UNIVERSITY OF WASHINGTON

APPLIED FISHERIES LABORATORY

SEATTLE 5, WASHINGTON

UNITED STATES ATOMIC ENERGY COMMISSION

CONTRACT NO. W-28-094-ENG-33

UNIVERSITY OF WASHINGTON · 1861 · LVX - SIT

REPORT NO. UWFL-19

UWFL-19

ENIWETOK RADIOLOGICAL RESURVEY JULY 1948*

by

Applied Fisheries Laboratory

University of Washington

Seattle, Washington

* This report is based on work performed under Contract No. W-28-094-eng-33 with the Atomic Energy Commission and in cooperation with the United States Navy.

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ENIWETOK RADIOLOGICAL RESURVEY JULY 1948*

Applied Fisheries Laboratory

University of Washington

Part 1. Organization and personnel.

Introduction

During May 1948 observations and collections of aquatic specimens were made at Eniwetok. Following the Runit Island test the marine organisms collected from the shallow water of the reef north of the test site were flown back to the Applied Fisheries Laboratory, University of Washington, for evaluation of the contamination. A report of the findings of this study was prepared (UWFL-18).

A second collection of biological samples from the Eniwetok area was made between July 21 and July 30, 1948, after the completion of the field survey of Bikini. The time interval between the two collections allowed absorption of active materials from the bomb burst to become manifest in biotic systems. The Eniwetok resurvey of the summer of 1948 was thus an extension of the Bikini study.

Organization

The radiobiological resurvey of Eniwetok was a continuation of the cooperative research effort of the Atomic Energy Commission, the

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United States Navy, and the University of Washington. At Eniwetok this team that functioned so smoothly at Bikini was joined by the United States Army detachment under the command of Major Norman M. Quist.

The Army maintained a shore station on Eniwetok and provided many facilities that greatly expedited the survey program. Especially helpful were the transport facilities provided by the air force based on Eniwetok Island.

Technical personnel.

The twelve technical staff members of the Bikini Resurvey continued the work at Eniwetok. This group was made up of a number of experienced personnel drawn mostly from the Applied Fisheries Laboratory, University of Washington. Additional specialists were borrowed from other Universities for the field trip.

In addition to the senior project leaders, one or more junior members were included in each research area to aid in the work and to gain experience in radiation detection and the evaluation of radiation damage.

With the completion of the field portion of the project the "borrowed" personnel were returned to their permanent stations. The evaluation of the absorbed radiation involving preparation of samples, counting the activity, organizing the data, and writing the reports has been the work of the regular members of the Applied Fisheries Laboratory staff.

Members of the Eniwetok Radiobiology Resurvey 1948

	Assignment	Permanent address and occupation
Donaldson, Lauren R., Ph.D.[1,2,3,4]	Groupleader and biologist	Prof. of Fisheries; Director, Applied Fisheries Laboratory, U. of W., Seattle 5, Wash.
Seymour, Allyn H.[2,4]	Executive officer, biostatistician and plankton work	Research Associate, Applied Fisheries Laboratory, U. of W.
Welander, Arthur D., Ph.D.[1,2,4]	Radiobiologist and ichthyologist	Asst. Prof. of Fisheries and Research Associate, Applied Fisheries Lab., U. of W.
White, Asher A., M.D.[1,4]	Medical Consultant	Lecturer, Univ. of Minn. College of Medicine and Nicollet Clinic, Minneapolis, Minnesota
Hollenberg, Geo., Ph.D.[4]	Marine algae	Professor of Botany, University of Redlands, Redlands, Calif.
Bullock, Theodore, Ph.D.[4]	Marine invertebrates	Assoc. Professor of Zoology, Univ. of Calif., Los Angeles, Los Angeles, California
Tinker, Spencer W.[4]	Marine biology	Director, Waikiki Aquarium, Univ. of Hawaii, Honolulu, T.H.
H eld, Edward E.[4]	Marine invertebrates	Graduate Research, Dept. of Zoology, U.C.L.A. Los Angeles, California
Lowman, Frank G.[4]	Biologist, electronics	Research Associate, Applied Fisheries Lab., U. of W., Seattle, Washington
Koch, John J.[4]	Tissue processing, radiation detection	Graduate Research, Applied Fisheries Lab., U. of W. Seattle, Washington
Osborn, Richard H.[2,4]	Biologist, photographer	Student, Medical School, U. of W., Seattle, Washington
Donaldson, John R.[4]	Fisheries biology and plankton	Student, School of Fisheries, Univ. of Wash., Seattle, Wash.

[1] Operations Crossroads, radiobiology, 1946

[2] Bikini Scientific Resurvey, radiobiology, 1947

[3] Operations Sandstone, radiobiology, 1948

[4] Bikini Scientific Resurvey, radiobiology, 1948

Part 2. Evaluation of the Counts of Beta-Gamma Activity in Fish Tissues.*

Collecting Methods

The collections were principally of reef fish but were supplemented by a few specimens caught by hook and line. The majority of collections were made during low tide periods on the coral reef in selected spots where the fish were most abundant, using finely ground derris root mixed in the water to kill the fish. In the warm water, the active ingredient in the derris root, rotenone, stunned or killed the fish within a few minutes. As the fish succumbed to the poison they were collected by hand or dip net. Collections were from waters of a depth of 10 feet or less, usually four to five feet.

Sampling Areas

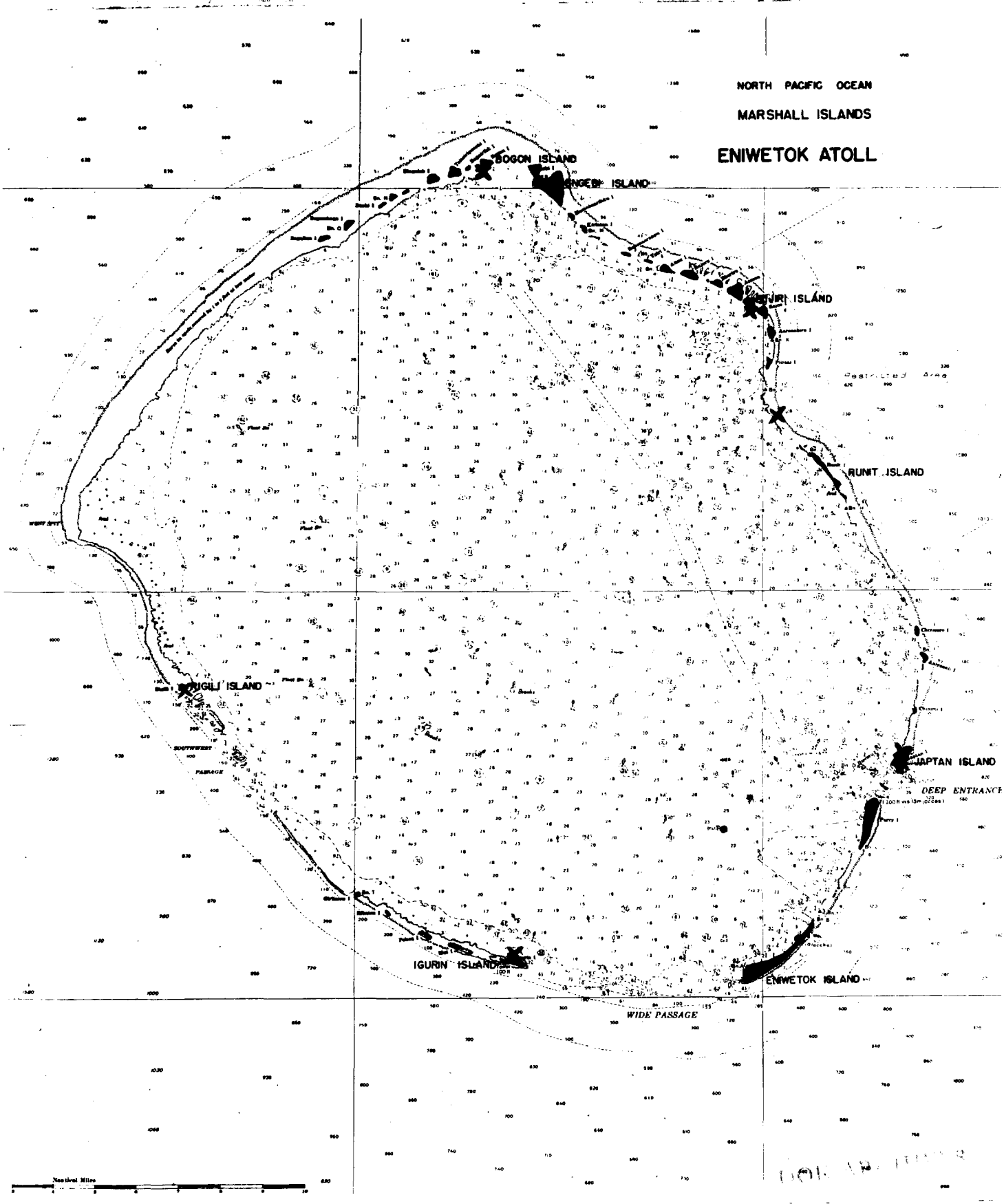
During the 10 days the resurvey party worked at Eniwetok collections of material were made at six major collecting stations. Of the six stations, three- in the vicinity of Runit, Biijiri and Bogon, were along the northeastern portion of the atoll rim near the three test sites of Runit, Aomon-Biijiri and Engebi. The other three major collections -Rigili, Igurin and Japtan- were from areas seven to fourteen miles removed and where it was expected the contamination would be slight or at most very much reduced.

