	.06
August	109	0.73	.03	.15	.24	.22	.41	.05
September	97	1.28	.05	.05	.28	2.38	.34	.05
October	78	1.93	.11	.14	.36	5.17	6.95	.08
Average		1.825	.045	.082	.297			.062

Bone

Month of landing	n*	K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	19	2.16	.16	.03	.67	.05	.00	.03
June	61	1.34	.12	.03	.77	.01	.00	.02
July	78	1.97	.07	.03	.24	.02	.27	.04
August	110	0.56	.07	.08	.24	.28	.25	.05
September	96	0.94	.12	.06	.24	1.62	.95	.04
October	79	2.10	.27	.13	.49	3.93	7.31	.05
Average		1.512	.135	.060	.442			.038

* Number of samples

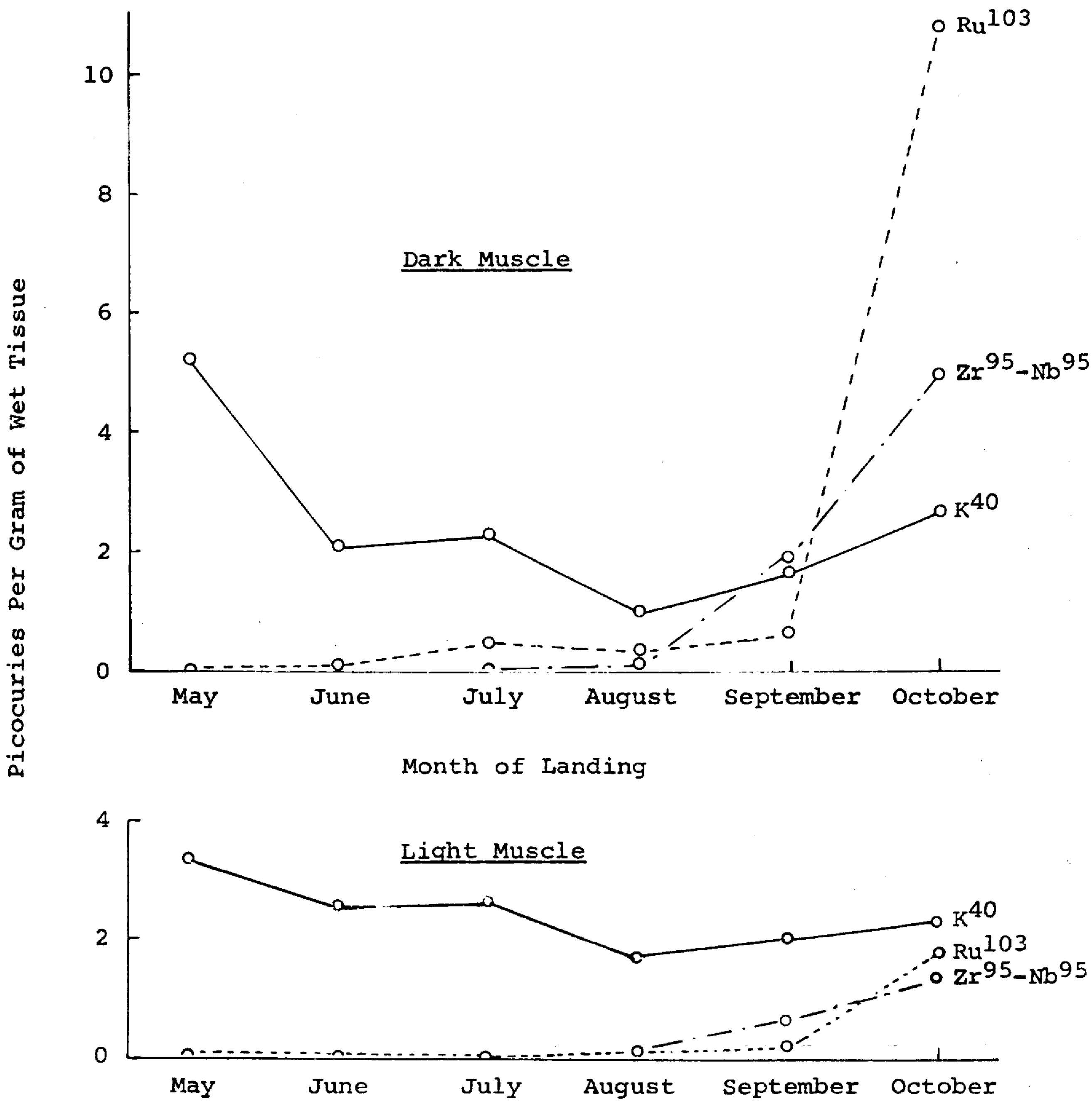

Figure 1. Average values by month of landing for potassium-40, zirconium-95--niobium-95, and ruthenium-103 in light muscle and dark muscle of 446 tuna landed at Tokyo in 1962.

