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Operation

CASTLE

PACIFIC PROVING GROUNDS

March — May 1954

Project 2.7a

RADIOACTIVITY OF OPEN-SEA PLANKTON SAMPLES

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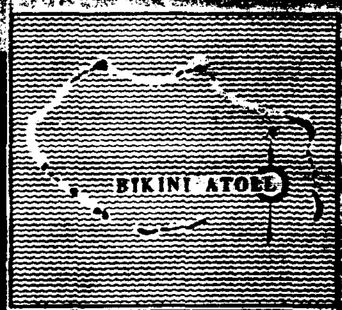

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WT-954

OPERATION CASTLE—PROJECT 2.7a

Report to the Scientific Director

RADIOACTIVITY OF OPEN-SEA PLANKTON SAMPLES

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ABSTRACT

Project 2.7a was an outgrowth of Project 2.7, the genesis of which is described in the Project 2.7 report, Reference 1. During the 2.7 surveys, samples of marine organisms of the deep sea were collected by Scripps Institution of Oceanography (SIO) and were later analyzed by SIO and the U.S. Naval Radiological Defense Laboratory (NRDL).

It was the objective of Castle 2.7a to ascertain and to report on the general relationship pertinent to the uptake of fission products by the marine organisms collected during the 2.7 survey in order to form a background for more extensive tests on Operation Wigwam. Gross beta activities, beta absorption curves and gamma spectra were analyzed, after identification of the organisms. A radiochemical analysis was performed by NRDL.

It was found: (1) that marine organisms concentrate activity from fallout fission products in the water by factors of the order of 1,000, (2) that the partition of fallout fission products in the ocean is profoundly influenced by biological processes and that a purely physical model is inadequate to predict distribution, (3) that the feeding mechanism of the organism does not clearly determine the amount of activity assimilated, (4) that there is evidence of fractionation of isotopes by different organisms, and (5) that there is some evidence that finely dispersed activity is retained more or less proportionally with the dry weight of the organism.

PREFACE

Much time has passed since the Castle Operation when the effects of fallout upon the open sea were first studied by oceanographic methods. More recent field tests have contributed far more data concerning the radioactive contamination of marine organisms than could be collected during the hastily outfitted cruise of the U.S.S. SIOUX following Castle, Shot 5. Nevertheless the two small samples of plankton that were collected by the SIOUX were sufficiently impressive to influence the thinking of people making preparations for later operations, and, in particular, the thinking of people involved in the problem of oceanic disposal of atomic wastes.

Today these specimens themselves do not appear so spectacular, nor have some of the hypotheses that guided their analyses been completely substantiated.

It is now common knowledge that marine organisms are notorious concentrators of radioactive debris from nuclear detonation; and biologists, radiochemists and oceanographers have acquired enough interest and experience to carry out well-organized and integrated research on the problems. For these reasons the original interim report has been rewritten and some of the conclusions have been left out. Critical original experimental data from field expeditions retains its value almost indefinitely, however, and this paper reports the first direct in situ evidence of the profound influence of deep sea organisms on the partition of radioactive debris from atomic weapons, and directly demonstrates the inadequacy of a model that accommodates only the physical processes of mixing, advection, etc. This fact justifies a final report.

The authors wish to point out that proper credit has not yet been directed to certain people who were largely responsible for the original conception of the expedition and outfitting of it so that it could be successful. It was Professor John D. Isaacs who, in fact, proposed that plankton samples be taken and who located and acquired the special net that was needed, as well as the other oceanographic gear, and it was to a great degree the scientific and administrative experience of Professor Isaacs and of Dr. Edward Martell that pulled the project together as an operational unit.

It is almost impossible to be sure that proper credit is given to everyone who contributed to this special aspect of the Castle project. The radioanalyses of Table 2 were done at NRDL by Doctors R.W. Rinehart, J.A. Seiler, W.H. Shipman, and others and the data transmitted to SIO by Dr. L.B. Werner with valuable comments.

Dr. Edward D. Goldberg was responsible for the beta and gamma measurements shown on Table 1 and Figures 1, 2, and 3; the beta analyses were carried out at SIO but the gamma spectra were measured at NRDL.

Dr. Martell reviewed the preliminary report and demonstrated that these early, scanty, experimental findings could hardly justify the conclusions expressed. The authors concurred and the report has been revised extensively.

CONTENTS

RADIOACTIVITY OF OPEN-SEA PLANKTON SAMPLES

BACKGROUND AND OBJECTIVES

Immediately following Shot 5 of Operation Castle in 1954 the Fleet Tug U.S.S. SIOUX manned by scientific personnel from NRDL and the Scripps Institution of Oceanography made a four-day long cruise through the oceanic area adjacent to Bikini. The extensive measurements of the pattern of gamma activity in the sea water were made and are the subject of a comprehensive report, Reference 1; and during the cruise, at two different stations, a net was lowered and a sample of the zooplankton population was taken. These zooplankton samples exhibited an intense concentration of gamma activity over that of the surrounding water. This was immediately apparent from the effect that their presence in the specimen jars had upon a portable gamma indicator, in spite of relatively high background aboard the ship.