In addition to the six major collecting stations material was gathered as available from anchorages and adjacent regions.

In Figure 1, a map of Eniwetok Atoll, the reef collecting areas are marked with x's. Other fish were caught by hook and line off Eniwetok, Kirinian and Engebi Islands.

* The outline of this report, in general, follows that of the 1948 Bikini Report, UNFL-16, and where applicable, sections or parts thereof, have been repeated.

Figure 1.


NORTH PACIFIC OCEAN
MARSHALL ISLANDS
ENIWETOK ATOLL
BOGON ISLAND
ENGEBI ISLAND
ENJIRI ISLAND
RUNIT ISLAND
KIDUGU ISLAND
SOUTHWEST PASSAGE
KAPTAN ISLAND
DEEP ENTRANCE
IGURIN ISLAND
ENIWETOK ISLAND
WIDE PASSAGE
Nautical Miles

Date of Collection

July 22 to July 28, 1948.

Groups Sampled

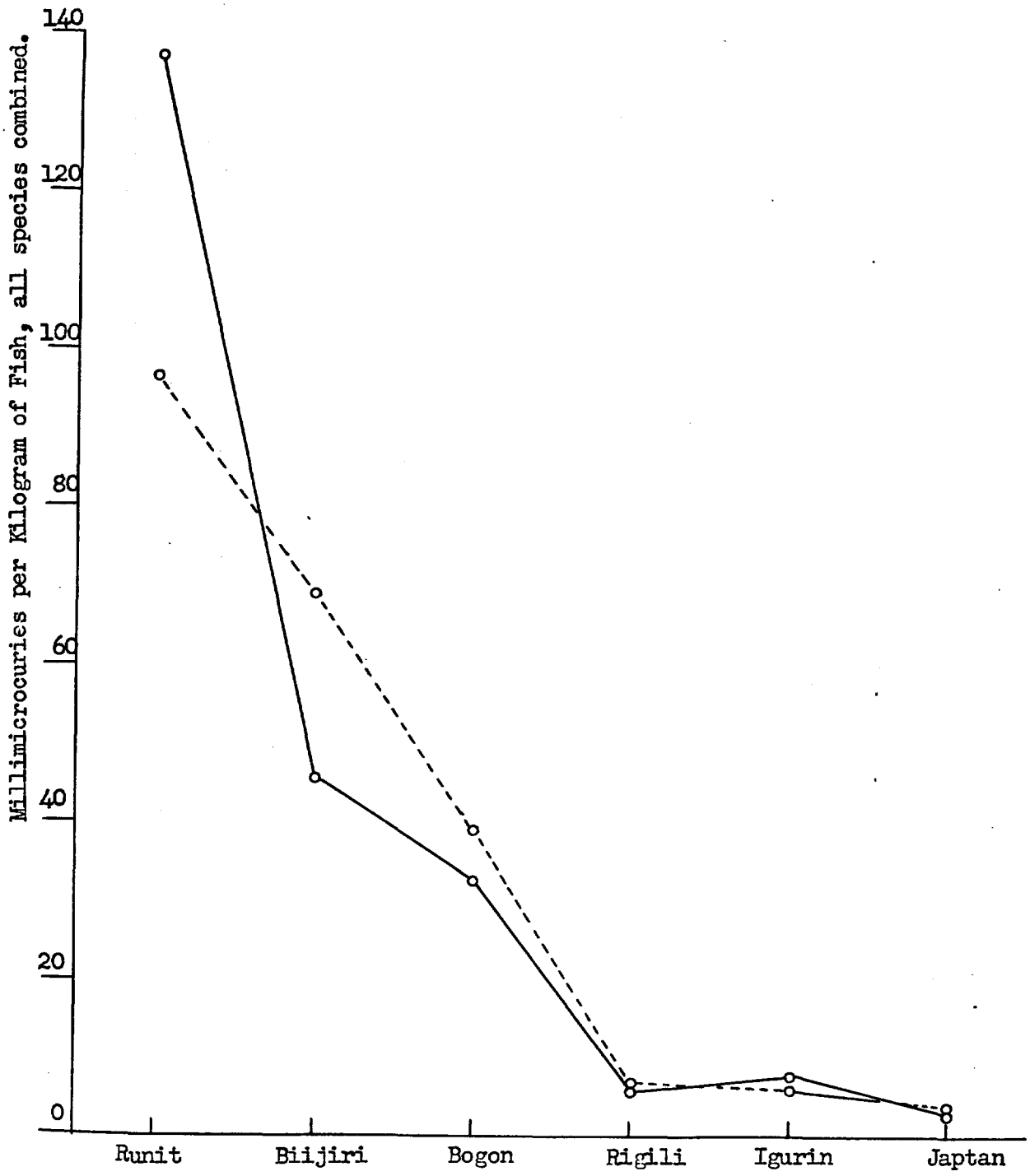
As at Bikini, an attempt was made to collect at each station the most common fishes that were likely to be distributed throughout the atoll. At five or more stations the following fishes were collected; cardinal, damsel, grouper, parrot, squirrel, surgeon, wrasse, eel, goatfish and lizard fish. Less than five samples were collected of the following; butterfly, mackerel, flounder, pigfish, tuna, siganid, goby, jack and shark.

Number of Samples

The collections were divided into two parts, similar as to number, size and type of specimens. One part was used fresh in the field for preparation of samples while the other was frozen and returned to the laboratory before samples were prepared. A comparison of the counts of the samples prepared from fresh and from frozen specimens was made and although statistical analysis was not feasible, from examination of Figure 2 it is believed that the difference is not significant. (Also see Table III.) For an exact comparison the samples should be of the same tissue, from the same species, and collected in the same area. By these standards there would be only a few samples for comparison. To increase the size of the lot for comparison the samples were grouped by species and by tissue and corrected for tissue to body ratio to give the total body count per kilogram of fish. This value plotted as the ordinate with the area as the abscissa is the graph plotted in Figure 2. It is reasonable to assume that the differences that do exist could arise from lack of identity in species and tissue in the comparison, and therefore the samples prepared from the fresh and from the frozen specimens were considered

Figure 2

Comparison of Eniwetok Samples Prepared in the Field with Those Frozen in the Field and Prepared at the University of Washington Laboratory. Samples corrected to an August 9, 1948, Counting Date. Values are from beta-gamma counts of Tissue Samples Converted to Total Body Count and Expressed as Millimicrocuries per Kilogram of Fish. All Species Combined.



to be similar. For future collections this means that serious error would not be introduced if the specimens were frozen in the field and the samples prepared at a later and more convenient time and place.