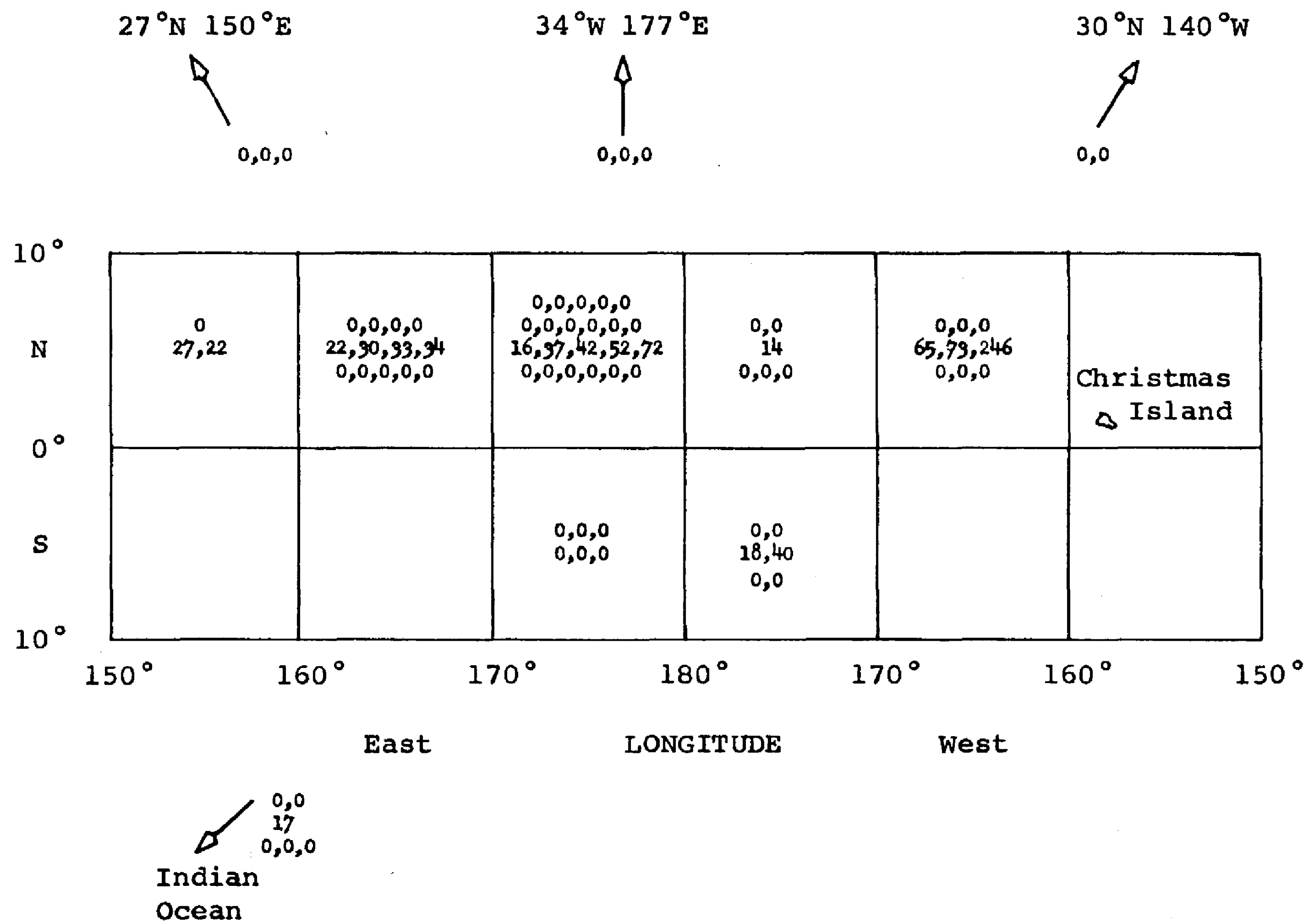

Figure 2. Ruthenium-103 in the dark muscle of 79 tuna by area of catch and landed in Tokyo during October 1962. Values in picocuries per gram of wet tissue.

Table 3. Average values by tissue and by month lf landing for seven gamma-emitting radionuclides in samples of 40 eviscerated tuna landed at Tokyo between May and October, 1962 and caught within 700 miles of Christmas Island. Values in picocuries per gram of wet tissue.

Light Muscle

Month of landing	n*	K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	6	3.64	.00	.00	.09	.02	.00	.04
June	18	3.01	.01	.05	.11	.01	.09	.04
July	0	--	--	--	--	--	--	--
August	2	3.65	.00	.07	.24	.00	.36	.06
September	5	2.78	.00	.00	.19	1.07	.38	.04
October	9	1.80	.06	.08	.00	1.24	5.58	.03
Average		2.976	.014	.040	.126			.042

Dark Muscle

Month of landing	n*	K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	6	6.39	.05	.00	.92	.12	.00	.19
June	18	2.32	.01	.07	.45	.02	.16	.02
July	0	--	--	--	--	--	--	--
August	2	3.41	.00	.33	1.04	.00	.00	.11
September	5	2.49	.00	.00	.37	2.80	2.24	.00
October	9	1.72	.21	.00	.18	3.59	41.7	.17
Average		3.266	.054	.080	.592			.098

Skin

Month of landing	n*	K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	6	3.92	.03	.00	.32	.22	.00	.03