The two bottles of plankton were immediately sent to NRDL and SIO for classification and analysis by biologists and radiochemists. The outcome is the subject of this report.

PROCEDURE

The samples were collected with a standard silk zooplankton net, having a diameter of one meter, using the technique customary in biological oceanography. The net was lowered into the water at 50 meters per minute until 200 meters of wire had run out. The wire was then hauled in at 20 meters per minute. This technique collects the organisms from roughly 500 cubic meters of water, including all depths between 0 and about 140 meters.

The samples were received at SIO about one week after collection and were then further preserved with formalin; most of the organisms were in good condition. Biological identification of the organisms was made at SIO.

Objectives of the Laboratory Studies. How fission products are distributed in the ocean after a fallout is of importance to those planning weapons tests and disposal of atomic wastes at sea. The distribution within the marine biosphere is of special importance, because (1) certain marine zooplankton are known to migrate vertically and therefore could be significant vectors of fallout activity through the stable layers where water transport is much reduced; (2) the activity in organisms is in a critical material, potential foodstuffs. Among other things, it was decided to investigate the possibility that an organism's activity was influenced by its feeding habits.

General Character of Biological Samples. Nets of the type used, pass most of the phytoplankton and very smallest zooplankters. Most of what is caught is of visible size. Many of the small animals display their ability for movement by darting about the collection jar. Certain large transparent passive gellatenous animals can be seen to contain smaller organisms, alive or dead. Since it is known that zooplankton depend ultimately upon the minute primary plants of the sea, it is certain that any catch of zooplankton must include also whatever phytoplankton exist as undigested fodder.

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Classification of Organisms. Marine zoologists are able to recognize amongst the zooplankton several characteristic modes of acquiring food, and it was found possible to separate the Castle catch into three sorts. The resulting splits admittedly were small, but this was all that the catch afforded.

The classifications generally used by biologists are as follow:

(S) Setal; feeding with the aid of protruding bristles (setae),
(R) Rapacious; seizing food agressively, and
(T) Tentacular; gathering food by means of tentacles.

Characteristics of the Sea Water Masses Involved. Although the two samples were collected many miles apart, there is oceanographic evidence that the samples came from similar water masses in the sense that no differences in the type of zooplankton might be expected. However, it has been estimated that fallout arrived at Station 6 when this water was about 180 miles from the shot center, whereas the fallout arrived at Station 8 when this water lay about 80 miles from ground zero. Thus the fallout particles at Station 6 likely were finer than those at Station 8. Both points lay more or less along the axis of the computed fallout pattern, Reference 1.

The gamma intensity measured by a Geiger detector (submerged but near the surface) at Station Y - 8 was roughly 10 times as high as the intensity similarly measured at Station Y - 6. These and other measurements indicate that the Sample Y - 8 came from water about 10 times more active than the Sample Y - 6.

There is oceanographic evidence that substantially only Shot 5 contributed to the contamination of the waters from which each sample was taken.

RESULTS

Gross Beta Activity Measurements. Gross beta activities of each type of feeder are compared in Table 1. An end-window Geiger-Muller counter having a window thickness of 1.4 mg/cm^2 was used. The organisms vary widely in size and in weight so that activity has been expressed in Table 1 in terms of wet weight as well as in terms of dry weight of organism.

Beta Absorption Analyses. Figure 1 compares the activities from three feeding types in terms of attenuation caused by aluminum filters interposed in front of the counter. A setal feeder and a rapacious feeder were studied as well as samples of fish larvae whose feeding habit was not classified. The types are identified in Table 1.

Beta Decay Characteristics. Figure 2 compares the decay of beta activities in four kinds of plankton; the curves were not normalized in percent of initial activity because their slopes are very similar and their superimposition would cause a confusing graphical picture.

Gamma Spectra. The gamma spectra of three selected plankton were obtained in the 70-channel gamma pulse analyser of NRDL and two are shown in Figure 3 along with the instrumental background spectrum. It will be noted in Table 1 that both organisms are