In the field 78 fresh fish were used to prepare a total of 474 samples. At the University of Washington Laboratory 67 frozen fish were used to prepare a total of 363 samples for a grand total of 145 and 837 respectively.

Tissues Sampled

Six tissues were usually sampled; skin, muscle, bone, liver, gut and gills. The spleen, kidney, and or gonad were also sampled when fish of sufficient size were available to yield an adequate sample, but of the 837 samples only 18 were of these three tissues.

Sample Preparation

The ashing and acid method described in previous Bikini (UWFL-16) and Eniwetok (UWFL-18) reports was followed.

The samples were prepared for counting by placing approximately one gram of tissue - if that much tissue was available - on a one-inch stainless steel plate stamped from .005 inch stock. The samples were heated to about 120° C. on a hot plate to remove the unbound water. After the tissues charred, a drop of olive oil was added to reduce sputtering. The trays bearing the tissue residue were then placed in a muffle furnace and the temperature gradually raised to 370° C. After two hours of heating the temperature was raised to 500° C. and maintained until a white ash was obtained. A drop or more of nitric acid was then added and the samples removed to cool. If the sample became hygroscopic it was reheated to 500° C. and a drop of sulfuric acid added. In spite of such treatment samples with a high calcium content

remained hygroscopic. Finally, after completing ashing and upon cooling, the plates were mounted on cards, covered with cellophane and sealed with Scotch tape. Fish samples that were prepared in the field were not counted until returned to the laboratory.

Counting Procedure

The samples were counted for beta-gamma activity only. The counting was done at the Applied Fisheries Laboratory, University of Washington, between August 9 and September 25, 1948. With only one scaler in operation and with a large number of fish and other samples to be counted it was decided beforehand to make five-minute counts. (See discussion below under "Error"). Five-minute recounts were made of samples whose net original counts were 0 to 4 per minute. The counter tube was set in a circular lead shield with a sliding plate holder and joined with a scale of 64 scaler. Both products were made by Victoreen, the scaler being Model X-327.

Corrections in Counts

The sample counts were corrected for background, for weight of sample, and for geometry. For the entire counting period, the average background count was 17.0 per minute. Using a U. S. Bureau of Standard Ra D+E standard of approximately 108 disintegrations per second the geometry was calculated as being 18.0 per cent. Because the activity of the samples was diminishing fairly rapidly it was necessary to correct the counts to the same day of counting. No correction was made for scattering, for self-absorption, for absorption by air and by counter window, or for the probability of ionization.

Calculations

The correction for date of counting was determined from the rate of

decay of sample XE-11. August 9, 1948, the first day of counting, was chosen as the date upon which all counts would be based. Hence, the count of a sample on some day other than August 9 was corrected by the ratio of the count of sample XE-11 on August 9 divided by the count of XE-11 on the day that the sample was counted. The values for XE-11 were taken from the curve plotted in Figure 3. Sample XE-11 was arbitrarily selected from a group of decay curves, all similarly shaped, of samples from specimens collected at Eniwetok in May, 1948. See UWFL-13.

Counts were eventually converted to millimicrocuries per kilogram of sample by the following formula:

$$\text{mμc/kg} = \frac{\text{net count per minute}}{(\text{sample wt. in gms.})(\text{geometry})(2.2)}$$

If the number of disintegrations per second for one curie is 3.7×10^{10} and this value is corrected for conversion to minutes and then the equation above is converted to millimicrocuries the resulting value is 2.2 as appears in the denominator.

The total activity per kilogram of an individual fish was calculated as the sum of the activity of all of its tissues. This value was obtained in the following manner: (millimicrocuries per kilogram of skin) x (ratio of total tissue weight to total body weight) + (mμc/kg of muscle) x (tissue to body ratio) + ditto for bone + for liver, etc. = millimicrocuries per kilogram of fish. The body ratios, Table I, were obtained by weighing the tissues of one fish from eight selected types. Fish, other than those listed, were placed under one of the eight types as follows: flounder, column 1; cardinal, goatfish, grouper, lizard, pigfish, halfbeak, goby, flathead and parapercid, column 2; damsel and butterfly, column 3; wrasse and birdfish, column 4; puffer, column 6; and jack and tuna, column 7.

Figure 3. Decay Curve for Sample XE-11 Used for Calculating Correction Factor for Decay of July, 1948, Eniwetok Samples between August 9, 1948, and Day of Counting.

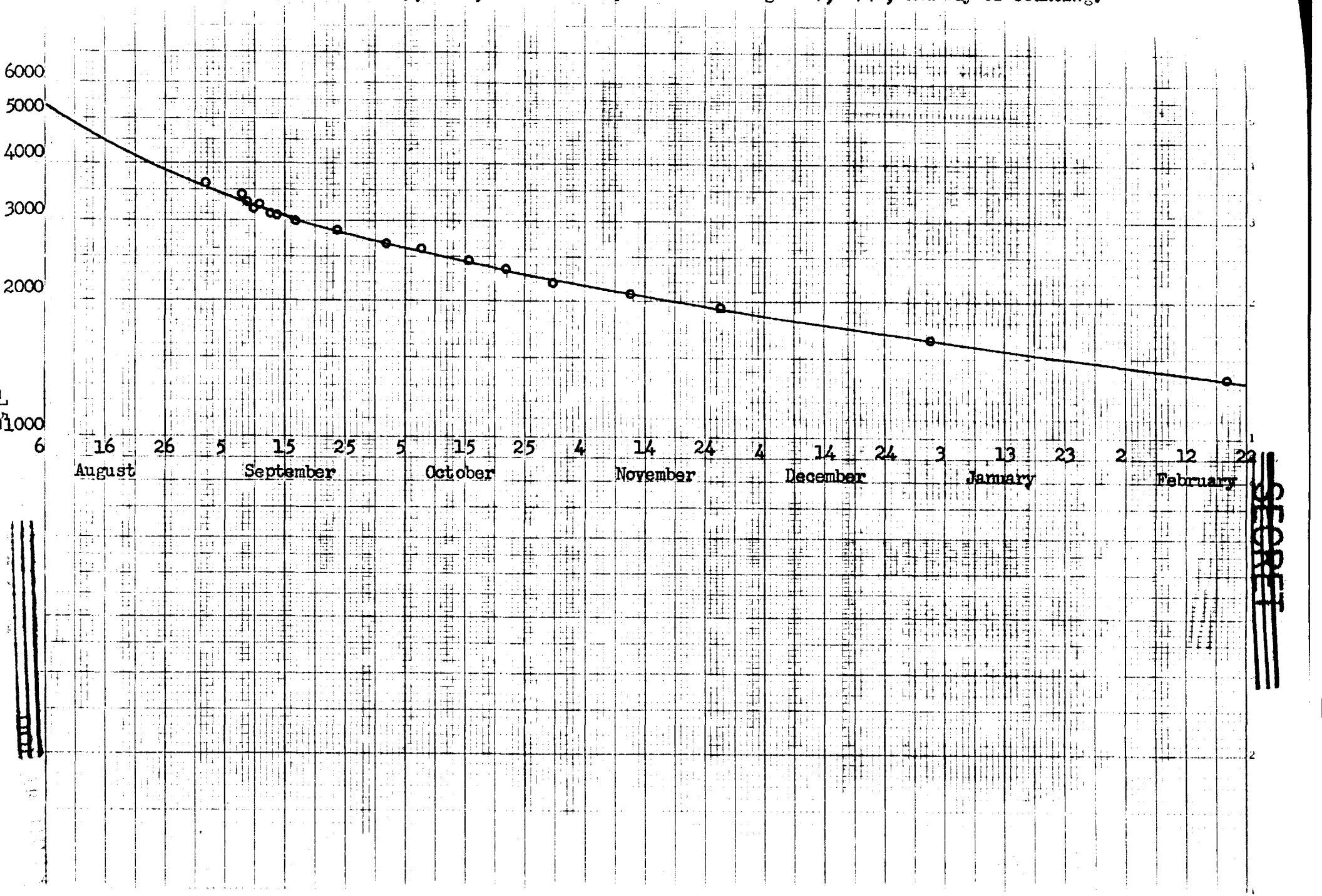


Table I. Ratio of Tissue Weight to Total Body Weight for Eight Selected Types of Fish