June	18	1.96	.04	.12	.15	.04	.32	.10
July	0	--	--	--	--	--	--	--
August	2	3.68	.12	.82	.42	.00	.00	.00
September	5	1.39	.00	.05	.62	4.29	.00	.00
October	9	0.62	.21	.05	.28	4.44	15.7	.16
Average		2.314	.080	.208	.358			.058

Bone

Month of landing	n*	K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	6	2.66	.06	.00	.34	.02	.00	.04
June	18	1.15	.10	.06	.34	.02	.00	.01
July	0	--	--	--	--	--	--	--
August	2	3.42	.10	.00	.44	.00	.00	.13
September	5	0.41	.18	.00	.61	1.81	1.62	.00
October	9	1.70	.18	.00	.05	3.30	8.58	.06
Average		1.668	.124	.012	.356			.048

* Number of samples.

The distribution of radionuclides in 13 tissues of whole tuna was determined by gamma-spectrum analyses of gill, bone, skin including scales, light muscle, dark muscle, liver, spleen, heart, pyloric caeca, stomach, stomach content, intestine, intestinal content, gonad and kidney. The samples were obtained from 11 tuna (7 skipjack, 2 yellowfin and 2 bigeye) that were landed in Tokyo between June 12 and September 14. All types of tissues were not available from all fish. The radioactivity of seven gamma-emitting nuclides by tissues is given in Table 4 without segregation for month of landing, species or area.