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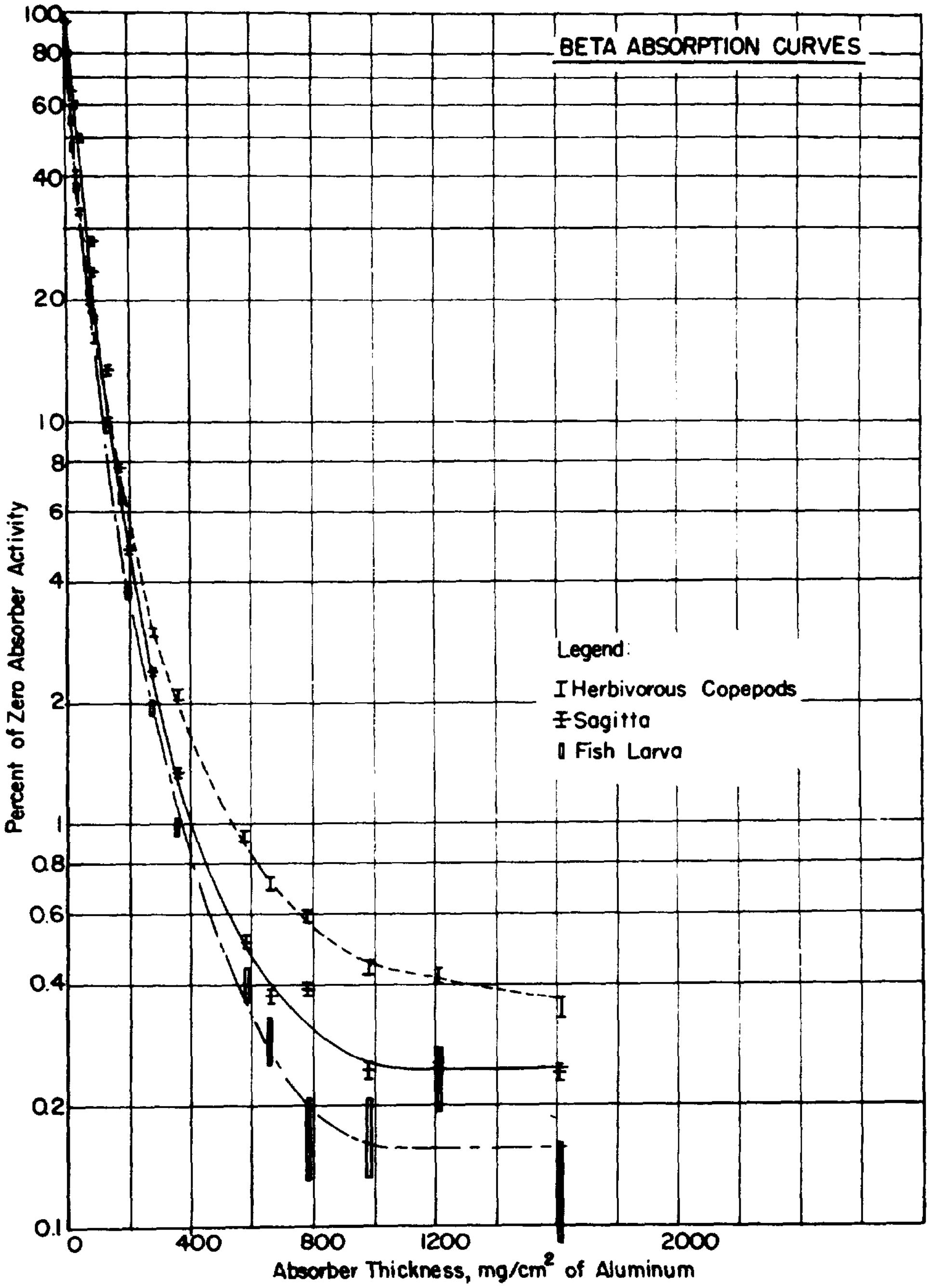

Figure 1 Beta-absorption curve.

of the setal feeding type. The third biological sample consisting of rapacious copepods produced a spectrum indistinguishable from background.

Radiochemical Analyses. Table 2 lists the results of the radiochemical analyses carried out at NRDL (Reference 2), and displays certain individual activities in terms of