	Fish Tissue	1. eel	2. brown spotted grouper	3. convict surgeon	4. parrot	5. siganid	6. squirrel	7. 2-line mackerel	8. shark (estimated)
Ratio tissue weight to total body weight	skin	.108	.064	.065	.114	.026	.173	.034	.100
	muscle	.686	.662	.567	.591	.616	.450	.788	.500
	bone	.099	.224	.175	.220	.170	.288	.118	.150
	liver	.013	.003	.020	.005	.009	.007	.005	.100
	gut	.084	.025	.151	.055	.164	.063	.030	.100
	gills	.009	.021	.022	.015	.013	.019	.025	.050
	spleen					.002			
	Total	.999	.999	1.000	1.000	1.000	1.000	1.000	1.000

Error in net count at the 95% confidence level was calculated from the formula, per cent error = $(K/\sqrt{C})(100)$ where K is a constant equal to 1.96 for the 95% confidence level, C is the total count and 100 the correction for per cent.

Analysis of Data

Because of wide variation, the data were divided geographically into two parts; (1) samples from areas adjacent to the bomb sites, and (2) samples from areas 7 to 14 miles from the bomb sites. Of the samples from areas adjacent to the bomb sites the highest counts would be expected from the area nearest the most recent explosion if decay is the principal factor. Upon this assumption the highest counts would be expected from samples collected adjacent to Runit, followed by Bijiri and then Bogon.

The data were analyzed with the purpose of extimating activity by area, by species, and by tissue. Analysis by area was based on the average total body activity of all species from one collecting area. Analysis of activity by species was calculated as being the average total body activity for one species from all areas. Tissue activity was calculated as the average activity per kilogram of tissue for all fish from all areas.

Results

The results are shown in tabular form in Tables II and III and in graphical form in Figures 4 and 5.

For samples from specimens collected adjacent to the bomb sites the counts of total body activity averaged 67 millimicrocuries per kilogram of fish and were inversely related to the elapsed time after the blast, i.e., the highest counts were from specimens collected in the area near the most recent blast, Runit Island. Beta-gamma activity of specimens collected 7 to 14 miles from bomb sites averaged 5 millimicrocuries per kilogram of fish. See Table II and Figure 4.

For samples collected at Runit, Bijiri and Bogon, the highest average tissue count was 689 millimicrocuries per kilogram of gut which indicates that the fish had been feeding upon organisms containing radioactive materials. The average gill count was 210 millimicrocuries per kilogram of gill but was largely dependant upon one sample the omission of which would reduce the average value from 210 to 79. This single high sample count probably resulted from speck contamination since the count of other tissues of the same fish, a shark, were practically background. Liver was next in value followed by bone, skin, and muscle. For tissue counts, see Figure 5 and Table III.

Twenty-four groups of fish were sampled of which the damsel, surgeon, goatfish, and parrot from the bomb site areas gave the highest total body activity. For the damsel and surgeon this value was calculated as being 180 millimicrocuries per kilogram of fish. For the total body activity of the other groups see Table II.

TABLE II.

Beta-Gamma Activity by Area and Species of Individual Fish From the July 1948 Eniwetok Collections

Expressed as Millimicrocuries per Kilogram of Fish

Area adjacent to bomb sites	Damsel	Surgeon	Goatfish	Parrot	Puffer	Butterfly	Wrasse	Siganid	Squirrel	Shark	Goby	Birdfish	Lizard	Grouper	Cardinal	Jack	Eel	Halfbeak	Mackerel	Flounder	Tuna	Flathead	Paraperoid	Pigfish	TOTAL	n	Ave. all Species
Rumit	363 513	323 438	57 40	130 114	71		7 254		74 98			21	5 56	22 10 3	20 15		6 10								2670	23	116
Biijiri	40 104 47	45 124 147	41 411	22 72		84	8 45		8 30	41			15 21	3 7	8 14		6 8								1351	24	56
Kirinian														36											36	1	36
Engebi																11 8									19	2	10
Bogon	87 107	57 123	3 25	42		5 101	6 35	52	1		0 46		9 7	29 12	18	7		5							777	22	35
Total	1261	1257	577	380	71	190	375	52	211	41	46	21	113	122	75	26	30	5							4853		
n	7	7	6	5	1	3	6	1	3	1	2	1	6	8	5	3	4	1								72	
Ave. by Areas	180	180	96	76	71	63	62	52	42	41	23	21	19	15	15	9	8	5									6
Area removed from bomb sites																											
Rigili	15 19	3	2 10	10 17		6 18	3 4 16		4 5				4 6	6 7	1 3		0 0 2			1 1	3	3		3	170	28	5
Igurin	11 11	10 11		4		7	3 6		7 4					6 21	1 6		1 2								111	16	7
Eniwetok														1 4 8		9			5						27	3	9
Japtan	2 4	6 7 7	0 8		8	3 2	2, 2 2 0		2		0		1 3	0 11			1 3			3			5		82	24	3
Total	60	44	20	31	8	36	38		22		0		14	64	11	9	9		5	5	3	3	5	3	390		
n	6	6	4	3	1	5	9		5		1		4	9	4	1	7		1	3	1	1	1	1		73	
Ave. by Areas	10	7	5	10	8	7	4		4		0		4	7	3	9	1		5	2	3	3	5	3			5

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Table III.

Beta-Gamma Activity of Fresh and Frozen Fish Tissues by Areas Expressed as Millimicrocuries per Kilogram of Wet Tissue for all Species Combined.

area adjacent to bomb sites		Gut total	Gut n	Gills total	Gills n	Liver total	Liver n	Bone total	Bone n	Skin total	Skin n	Muscle total	Muscle n
Runit,	fresh	12083	11	665	11	1521	11	833	11	401	11	174	11
	frozen	18616	12	2067	11	1465	10	247	12	349	12	169	12
Biijiri,	fresh	3316	12	8816	12	911	12	290	12	534	12	154	12
	frozen	4754	11	1008	10	513	8	1908	11	1746	11	654	11
Bogon,	fresh	4706	10	373	11	1580	10	186	11	342	11	115	11
	frozen	3903	10	477	6	458	4	166	10	92	10	68	10
Kirinian,	fresh	0	1	8	1	25	1	166	1	0	1	0	1
Engebi,	fresh	184	2	14	2	122	2	18	2	36	2	16	2
Total		47562	69	13428	64	6595	58	3814	70	3500	70	1350	70
Average		689		210		114		54		50		19	
area removed from bomb sites													
Rigili,	fresh	568	15	90	15	219	15	25	15	76	15	40	14
	frozen	795	13	557	13	379	4	97	13	227	13	93	13
Igurin,	fresh	283	9	150	9	325	9	99	9	29	9	29	9
	frozen	203	7	35	7	0	3	64	7	22	7	56	7
Japtan,	fresh	121	11	31	11	47	11	42	11	22	11	24	11
	frozen	143	12	197	12	332	7	35	12	91	12	64	12
Eniwetok,	fresh	5	5	23	5	62	5	17	5	19	5	32	5
Total		2118	72	1083	72	1364	54	379	72	486	72	338	71
Average		29		15		25		5		7		5	

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Figure 4. Average Total Body Beta-Gamma Activity of Fish by Areas from Reef Stations, all Species Combined, and Expressed as Millimicrocuries per Kilogram of Fish. Areas listed in an East to West Counter-clockwise Direction About the Atoll.