Analysis for Fe^{55} requires special sample preparation and detection equipment. This radionuclide decays to stable manganese-55 (Mn^{55}) by electron capture and, in the process, a 5.9 kilovolt X-ray is emmitted which is not detected by the usual method of gamma-spectrum analysis. Because of the low energy of the radiation, a thin sample with a minimum of self-absorption is required for counting. This is accomplished by separating the iron isotopes from other transition elements in the sample by selective elution of iron in its chloro-complex form from an anion-exchange resin by the method of Kraus and Moore (1953) as modified by Joyner and Chakravarti (1960). The X-rays emitted by the Fe^{55} in the sample were detected by a thin (2 mm), beryllium-coated sodium iodide crystal.

Table 4. Average values by tissues for seven gamma-emitting radionuclides in samples from 11 whole tuna landed at Tokyo between June and September, 1962. Values in picocuries per gram of wet tissue.

Tissue	n*	K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95} Nb^{95}	Ru^{103}	Cs^{137}
Muscle, light	10	2.80	.00	.08	.11	.00	2.57	.01
Muscle, dark	11	3.20	.04	.12	.29	.30	18.6	.01
Skin and scales	10	2.36	.00	.15	.00	18.7	.00	.02
Bone	10	1.86	.00	.14	.42	3.57	51.7	.02
Liver	11	3.64	.00	.68	2.49	12.4	139.	.12
Kidney	11	5.44	.00	.39	.10	20.6	129.	.07
Spleen	8	7.72	.28	.00	1.42	42.8	.00	.40
Gonad	5	1.56	.00	.00	7.93	5.76	.00	.00
Gills	9	1.63	.09	.14	2.62	3.42	66.9	.00
Heart	11	.00	.00	.45	.87	8.67	.00	.10
Stomach	10	2.27	.00	.08	5.66	1.99	.00	.06
Intestine	10	6.82	.00	.71	3.92	4.17	.00	.08
Pyloric caeca	11	2.78	.03	.18	2.85	1.77	16.9	.02
Stomach content	5	1.52	.00	.00	1.61	2.80	.00	.00
Intestinal "	5	1.97	.17	.90	1.68	10.3	.00	.10

* Number of samples.

Iron-55 values for thirteen tissues from one skipjack tuna are given in Table 5. This skipjack (M-2) was caught between April 20 and May 21, 1962 in the area 24°-27°N and 157°-160°W.

RESULTS AND SUMMARY

The amounts of K^{40}, Mn^{54}, Co^{60}, Zn^{65}, Zr^{95}-Nb^{95}, Ru^{103} and Cs^{137} were determined by gamma-spectrum analysis in 1,775 samples. The samples included tissues of light and dark muscle, skin and bone and were obtained from 446 eviscerated fish, 438 tuna and 8 swordfish, caught by Japanese commercial fishermen in the western Pacific between February 20 and October 19, 1962. The samples were grouped into six periods, May to October, corresponding approximately to the month in which the fish were landed in Tokyo. From these analyses, the following observations have been made:

1. The radionuclide values were small; many values--80 per cent of the fallout radionuclide values--were not significantly greater than the background counts.

2. The average values by month of landing and by tissue for naturally-occurring K^{40}, in terms of picocuries per gram of wet tissue (pc/g wet) ranged from 0.6 (bone, August) to 5.2 (dark muscle, May).