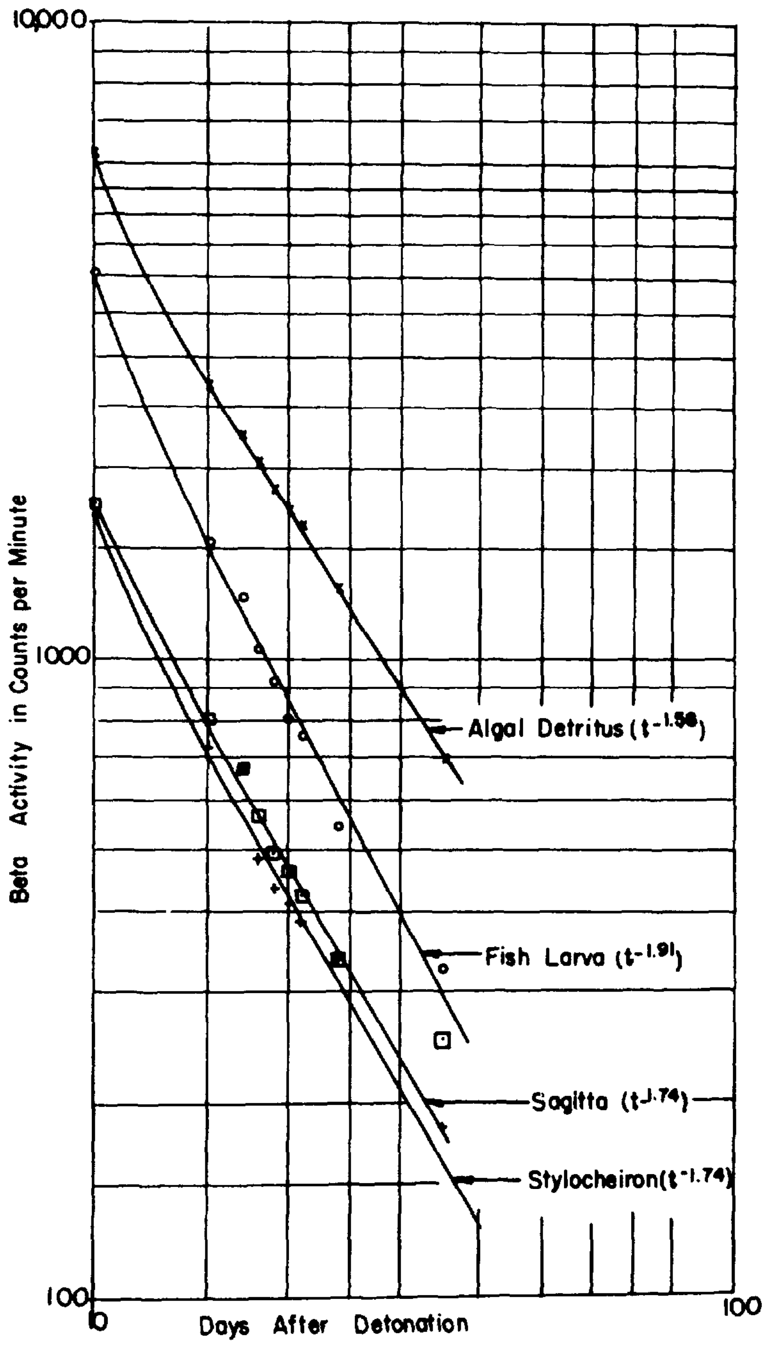

Figure 2 Beta decay curves.

certain activity totals. This tabulation also is the result of the initial interest in the matter of how the various nuclides are distributed in sea water containing plankton.

The total weights and volumes of the portion of the haul analyzed here was not reported but they were contained in specimen bottles holding about 200 ml water with plankton that, it is believed, would have a "drained volume" of about 1 to 2 ml. Therefore in Table 2 the total activity per ml volume is of the order of 1,000 times higher in