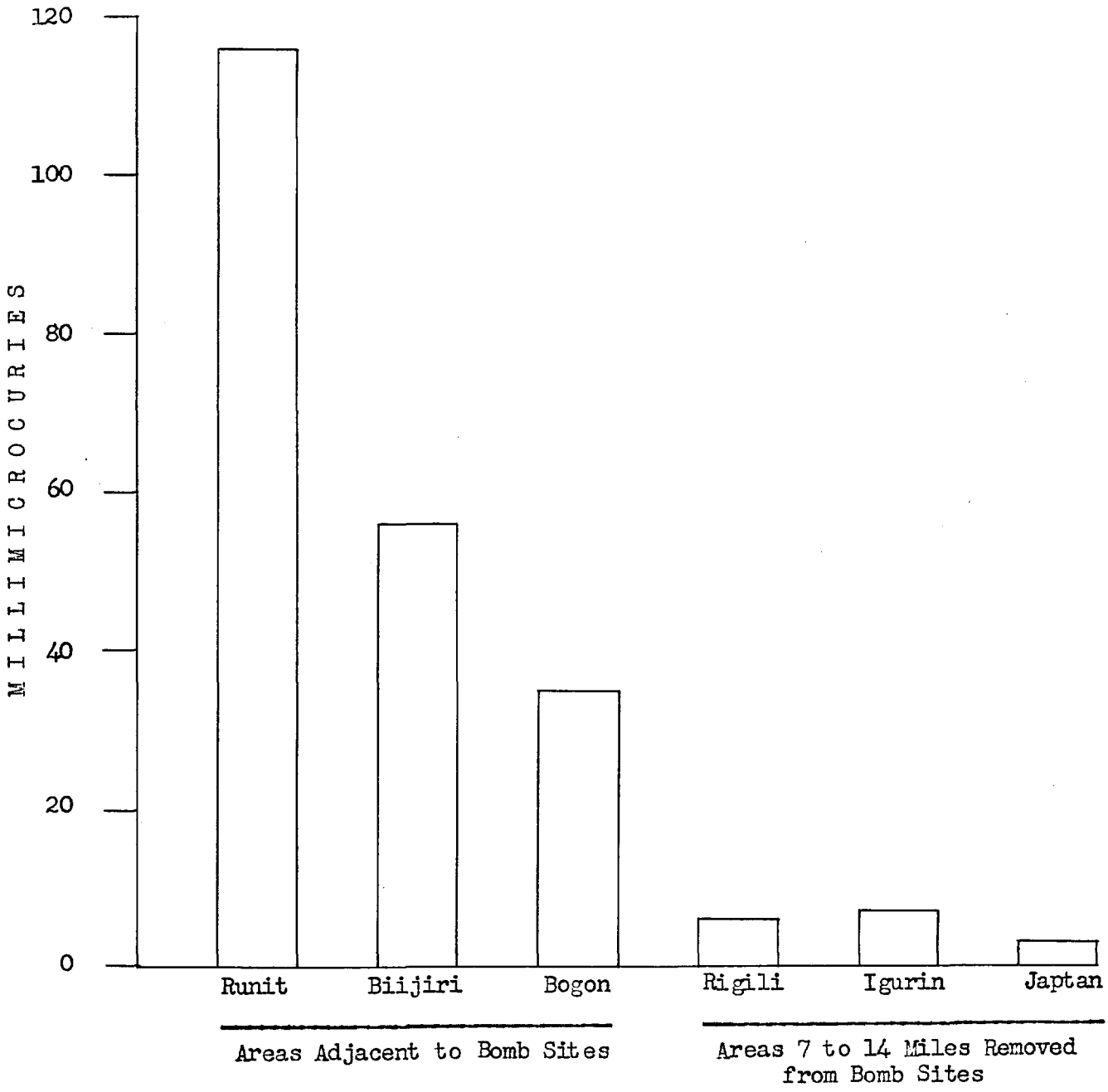
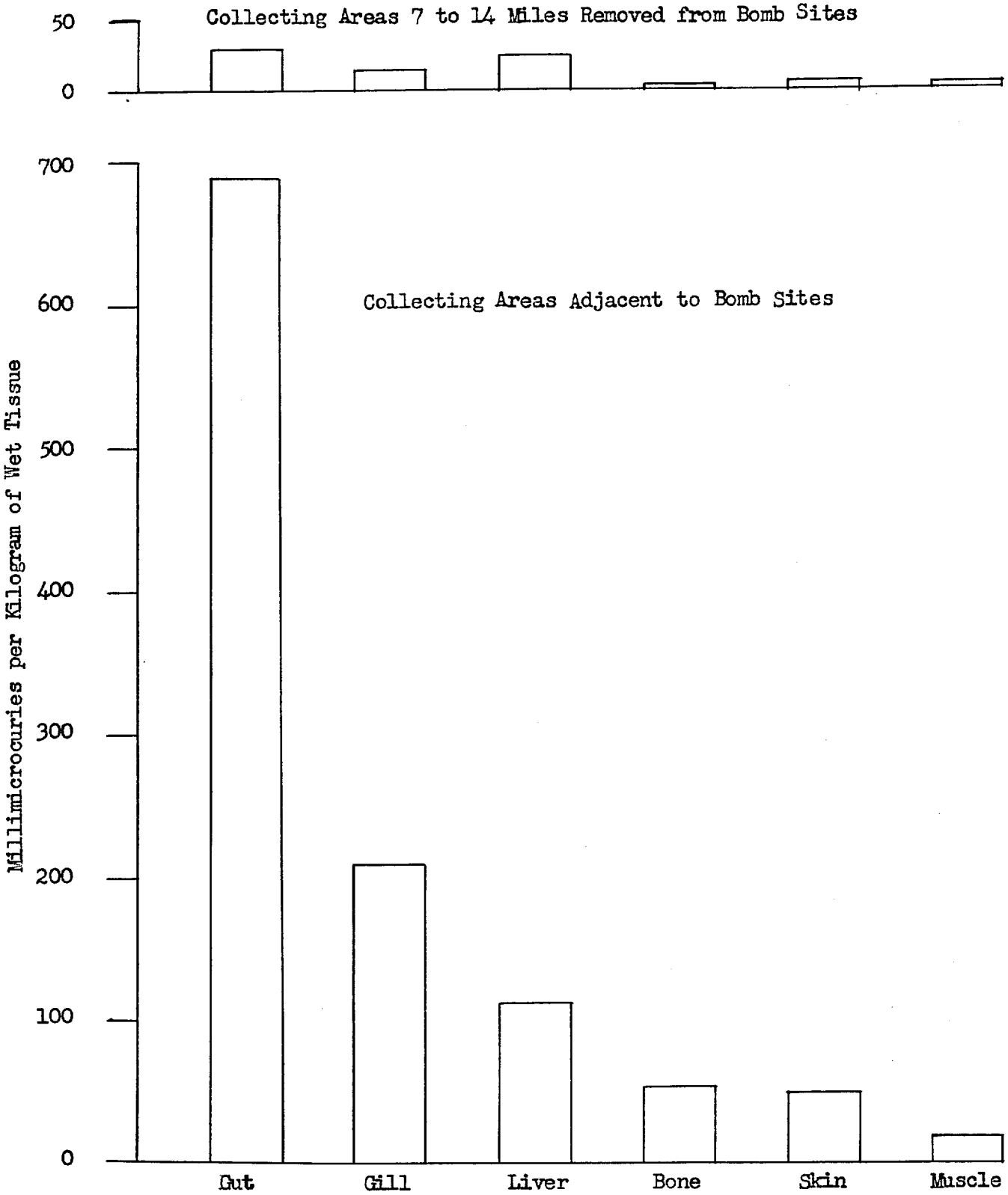


Figure 5. Average Beta-Gamma Activity of Fish Tissues Expressed as Millimicrocuries per Kilogram of Wet Tissue. All Species from all Areas Combined.