3. The average values by month of landing and by tissue for the six fallout radionuclides were less, and usually very much less, than the K^{40} values in all except seven of 168

Table 5. Iron-55 (Fe^{55}) in each of thirteen tissues from one skipjack tuna.*

Tissue	Tissue	Picocuries/gm. (wet) ± 95% counting error
	Gill	9.8 ± 0.6
	Spleen	7.8 ± 1.8
	Kidney	7.4 ± 0.5
	Heart	5.1 ± 0.5
	Bone	4.3 ± 0.6
	Pyloric caeca	4.0 ± 0.2
	Intestine	3.4 ± 0.3
	Gonad	2.2 ± 0.2
	Stomach	2.1 ± 0.5
	Liver	1.8 ± 0.4
	Muscle, dark	0.8 ± 0.1
	Muscle, light	0.3 ± 0.1
	Skin	0.0

* Sample M-2. Fish was caught between April 20 and May 21, 1962 in the area bordered by 24°-27° N and 157°-160° W. Date sampled was June 12, 1962.

average values (7 nuclides x 6 landing periods x 4 tissues = 168). The exceptions were either Zr^{95}-Nb^{95} or Ru^{103} values for samples taken in September or October, the greatest average value being 10.8 pc Ru^{103}/g (wet) in the October sample of dark muscle.

4. The maximum single value in 12,425 determinations (1,775 samples x 7 nuclides) was 240 pc Ru^{103}/g (wet) for a dark muscle sample from a bigeye tuna caught between August 20 and September 26 at approximately 6°N and 161°W, about 350 miles northwest of Christmas Island.*

5. Zinc-65 was the most abundant fallout nuclide present in the samples from fish caught prior to the 1962 series of nuclear detonations at Christmas Island. The average values by tissues were one picocurie or less per gram (less than K^{40}), the highest single value being 8.2 pc/g (wet) for a bone sample.

6. Values for Cs^{137} did not change significantly from month to month, but the values for the other fallout radionuclides were greater at the end of the sampling period than in any previous period.

7. An unexpected monthly variation was observed for K^{40}, as values for samples of tuna landed during August were one half

*One estimate of the allowable continuous intake of Ru^{103} for the general population is 176,000 pc per day. This value was calculated from the value of 8×10^{-4} μc/cc as given in the National Bureau of Standards Handbook 69 for the maximum permissible concentration of Ru^{103} in drinking water that is consumed at a rate of 2,200 cc per day, seven days per week. The NBS value was corrected by factors of 2,200 (daily water intake in cc) and 0.1 (the correction for general population exposure relative to occupational exposure).

to one sixth the values for samples of tuna landed before or after August. The greatest difference was between the May and August values.

8. A strict relationship between the radioactivity in the tuna and the distance from Christmas Island was not evident from inspection of the analytical data.

The results of analyses by Kawabata et al. (1963) to measure radioactivity in duplicate samples also indicated little activity. There were only seven samples with gross-beta activity greater than background and no samples with gross-gamma activity greater than background. The beta detector at the Tokyo laboratory was a 1.4 mg/cm^2 end-window type G-M counter with an efficiency of 20.2 per cent for a uranium (U_3O_8) standard. The gamma detector was a 1-inch x 1-inch NaI crystal with type ND-10 probe for which the efficiency was 7.0 per cent for a U_3O_8 standard.

The distribution of the seven radionuclides in the tissues of whole tuna was determined by gamma-spectrum analysis of 13 kinds of tissues from 11 tuna landed in Tokyo between June and September. The following results were observed:

1. The average values for K^{40} in pc/g (wet), ranged from 1.6 (gonad) to 7.7 (spleen), except for heart samples, for which there were no values significantly greater than the background count.

2. The Mn^{54}, Co^{60} and Cs^{137} values were much less than the K^{40} values for all tissues except heart.

3. The largest average values were 140 and 130 pc Ru^{103}/g (wet) for liver and kidney tissues, respectively, the largest single value being 810 pc Ru^{103}/g (wet) for a liver sample.

4. No one tissue had consistently high values for all radionuclides.

The results of analyses for Fe^{55} in 13 tissues from one tuna indicate that the maximum values were those for the blood-rich tissues--gill, spleen and kidney. Values ranged from 9.8 pc/g (wet) to zero (skin) and hence were not greatly different from the K^{40} values.