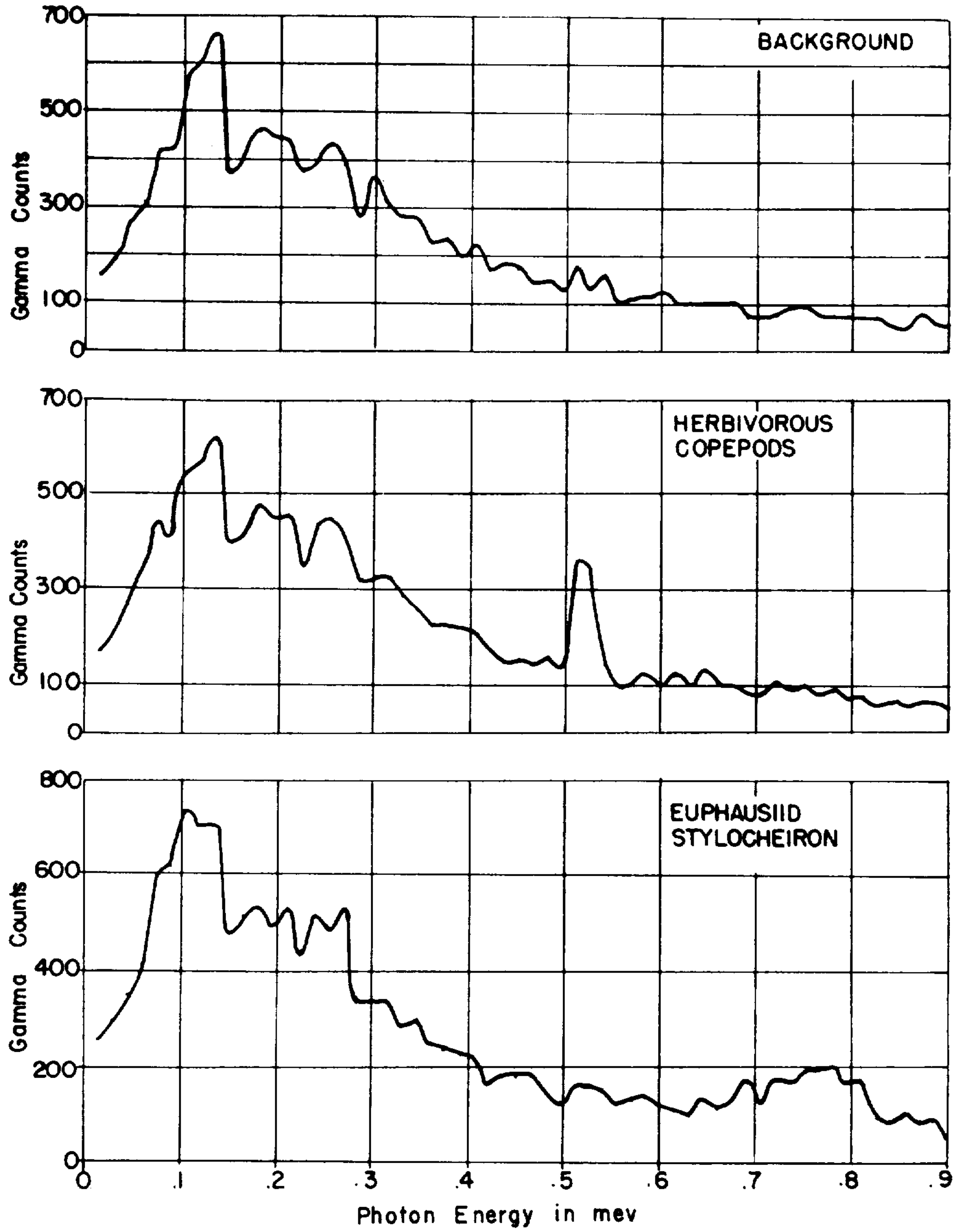

Figure 3 Gamma energy spectra

the solid fraction (drained zooplankton) than in the filtrate. More details are given in Table 2 which lists the ratio of the specific activity of each fraction of the organic material to that of the supernatent liquor.

The analyses of sea water samples taken in this area are still considered classified data and cannot be discussed here in such a way as to give more information concerning the concentrating ability of plankton to fallout materials. Furthermore, the analysis of the samples of water taken in this area was reported in terms of gamma activity making valid comparisons with Table 2 difficult.

Table 2 compares the compositions of the radioactivity retained by two species of marine organisms that were selected from the solid fraction mentioned in Table 2. Even from the meager data shown here, it can be seen that there are significant variations in the amounts and kinds of activity retained.

State and Size of Fission Particles in Sea Water. Table 3 is taken from earlier laboratory experiments at NRDL by Greendale and Ballou (Reference 3) where fission products were vaporized in sea water. The four nuclides listed display some tendency to

TABLE 1 BETA ACTIVITIES OF ORGANISMS FROM CASTLE*

S - Setal feeders, R - Rapacious feeders, T - Tentacular feeders, Parens - Estimated values.

Sample	Feeding Type	Organism	No.	Total Activity	Activity per Organism	Wet Weight	Dry Weight	Activity c/min/gm Wet Weight	Activity‡ c/min/gm Dry Weight
				c/min		mg	mg		
Y - 8 Collected	S	Herbivorous copepods (Calanus) adult	10	9,119	920	24.9	1.5	3.7×10^5	6.1×10^6
1500 9 May	S	Herbivorous mixed Calanoid copepods	21	4,465	214	(75.0)	4.5	0.60	0.99
1954	S	Stylocheiron (Euphausiid)	10	6,143	614	17.9	2.1	3.4	2.9
	R	Rapacious copepods adult	10	5,259	526	15.9	1.2	3.3	4.4
	R	Rapacious copepods	10	2,968	297	8.8	1.5	3.3	2.0
	R	Sagitta 12 - 18 mm	10	6,127	613	16.8	3.1	3.6	2.0
	R	Sagitta 10 - 12 mm	10	3,248	325	9.8	1.3	3.3	2.5
	T	Siphonophore piece	1	245	245	3.2	0.2	0.77	1.2
	†	Lucifer 7 mm	4	1,474	369	5.3	0.2	4.6	7.4
	†	Fish Larva	1	1,258	1,258	4.0	1.1	3.2	1.1
	†	Polychaete fragment (Syllid) 25 mm	—	2,272	2,272	6.3	1.1	3.6	2.1
	†	Pieces of algal detritus	—	722	—	(8.0)	0.72	0.90	1.0
Y - 6 Collected	S	Copepods, Pleuromamma	10	219	22	(3.5)	0.22	0.63	1.0
	S	Ostracoda, small	8	1,122	140	(11)	1.1	1.0	1.0
2400 7 May	S	Copepods, Pleuromamma adult	10	3,635	363	(61)	3.7	6.0	0.98
1954	S	Euphausiids, 3.9 mm	2	2,053	1,027	(20)	2.05	1.0	1.0
	R	Copepods, rapacious	10	328	33	(3)	0.33	1.1	1.0
	R	Sagitta 5 - 15 mm	10	450	45	(2.3)	0.45	2.0	1.0
	R	Copepods, rapacious	10	537	54	(6)	0.54	0.90	1.0
	R	1 Phronima 7 mm and 1 amphipod 2 mm	2	235	118	(2)	0.2	1.2	1.2
	R	Copepods, Corycaeus	25	223	9	(2.5)	0.22	0.90	1.0
	T	Siphonophore pieces	—	340	—	(5.0)	0.31	0.68	1.1
	†	Flocculent detritus	—	4,757	—	(50)	4.8	0.95	1.0

*Counts reduced to time of counting, 22 May 1954.