Error

The percentage error in counting and hence in estimating activity is dependent upon both the activity of the sample and the length of counting period, and therefore is less for samples of high activity as long as the counting period remains constant.

In general, values of less than five millimicrocuries per kilogram are of questionable significance. Such a value would result if the sample weight were 1 gram, the geometry 18%, and the net count per minute, 2.

Counting time was five minutes (see "counting procedure") except for those samples which had original net counts between 0 and 4 per minute. In this case the sample was recounted for five minutes and the average based on a 10-minute counting period. Of the 837 samples, 230 (27.5%) counted background or less. For the remaining 607 samples, the error in counting (see page 13 "Calculations") was divided by the net count, i.e., sample count less background, to give a value for the per cent of error in the net count. For 86 samples (14%) the error was twenty-five per cent or less, for 72 samples (12%) the error was between twenty-five and fifty per cent, for 178 samples (29%) the error was between fifty and one hundred per cent, and for 270 samples (45%) the error was greater than one hundred per cent. The majority of samples with background count or less and with low counts and consequently with high percentage error in net count were from specimens collected at Rigili, Igurin, and Japtan.

In estimating the average total body activity in different areas where species differ there may be a slight error due to the fact that some species may be more radioactive than others. The error was minimized by attempting to

collect the same species from all areas.

The calculation of total body activity assumes that the body ratios of Table I are valid. It is known that body ratio varies with size, age and stage of maturity of individuals even of the same species and certainly between individuals as categorized in Table I, but the error is relatively insignificant as compared to the percentage error of the net count.

From techniques recently developed for preparation of calcium carbonate samples for ashing there is strong evidence that some activity may have been driven off by the ashing technique described above. See UWFL-16, page 20. Thus, loss by ashing and by the uncorrected factors listed above have given minimum values for the estimates of activity recorded in this report.

Summary

Collections of fish were made principally at three reef stations -Runit, Bijiri and Bogon- in the vicinity of the bomb sites and at three reef stations 7 to 14 miles removed from the bomb sites -Rigili, Igurin and Japtan. The collection also included a few fish caught by hook and line. From 145 fish 837 samples were prepared. Only beta-gamma counts were made. The counter was calibrated with a Ra D+E standard. No great difference was found in comparing samples prepared from fresh with those from frozen specimens. The average total body activities for all species combined were 116, 56, and 35 millimicrocuries per kilogram for Runit, Bijiri, and Bogon respectively and 6, 7, and 3 for Rigili, Igurin, and Japtan respectively. The first three stations are listed in reverse chronological order relative to time of explosion. For the bomb site areas the greatest amount of total body activity was found in the damsel, surgeon, goatfish, and parrot fish with the value for

the first two being 180 millimicrocuries per kilogram of fish. Values for other species are listed. The beta-gamma activity of fish tissues for all species combined from the bomb site collecting areas expressed as millimicrocuries per kilogram of wet tissue was 689 for gut, 210 for gills, 114 for liver, 54 for bone, 50 for skin and 19 for muscle. The counts were corrected for background, for weight of sample, for geometry, and for date of counting. Because there was probably some loss of activity during the ashing process and no corrections were made for scattering, for self absorption, for absorption by air and by counter window, or for the probability of ionization, the estimates of activity are minimum values.

Part 3. Evaluation of the Counts of Beta-Gamma Activity of Algae Samples.

In the preceding discussion of the beta-gamma activity of fish, the sections pertaining to collecting areas, date of collection, sample preparation, counting procedure, correction in counts and calculations are also applicable to the algae data.

Collecting Methods

Samples were gathered by hand in the vicinity of the fish collecting stations in waters five feet or less in depth.

Groups and Number Sampled

An effort was made to collect the same genus in all areas for comparative purposes. However, only two genera were collected at all of the six major reef collecting stations. Sixteen genera plus one general group were gathered from all stations and from these, 64 samples were prepared and counted for beta-gamma activity. The samples were weighed wet, that is, the sample was removed from a bucket of salt water, drained but not dried, then weighed. The samples were counted between September 24 and 26, 1948, but were corrected to the same counting date as the fish samples, August 9, 1948.

As with the fish samples, recounts were made of those samples with net counts of 0 to 4 and the data of the two counts averaged.

Analysis of Data

Activity was calculated as millimicrocuries per kilogram of wet tissue. The average activity for all groups of algae from one area was determined as well as the average activity from all areas for one group.

Results

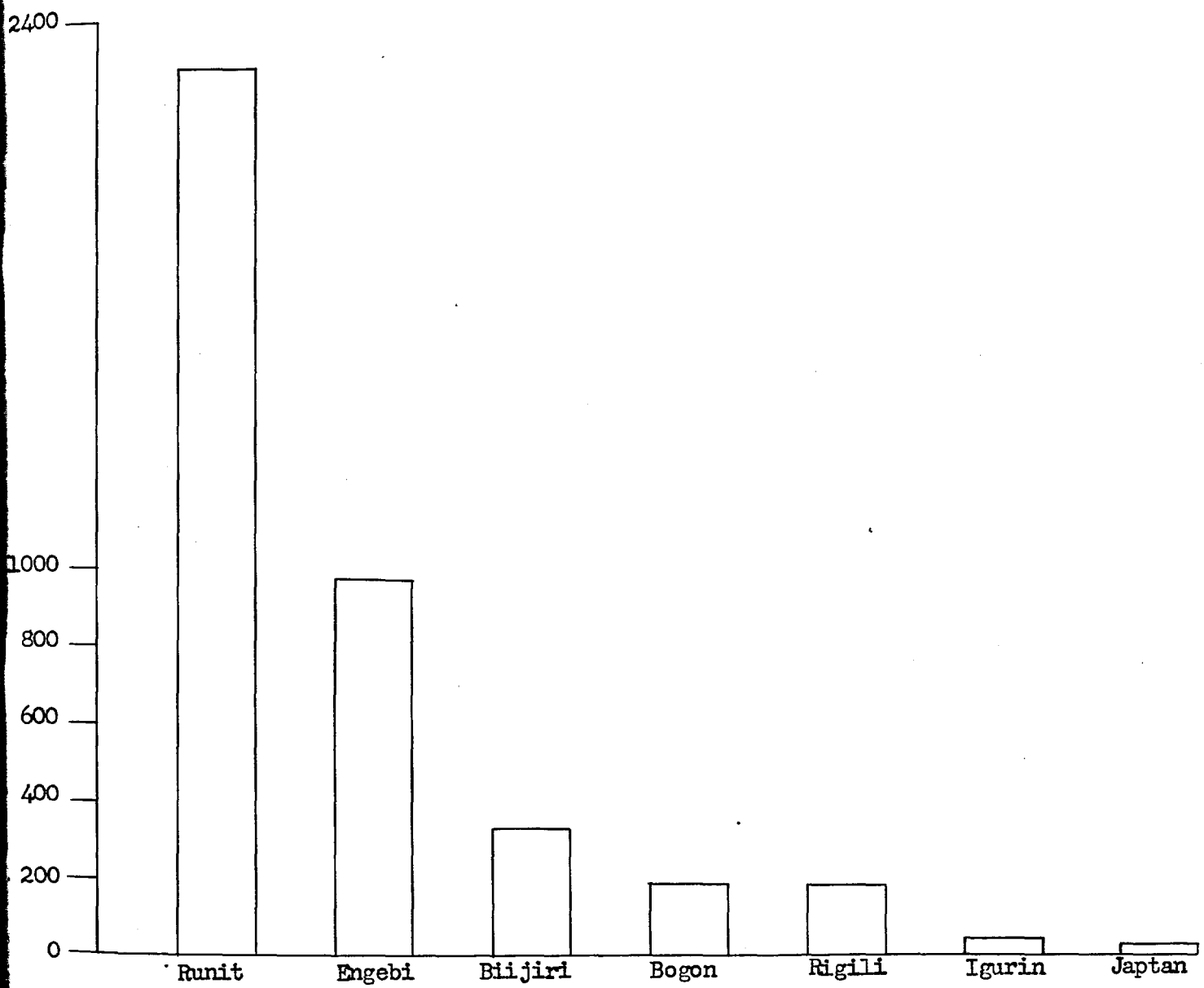
Expressed as millimicrocuries per kilogram of wet sample the average value of samples from the collections in areas adjacent to the bomb sites was 1004 and ranged from 0 to 5335 for individual samples. For samples from the other areas the average was 79. Individual samples ranged from 0 to 544. See Table IV and Figure 6. The highest counts were of samples of the genus Bryocladia. Values for other groups of algae are listed in Table IV. Since there are only a few samples for each alga, and there is wide variation within groups the relationship between amount of activity and kind of alga as shown in Table IV is of doubtful meaning.