In conclusion, the results of Kawabata et al. (1963) and those reported here indicate that fallout during the spring and summer of 1962 contributed very little radioactivity to the tuna in the western Pacific. Residual fallout nuclides were detectable in some tuna samples collected before the 1962 tests of nuclear devices at Christmas Island but in amounts one-third or less the amount of radioactivity from naturally occurring K^{40}. There was little change in these values during the sampling period except for an increase in the amount of Zr^{95}-Nb^{95} and Ru^{103} in some of the September and October samples. The nature of the distribution of fallout nuclides in western Pacific tunas is that of a little radioactivity in an occasional fish rather than general contamination of the entire population.

The supervision of sample preparation by L. Lueders, of counting and computer analyses by D. Engstrom and of chemical separation and plating of Fe^{55} by D. Chakravarti is gratefully acknowledged.

LITERATURE CITED

Joyner, T. and D. Chakravarti. 1960. The analysis of some trace elements in fish tissues. U.S. AEC report No. UWFL-68. Laboratory of Radiation Biology, University of Washington.

Kawabata, T., T. Miura and K. Shimanuki. 1963. Radioactivity survey of the mid-Pacific area, 1962. III. At the Tokyo Central (Tsukiji) Fish Market. Department of Food Control, National Institute of Health, Tokyo.

Kraus, K.A. and G.E. Moore. 1953. Anion-exchange studies. VI. The divalent transition elements manganese to zinc in hydrochloric acid. J. Am. Chem. Soc. 15:1460.

U.S. Department of Commerce, National Bureau of Standards Handbook 69. 1959. Maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and in water for occupational exposure. Government Printing Office, Washington, D.C.

Appendix Table 1. Number of samples, average values and maximum values by tissue and by month of landing for seven gamma-emitting radionuclides in samples from 446 eviscerated tuna landed at Tokyo between May and October, 1962. Values in picocuries per gram of wet tissue.

1. Light Muscle

Month of landing		K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	n*	20/20	1/20	4/20	10/20	2/20	0/20	9/20
	ave.	3.34	<.01	.03	.12	.02	--	.03
	max.	4.56	.07	.22	.44	.17	--	.08
June	n*	58/62	7/62	5/62	24/62	2/62	2/62	19/62
	ave.	2.59	.01	.02	.13	.01	.05	.03
	max.	5.31	.12	.34	.55	.23	1.55	.22
July	n*	70/77	4/77	12/77	19/77	8/77	12/77	27/77
	ave.	2.60	.01	.02	.09	.02	.13	.03
	max.	7.20	.14	.33	1.24	.34	2.24	.24
August	n*	82/110	7/110	18/110	24/110	25/110	7/110	23/110
	ave.	1.70	.01	.05	.05	.08	.07	.02
	max.	4.02	.08	2.22	.41	.75	2.10	.16
September	n*	81/97	24/97	10/97	27/97	58/97	8/97	26/97
	ave.	2.00	.03	.02	.11	.60	.19	.03
	max.	5.97	.58	.38	.98	3.28	3.28	.24
October	n*	70/77	19/77	25/77	23/77	60/77	14/77	24/77
	ave.	2.24	.04	.08	.10	1.42	1.85	.03
	max.	4.88	.22	.46	.69	4.40	25.0	.21

* Number of samples with values greater than the background count plus the 95 per cent counting error/ total number of samples.

Appendix Table 1. (continued)