† Feeding type unknown.

‡ Efficiency of the Beta Counter was about 14 percent.

segregate between three states of dispersal; however, it must not be inferred from these laboratory data alone that in the case of fallout into the sea and in the presence of living organisms these elements would be permanently partitioned in the manner tabulated. Moreover, a living organism might possess an affinity for activity in quite a different kind and degree than would the same organism dead.

Table 3 does not indicate the physical state of barium, but from its chemical and physical properties one would expect it to behave much like strontium and some indication of this is shown in Table 2.

It is known that the size of fallout particles are related to the distance from the explosion at which the fallout occurs; and that the mean particle size in general decreases as distance increases. It is most likely therefore that the particles arriving at Station Y - 8 (80 miles from ground zero) were larger than those arriving at Station Y - 6 (180 miles from ground zero at the time of arrival). However, no direct measurements were made, and numerical estimates of particle size require extensive qualification beyond the scope and classification of this paper.

DISCUSSION

In Table 1 it will be noted that each of the classes as well as each type of organism in Sample Y - 6 shows the remarkably similar specific activity when referred to dry

TABLE 2 ANALYSIS AND COMPARISONS

Fraction	Gross Activity	Rare Earths	Ba^{140}	$Sr^{89,90}$	Zr^{95}	Nb^{95}	$Ru^{103,106}$	Undetermined
Radiochemical Analysis of Separated Fractions of Samples Y - 8, c/min of Beta activity								
Water*	82,500 (410)‡	3,530	1,780	1,600 (8)‡	890 (4.5)‡	840	33,900	39,960
Solid Fraction†	320,000 (320,000)‡	97,000	640	80 (80)‡	69,300 (69,000)‡	29,000	74,000	49,980
Total	402,500	100,530	2,420	1,680	70,190	29,840	107,900	89,940
Percent of Total Activity Contributed by Separated Fractions of Sample Y - 8								
Water	20.5	0.88	0.44	0.40	0.22	0.21	8.43	9.92
Solid Fraction	79.5	24.1	0.16	0.02	17.2	7.20	18.4	12.42
Apparent Specific Concentration Factors of Organic Material Over Supernatent Water, (c/min/gm)/(c/min/gm)								
	780	5,500	70	10	15,000	6,900	440	—
Comparison of the Compositions of the Activity Retained in Two Selected Organisms from Sample Y - 8. (Activity given relative to total for each organism, in percent)								
Copepods (mixed)	—	23.8	0.26	0.17	—	—	—	75.7
Sagitta (robusta)	—	40.8	1.2	0.60	—	—	—	57.4

* Filtered through sintered glass.
† Solid fraction retained by filter (mostly inorganic remains).
‡ Approximate specific activity c/min/gm; i.e. assuming 200 ml supernatent and 1 gram wet plankton in the specimen.

weight (Column 10); whereas no comparable consistancy appears in the activities of the components of Sample Y - 8. This inconsistancy possibly is related to the difference in size of the fallout particles at the two ranges.

Because of the large variation in size, and presumably therefore also in food consumption, it is unconvincing to compare activities of individuals of quite different sizes. Amongst the possible reference parameters in the data, dry weight would appear to offer the best reference for such comparisons as are being made here. However, it is possible that organisms may share activities in the preserving bottle, and if this were true, dried specimens having properties quite different in life might appear the same in the dry weight basis. This type of sharing is, of course, no less interesting but obscures the vital effects. There appears no way to avoid this difficulty entirely unless biological classifications were carried out immediately. Experience shows that this is impractical on board ship. It is difficult, however, to visualize the sharing process restricted to one sample and not the other, and, in addition, extremely difficult to conceive of a mechanism that controls the sharing on a dry weight basis, rather than on wet weight, total surface or some other parameter. The remarkably consistant results of activity on a dry weight basis, of one sample, leads one to suspect that the uptake and retention of radionuclides from fine fallout is directly related to the anhydrous weight of the organism throughout a wide range of water content.

Certain of the Y - 8 zooplankton types are roughly 5 times as active, specifically, as are similar organisms in the Y - 6 catch. Increase of this sort could have been expected since the Y - 8 water mass was found by field gamma measurements to have been (Reference 1) roughly ten times more radioactive than the Y - 6 and also because the Y - 8 organisms were exposed roughly twice as long to the contaminated water as those of the Y - 6 samples. However, there is no exact proportion exhibited between resulting activity, and time multiplied by exposure activity; this too may be entirely the result of the presence of large particles in the Y - 8 water as discussed above.