TABLE IV

Beta-Gamma Activity of Algae Samples by Area Expressed as Millimicrocuries per Kilogram of Wet Sample

	near bomb site areas					7 to 14 miles from bomb site areas			
	Runit	Engebi	Bijiri	Begon	Average	Rigili	Igurin	Japtan	Average
Bryocladia	5242				5242	316			316
Sphacelaria	4705				4705				
Blue green	2390	780, 3191			2120	182	8		95
Pocockiella	5335		401	523	2086			23	23
Rhipilia	1974		220		1097			70	70
Polysiphonia			845		845				
Dictyota		832			832				
Udotea	1640		384	296	773	544, 480	202, 28	19	255
Caulerpa urvilliana (Mont.) Weber van Bosse	1253		168	107	509	62, 71	8		47
Microdictyon			508		508				
Ectocarpus				215	215		125		125
Dictyosphaeria	96		53, 274		141		22, 38	22, 23	26
Halimeda	194	0, 49	130, 152	32, 78	91	44, 115	6, 14	8, 0	31
Turbinaria				47	47				
Lithophyllum							40		40
Spyridia filamentosa (Wulfen) Harvey								38	38
Hydroclathrus								28	28
Caulerpa racemosa (Forssk.) J. Ag.	13				13	0, 1	0, 0	0	0
TOTAL	22842	4852	3135	1298	32127	1815	491	231	2537
n	10	5	10	7	32	10	12	10	32
Average	2284	970	314	185	1004	182	41	23	79

Figure 6. Average Beta-Gamma Activity of Algae by Areas Expressed as Millimicrocuries per Kilogram of Wet Sample



Part 4. Evaluation of the Counts of Beta-Gamma Activity in Invertebrate Samples.

Unless noted, methods and procedures are the same as described in parts 2 and 3.

The invertebrate collections were from shallow reef waters in the vicinity of the six fish collecting stations plus one additional station at Engebi. General observations made at Engebi are noted in part 6.

Some of the smaller invertebrate groups were combined into the more general groups shown in Table V. Altogether 191 samples were prepared, some in the field and some at the University of Washington, and were counted between August 1948 and February 1949. Most of the samples were counted during August and all were corrected to the August 9, 1948, counting date. If there were more than one tissue from a single specimen the average value of all tissues, without weighting was used to calculate average count by group or by area.

Results

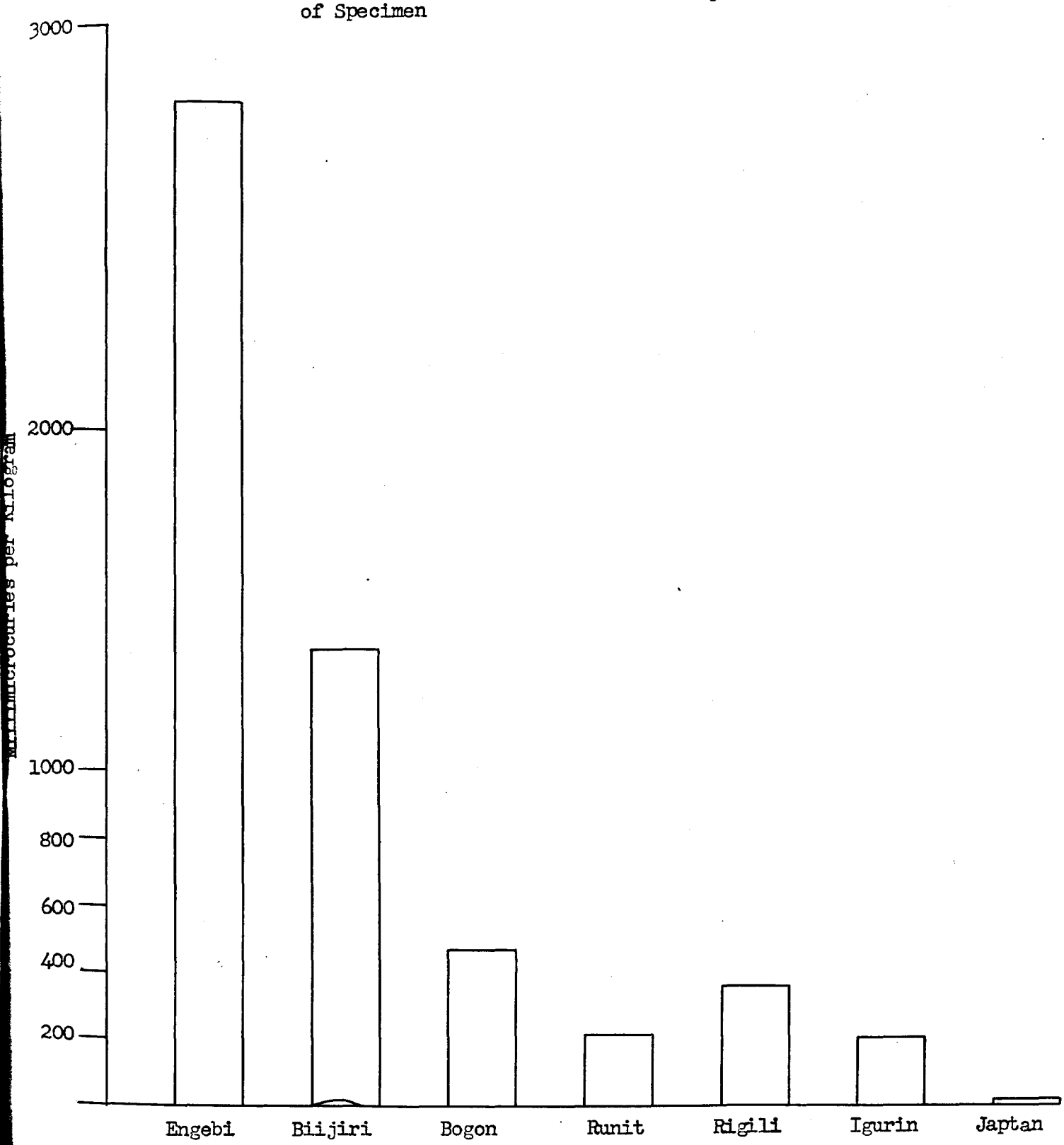
The individual and average beta-gamma activity estimates of invertebrates by groups and by areas are tabulated in Table V. In Figure 7, activity estimates by areas, of all samples combined are shown as a histogram. This differs from the histograms of Figures 4 and 6 in that the value for Runit is the lowest of the bomb site areas (even lower than Rigili) whereas for the fish and algae it was by far the greatest. For the other areas the values are similar. The average count expressed as millimicrocuries per kilogram ranged from 2969 at Engebi to 10 at Japtan. The highest invertebrate counts were those from samples of the sponge with the highest individual count equivalent to 19722 m/uc/kg. Other invertebrates with individual values of 1000 or more m/uc/kg were crab, starfish, coral and snail. For the complete list see Table V.