2. Dark Muscle

Month of landing		K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	n*	14/20	2/20	0/20	13/20	2/20	0/20	6/20
	ave.	5.21	.04	--	.92	.07	--	.10
	max.	20.0	.52	--	3.21	.74	--	.56
June	n*	39/62	4/62	5/62	46/62	7/62	2/62	8/62
	ave.	2.06	.01	.03	.63	.06	.05	.0[illegible]
	max.	7.30	.27	.11	6.26	.95	1.78	.6[illegible]
July	n*	50/78	6/78	9/78	30/78	4/78	15/78	12/78
	ave.	2.24	.01	.06	.27	.03	.45	.0[illegible]
	max.	6.84	.24	.93	2.28	.81	10.1	.6[illegible]
August	n*	36/110	9/110	20/110	38/110	26/110	10/110	14/110
	ave.	.97	.02	.10	.28	.16	.30	.0[illegible]
	max.	6.06	.46	1.97	1.45	1.71	6.17	.4[illegible]
September	n*	48/97	13/97	7/97	30/97	70/97	9/97	13/97
	ave.	1.60	.04	.28	.33	1.78	.59	.0[illegible]
	max.	7.35	.62	19.6	2.85	11.7	12.9	.7[illegible]
October	n*	48/79	19/79	15/79	25/79	66/79	18/79	15/[illegible]
	ave.	2.68	.11	.15	.42	4.94	10.8	[illegible]
	max.	10.5	.75	1.64	2.58	13.1	239.	.7[illegible]

Appendix Table 1. (continued)

3. Skin

Month of landing		K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	n*	16/20	3/20	1/20	10/20	4/20	0/20	7/20
	ave.	4.14	.03	.05	.38	.10	--	.08
	max.	8.59	.23	1.02	2.74	.67	--	.41
June	n*	14/62	4/62	4/62	21/62	3/62	4/62	10/62
	ave.	1.12	.02	.06	.37	.03	.20	.05
	max.	8.81	.54	1.50	2.68	.66	5.45	.56
July	n*	34/78	10/78	5/78	13/78	6/78	7/78	15/78
	ave.	1.75	.03	.04	.15	.05	.26	.06
	max.	7.06	.55	1.36	1.68	1.03	5.08	.91
August	n*	18/109	12/109	21/109	23/109	22/109	11/109	18/109
	ave.	.73	.03	.15	.24	.22	.41	.05
	max.	6.80	.56	3.03	2.03	1.90	9.56	.72
September	n*	28/97	13/97	7/97	22/97	66/97	3/97	18/97
	ave.	1.28	.05	.05	.28	2.38	.34	.05
	max.	9.05	.70	1.48	2.90	14.1	19.7	.45
October	n*	29/78	17/78	12/78	19/78	66/78	14/78	18/78
	ave.	1.93	.11	.14	.36	5.17	6.95	.08
	max.	15.1	.85	2.04	3.07	14.2	96.4	.70

Appendix Table 1. (continued)

4. Bone

Month of landing		K^{40}	Mn^{54}	Co^{60}	Zn^{65}	Zr^{95}-Nb^{95}	Ru^{103}	Cs^{137}
May	n*	18/19	14/19	4/19	16/19	4/19	0/19	8/19
	ave.	2.16	.16	.03	.67	.05	--	.03
	max.	3.60	1.64	.14	8.21	.61	--	.13
June	n*	33/61	37/61	4/61	42/61	2/61	0/61	9/61
	ave.	1.34	.12	.03	.77	.01	--	.02
	max.	4.54	.42	.61	8.20	.34	--	.19
July	n*	45/78	22/78	7/78	22/78	4/78	13/78	16/78
	ave.	1.97	.07	.03	.24	.02	.27	.04
	max.	8.47	.78	.62	2.84	.54	2.74	.30
August	n*	18/110	23/110	14/110	32/110	29/110	8/110	22/110
	ave.	.56	.07	.08	.24	.28	.25	.05
	max.	7.28	.64	2.49	2.08	9.57	8.32	.68
September	n*	25/96	32/96	10/96	18/96	65/96	12/96	15/96
	ave.	.94	.12	.06	.24	1.62	.95	.04
	max.	10.4	.89	1.14	2.06	8.91	11.3	.37
October	n*	42/79	37/79	15/79	24/79	65/79	16/79	12/79
	ave.	2.10	.27	.13	.49	3.93	7.31	.05
	max.	15.0	4.23	1.45	6.98	17.1	115.	1.47

* Number of samples with values greater than the background count plus the 95 per cent counting error/total number of samples.