TABLE 3 THE PHYSICAL STATE OF FISSION PRODUCT ELEMENTS IN SEA WATER FOLLOWING AN UNDERWATER VAPORIZATION (From Reference 2)

Element	Physical State		
	Ionic	Colloidal	Particulate
	pct	pct	pct
Sr	85	5	10
Zr	1	3	96
Nb	0	0	100
Ru	0	5	95
Ce	1	4	95

Table 2 illustrates again that radio nuclides of zirconium and niobium are likely to be concentrated upon solid suspended particles especially on living organic materials. The same thing is seen on land where these particles collect on tree leaves and on carpet dust. No analyses were made during this early study of the sea water in these neighborhoods that would lead to an absolute estimate of the radiostrontium in the sea itself. Only gamma analyses were made of the water samples taken in this vicinity. Therefore it is not possible to estimate what affinity the organisms have toward strontium in comparison with any other radionuclides.

Figure 3 illustrates that two different setal feeders, namely the herbivorous copepod and the euphausiid Stylocheiron, exhibit a different affinity for gamma emitters. The former show a strong spectral peak of energy between 0.49 Mev and 0.54 Mev, while the latter shows a broad peak between 0.65 Mev and 0.85 Mev. The sample of rapacious copepods showed no significant peak above background. Thus there is no apparent relationship between feeding method and activity whereas there is an indication that two species within the setal feeding class behave quite differently regarding the kind of activity retained in a preserved sample.

From Figure 1 it can be seen that the beta energies of a setal, rapacious and an unclassified type are similar whereas the ratios of the beta to gamma energies are somewhat different. The latter is the only strong correlation between feeding type and affinity to active material.

The curves of beta decay between 10 and 60 days shown in Figure 2 can scarcely be distinguished. The mean coefficients all lie between 1.6 and 1.9 and unclassified biological types vary more than do classified types.

CONCLUSIONS

Open-sea marine plankton can concentrate fallout activity strongly and therefore should be included in fallout transport considerations and in plans for disposal of atomic waste. This concentration is especially significant because it appears in an organic food.

There is evidence from both beta and gamma analyses that certain plankton types have affinities for specific isotopes.

The radioanalyses of the first two samples of contaminated oceanic zooplankton has not demonstrated that there exists a simple relationship between the affinity of a class of plankton toward radioactivity, and the size of food it apparently prefers to eat. There is more variability within the classes than between these classes.

Oceanic zooplankton appear to be very effective concentrators of materials that are likely to be available in a particulate form, but they may concentrate certain other materials also, such as radiostrontium which is more likely to be in ionic form.

There is some evidence that the retention of finely dispersed activity varies more or less proportionally with the organism's dry weight over a considerable range in body size, surface area, and water content.

REFERENCES

1. Folsom, T.R. and Werner, L.B.; "Distribution of Radioactive Fallout by Survey and Analysis of Contaminated Sea Water"; Project 2.7, Operation Castle, ITR-935, May 1954, Scripps Institution of Oceanography and U.S. Naval Radiological Defense Laboratory; Secret Restricted Data.

2. Personal communication from Dr. L.B. Werner; U.S. Naval Radiological Defense Laboratory, including assay report of R.W. Rinehart, NRDL file No. 3-935, RWR:Lad, 15 July 1954.

3. Greendale, A.E. and Ballou, N.E.; "Physical State of Fission Product Elements Following Their Vaporization in Distilled Water and Sea Water"; U.S. Naval Radiological Defense Laboratory No. 436.

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1 Commanding Officer, U.S. Naval Damage Control Training Center, Naval Base, Philadelphia, Pa. ATTN: ABC Defense Course
1 Commander, U.S. Naval Ordnance Laboratory, Silver Spring 19, Md. ATTN: R

1 Commander, U.S. Naval Ordnance Test Station, Inyokern, China Lake, Calif.
1 Commanding Officer, U.S. Naval Medical Research Inst., National Naval Medical Center, Bethesda 14, Md.
1 Director, The Material Laboratory, New York Naval Shipyard, Brooklyn, N. Y.
1 Commanding Officer and Director, U.S. Navy Electronics Laboratory, San Diego 52, Calif. ATTN: Code 4223
4 Commanding Officer, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. ATTN: Technical Information Division
1 Commander, U.S. Naval Air Development Center, Johnsville, Pa.
1 Commanding Officer, Clothing Supply Office, Code 1D-0, 3rd Avenue and 29th St., Brooklyn, N.Y.
1 Commandant, U.S. Coast Guard, 1300 E. St. N.W., Washington 25, D.C. ATTN: (OIN)
1 Commander-in-Chief Pacific, Pearl Harbor, TH
5 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)