TABLE V

Beta-Gamma Activity of Invertebrate Samples by Areas Expressed as Millimicrocuries per Kilogram of Sample

	Engebi	Bijiri	Bogon	Runit	Average	Rigili	Igurin	Japtan	Average
sponge	19722	4460 4440	631 1774	843	5312	3229	1245, 73 1171, 50 772		1090
starfish		5640	1517		3578		166	61	114
crab	6269	802	119, 154	205	1510	145, 118	19	4	72
oyster		922			922				
octopus		666			666				
snail		1116	718, 719 28	98	536	45	52	4	34
coral	2482, 2572, 54 107, 339	44, 52	252, 485 20	185, 47 100, 94	488	210, 94 76, 98	15, 78 0, 3	17, 17 0, 0	51
sea cucumber	516	263	178	242	300		18	9	14
brittle star		348		180	264				
clam	172, 235 187	106, 34	149, 170	183	154	82	15, 9	3	27
ascidian						115			115
barnacle						56, 106	22		61
shrimp							60		60
urchin		83	20	90	64	127	7	6	47
nemertean								6	6
tunicate							4		4
sea slug								0, 5	3
TOTAL	32655	18976	6934	2267	60832	4501	3779	132	8412
n	11	14	15	11	51	13	19	13	45
Average	2969	1355	462	206	1193	346	199	10	187

Figure 7. Average Beta-Gamma Activity of Invertebrates by Areas Expressed as Millimicrocuries per Kilogram of Specimen



Part 5. Evaluation of the Counts of Beta-Gamma Activity of Plankton Samples.

Plankton tows, as time permitted, were made in the lagoon. Two types of nets were used, a standard one-meter Michael Sars net constructed of #14 and #24 xxx silk grit gauze and a smaller 12" marine type towing net constructed of silk of 125 meshes per inch. Hauls were made off Eniwetok, Engebi and Acmon anchorage. One sample from each of 14 tows was prepared in the field and were counted at the University of Washington Laboratory on August 6, 1948.

The beta-gamma counts for all samples, expressed as millimicrocuries per kilogram of damp, drained sample are given in Table VI. The highest counts were of samples from the waters near the bomb sites. However, the most striking feature regarding the plankton tows was the fact that the counts of the fine meshed net were considerably greater than those from the coarse net. The average values were 1402 and 38 respectively. The greatest value for a single tow was 5684 mμc/kg.

SECRET

Table VI.

Beta-Gamma Activity of Plankton Samples Expressed as Millimicrocuries per Kilogram of Wet Sample.

Area	Date	Hour	1 m. net	12" fine net	Average
Eniwetok	7/23/48	3:40- 4:40 P.M.	13	11	121
"	7/28/48	10:05-10:35 P.M.	36	423	
Engebi	7/25/48	10:15-11:15 A.M.	7	1297	450
"	7/25/48	10:10-10:40 P.M.	49	445	
Aomon	7/26/48	3:15- 4:15 P.M.	8	437	
"	7/26/48	9:45-10:15 P.M.	140	5684	1299
"	7/27/48	10:00-11:00 A.M.	10	1517	
Average			38	1402	

SECRET

Part 6. Underwater survey of the life zone adjacent to the test site on Engebi Island.

A survey of the reef area north of the crater on the tip of Engebi Island was made on the morning of July 26, 1948. The notes on this trip present some qualitative data regarding the damage to the forms living in the region.

The four members of the party surveyed an equilateral triangular plot on the north shore of Engebi Island just north of the four concrete bases in the middle of the crater. The first leg of the triangle extended northwest a distance of 350 yards. The second leg was eastward for about the same distance, and the third leg returned southward to the point of origin. All members of the party were equipped with face masks and explored the area by diving, wading, swimming or observing from a rubber boat. Beneath the surface clear water permitted good vision..

The recorded observations may be summarized by the following statements:

The area of kill was shown by the presence of skeletons of the sedentary forms like clams and coral.

All coral and clams were dead out to 250 yards on the northwest leg of the triangle.

The first live coral and clams were seen 50 yards from the shore on the third leg of the triangle.

Appreciable quantities of living coral and clams were observed 300 yards and farther from shore on the northwest leg and 150 yards on the third leg.

Numbers of clams were dying or had died within the previous few days. These clams were agape with the soft parts in various stages of decay.

Motile forms such as fish, sea cucumbers and sea urchins were seen alive close to shore, possibly having immigrated from surrounding areas to replace forms that had been killed by radiation.

At this bomb test there was an opportunity to observe possible differences in tolerance of various sedentary animals. No differences appeared in the proximity to the crater at which living animals belonging to different zoological groups, (eg. clams and coral) were found.

Algae continued to grow in the area, even close to shore, where other organisms were dead. Fish were observed feeding on this algae that had undoubtedly absorbed radioactivity.

Part 7. Summary and Conclusions

Marine organisms including fish, invertebrates, algae, and plankton were collected at Eniwetok Atoll between July 22 and 28, 1948. Practically all specimens except for plankton were collected in the shallow waters of the reef. Plankton tows were made in the lagoon as time allowed. The reef collections were made at six major stations, three of which were near the bomb test sites. Procedures used in collecting material were similar to those for the 1948 Bikini Resurvey.

Samples were prepared both in the field from fresh specimens and in the laboratory at the University of Washington from frozen specimens. Counts of samples prepared from fresh specimens were similar to like samples from frozen specimens. Only beta-gamma counts were made. The counts were corrected for background, for weight of sample, for geometry, and for date of counting but were not corrected for scattering, self-absorption, for absorption by air or by counter-window, or for the probability of ionization. Since the factors for which the counts are not corrected would change the values in a positive direction only, the estimates of activity as recorded are minimum values.

Sample counts of radioactivity were converted to either millimicrocuries per kilogram of sample or millimicrocuries per kilogram of organism. Analysis was made of the distribution of activity by tissue, by species, and by area. The activity of fish, algae, and invertebrate samples from areas near the bomb test sites was so much greater than similar samples from areas 7 to 14 miles removed from the bomb test sites that the data were so categorized.

For the fish samples, the average total body activities for all species combined were 116, 56, and 35 millimicrocuries per kilogram for Runit, Biijiri, and Bogon respectively and 6, 7, and 3 for Rigili, Igurin, and Japtan respectively. For damsel and surgeon fish collected near the bomb site areas the average total body activity was 180 millimicrocuries per kilogram of fish. The average tissue counts for all species collected near Runit, Biijiri, and Bogon ranged from 689 for gut to 19 for muscle.

The average value of the number of millimicrocuries per kilogram of algae for the areas adjacent to the bomb sites was 1004 as compared to 79 for the areas 7 to 14 miles removed. Individual sample values for algae ranged from 0 to 5335 and in general were considerably greater than the activity of fish samples.

The invertebrate collections included such animals as sponges, crabs, starfish, corals, snails, oysters, worms, urchins, clams, sea cucumbers, barnacles, shrimps, and sea slugs. Counts of invertebrate samples were higher than either algae or fish. The greatest value was 19,700 millimicrocuries per kilogram of sample for a sponge collected in an area near a bomb test site.

Activity of plankton samples from the fine-meshed nets was approximately of the same order of magnitude as the algae. The average value was 1402, the greatest single value being 5684 m/uc/kg of wet sample. From simultaneous tows of a coarse-meshed and a fine-meshed net the estimated activity of the latter was 30 to 40 times greater than the former.

This report does not complete the evaluation of the material collected. Studies are needed to determine the presence of alpha contamination.

Chemical separations are needed to determine the identification and the amounts of the elements contributing to the activity.

Since the metabolism of plants and animals involves complex biological processes time is required for the radioactive elements to produce their effect upon the organisms, and therefore continued observation and study are essential to further the understanding of the problems. This is especially true of the Eniwetok experiments for they can form an area of study leading to a better understanding of contaminated land and water regions.