AIR FORCE ACTIVITIES

1 Asst. for Atomic Energy Headquarters, USAF, Washington 25, D.C. ATTN: DCS/O
1 Director of Operations, Headquarters, USAF, Washington 25, D.C. ATTN: Operations Analysis
1 Director of Plans, Headquarters, USAF, Washington 25, D.C. ATTN: War Plans Div.
1 Director of Research and Development, DCS/D, Headquarters, USAF, Washington 25, D.C. ATTN: Combat Components Div.
2 Director of Intelligence, Headquarters, USAF, Washington 25, D.C. ATTN: AFOIN-IB2
1 The Surgeon General, Headquarters, USAF, Washington 25, D.C. ATTN: Bio. Def. Br., Pre. Med. Div.
1 Asst. Chief of Staff, Intelligence, Headquarters, U.S. Air Forces-Europe, APO 633, New York, N.Y. ATTN: Directorate of Air Targets
1 Commander, 497th Reconnaissance Technical Squadron (Augmented), APO 633, New York, N.Y.
1 Commander, Far East Air Forces, APO 925, San Francisco, Calif. ATTN: Special Asst. for Damage Control
1 Commander-in-Chief, Strategic Air Command, Offutt Air Force Base, Omaha, Nebraska. ATTN: OAWS
1 Commander, Tactical Air Command, Langley AFB, Va. ATTN: Documents Security Branch
1 Commander, Air Defense Command, Ent AFB, Colo.
2 Research Directorate, Headquarters, Air Force Special Weapons Center, Kirtland Air Force Base, New Mexico, ATTN: Blast Effects Res.
1 Commander, Air Research and Development Command, Andrews AFB, Washington 25, D.C.
1 Commander, Air Proving Ground Command, Eglin AFB, Fla. ATTN: Adj./Tech. Report Branch
2 Director, Air University Library, Maxwell AFB, Ala.
8 Commander, Flying Training Air Force, Randolph AFB, Tex. ATTN: Director of Observer Training
1 Commander, Crew Training Air Force, Randolph Field, Tex. ATTN: 2GTS, DCS/O
2 Commandant, Air Force School of Aviation Medicine, Randolph AFB, Tex.
2 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, O. ATTN: WCOSI
2 Commander, Air Force Cambridge Research Center, LG Hanscom Field, Bedford, Mass. ATTN: CRQST-2
3 Commander, Air Force Special Weapons Center, Kirtland AFB, N. Mex. ATTN: Library
1 Commander, Lowry AFB, Denver, Colo. ATTN: Department of Special Weapons Training
1 Commander, 1009th Special Weapons Squadron, Headquarters, USAF, Washington 25, D.C.
2 The RAND Corporation, 1700 Main Street, Santa Monica, Calif. ATTN: Nuclear Energy Division
1 Commander, Second Air Force, Barksdale AFB, Louisiana. ATTN: Operations Analysis Office
1 Commander, Eighth Air Force, Westover AFB, Mass. ATTN: Operations Analysis Office
1 Commander, Fifteenth Air Force, March AFB, Calif. ATTN: Operations Analysis Office
1 Commander, Western Development Div. (ARDC), PO Box 262, Inglewood, Calif. ATTN: WDSIT, Mr. R. G. Weitz
5 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

1 Asst. Secretary of Defense, Research and Engineering, D/D, Washington 25, D.C. ATTN: Tech. Library
1 U.S. Documents Officer, Office of the U.S. National Military Representative, SHAPE, APO 55, New York, N.Y.
1 Director, Weapons Systems Evaluation Group, OSD, Rm 2E1006, Pentagon, Washington 25, D.C.
1 Chairman, Armed Services Explosives Safety Board, D/D, Building T-7, Gravelly Point, Washington 25, D.C.
1 Commandant, Armed Forces Staff College, Norfolk 11, Va. ATTN: Secretary
1 Commander, Field Command, Armed Forces Special Weapons Project, PO Box 5100, Albuquerque, N. Mex.
1 Commander, Field Command, Armed Forces Special Weapons Project, PO Box 5100, Albuquerque, N. Mex. ATTN: Technical Training Group
5 Commander, Field Command, Armed Forces Special Weapons Project, P.O. Box 5100, Albuquerque, N. Mex. ATTN: Deputy Chief of Staff, Weapons Effects Test
11 Chief, Armed Forces Special Weapons Project, Washington 25, D.C. ATTN: Documents Library Branch
1 Commanding General, Military District of Washington, Room 1543, Building T-7, Gravelly Point, Va.
5 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)

ATOMIC ENERGY COMMISSION ACTIVITIES

3 U.S. Atomic Energy Commission, Classified Technical Library, Washington 25, D.C. ATTN: Mrs. J. M. O'Leary (For DMA)
2 Los Alamos Scientific Laboratory, Report Library, PO Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman
5 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: H. J. Smyth, Jr.
3 University of California Radiation Laboratory, PO Box 808, Livermore, Calif. ATTN: Clovis G. Craig
1 Weapon Data Section, Technical Information Service Extension, Oak Ridge, Tenn.
12 Technical Information Service Extension, Oak Ridge, Tenn. (Surplus)

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