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U. S. Atomic Energy Commission

New York Operations Office

Health and Safety Laboratory

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Health and Safety Laboratory

Operation Troll

JOINT PRELIMINARY REPORT

U. S. Atomic Energy Commission

Office of Naval Research

Edited by John H. Harley

U. S. Atomic Energy Commission

New York Operations Office

PRINTED IN USA
PRICE 30 CENTS

Available from the
Office of Technical Services,
U.S. Department of Commerce,
Washington 25, D.C.

April 1956 750 copies

Abstract

Operation Troll was a joint undertaking of the AEC and ONR to evaluate residual radioactivity in the Pacific Ocean a year after the Pacific nuclear tests held in the spring of 1954. The cutter ROGER B. TANEY was assigned to the operation by the US Coast Guard, and measurements were made over a course of 17,419 miles lasting from February 25 to May 3, 1955.

Widespread low-level activity was found in sea water, plankton and fish samples, but none of the levels was high enough to cause concern as a possible hazard. The results do have scientific value, however, and are presented in full as an aid to other studies.

Acknowledgements

Operation Troll was conceived by Mr. Merril Eisenbud, Director of the Health and Safety Laboratory. The basic idea was confirmed and elaborated by Dr. Allyn C. Vine of Woods Hole Oceanographic Institution, and the project presented to the Division of Biology and Medicine for approval.

The general concepts of the operation were discussed at an ad hoc meeting in Washington on January 12, 1955. The following were present:

Dr. A.C. Vine, Woods Hole Oceanographic Institution
Dr. J. Isaacs, Scripps Institution of Oceanography
Dr. T. Folsom, Scripps Institution of Oceanography
Mr. F. Jennings, Scripps Institution of Oceanography
Dr. J. Smith, Office of Naval Research
Mr. J. Kane, Office of Naval Research
Mr. H.D. LeVine, US Atomic Energy Commission.

Drs. Vine and Isaacs were of the opinion that there was a probability that the radioactive water was still contained in the currents and, although reduced in intensity, might well be on the way to Japan. They also expressed the belief that there must be a concentration of activity by the plankton and an additional concentration in the tuna which feed on the plankton in this stream. For this reason, they recommended that the investigation proceed.

The detailed planning was worked out among Mr. James W. Smith and Mr. John J. Kane of the Office of Naval Research, Dr. Warren S. Wooster of the Scripps Institution of Oceanography, Mr. Howard Brown and Dr. Willis R. Boss of Biology and Medicine, and Mr. Eisenbud and Dr. Harley of HASL.

Work at sea was carried out by the following personnel, under the leadership of Dr. Harley:

New York Operations Office, US Atomic Energy Commission

John H. Harley, Chief, Analytical Branch, HASL
Robert S. Morse, Chemist, HASL
Rudolf Anker, Electronics Technician, HASL

Scripps Institution of Oceanography, University of California

Warren S. Wooster, Assistant Research Oceanographer
Robert W. Gilkey, Senior Marine Technician

Applied Fisheries Laboratory, University of Washington

Allyn Seymour, Assistant Director

The officers and men of the TANEY, under the command of Cdr. Albert J. Carpenter, USCG, supplied invaluable assistance throughout the cruise. In particular, the following should be commended:

Cdr. Donald M. Morell, Executive Officer
Cdr. William B. Durham, Chief Engineer
Lt. Mark F. Mitchell, Navigator
Ens. James M. Fournier, Communications Officer
BMS Henry T. Scheiding

The following men served as technicians in the collection and preparation of samples:

BM2 Edward Hall
BM3 Ronald E. Petschlag
SN Marvin L. Fisher
SN Martin Harris

In the preparation, Mr. Harris D. LeVine and his staff of the Instruments Branch, HASL, designed and built the required equipment for radioactivity measurement.

All radiochemical equipment was furnished by HASL. Oceanographic equipment was supplied by the Scripps Institution except for the oceanographic winch which was borrowed from the US Navy Electronics Laboratory, San Diego. Some additional biological collecting equipment was furnished by the Applied Fisheries Laboratory, University of Washington.

OPERATION TROLL

Historical

During May and June of 1954, the Japanese survey ship SHUNKOTSU-MARU made several traverses of Pacific currents to measure the amounts of radioactivity present in sea water and marine life. The Japanese scientists returned to Tokyo on July 7, 1954, and their results were published in "Papers in Meteorology and Geophysics," Miyake, Sugiura and Kameda, Vol. V, Nos. 3-4, 1955.

These particular results were made available to Mr. Merril Eisenbud through the courtesy of Dr. Miyake at the Radiobiology Conference held in Tokyo in November of 1954. Thus, the AEC staffs in the Division of Biology and Medicine and the Health and Safety Laboratory had a chance to study the original data before publication.

The maximum sea water activity* found during the Japanese expedition was about 91,000 d/min/liter, 450 km west of Bikini on June 21, 1954. Over 1000 d/min/liter was found as far as 2000 km WNW of Bikini. According to the Japanese scientists, this activity was in solution, since it passed through a fine filter paper. In addition, samples taken in depth showed activity was present at some locations down several hundred meters.

General consideration of the decay and dispersion of the radioactivity indicated to Mr. Eisenbud that it was possible that measurable activity from the nuclear tests at the Eniwetok Proving Grounds in the Spring of 1954 might still exist in the Pacific early in 1955. An opinion on the oceanographic factors was required and Dr. Allyn C. Vine of the Woods Hole Oceanographic Laboratory was called in as a consultant.

Dr. Vine's estimate of the movement and dispersion of the radioactive material was compatible with previous calculations. From known current distributions and velocities, it was apparent that the activity measured by the SHUNKOTSU-MARU might be detectable in the far-western Pacific early in 1955. Based on these calculations, Operation Troll was designed to attempt the measurement of residual activity in the Pacific Ocean.

On February 1, at a meeting in Washington, Captain Carl G. Bowman of the US Coast Guard made arrangements for use of the cutter TANEY, and February 25 was set as the sailing date.

Operational

Scientific Personnel

The scientific personnel assigned to the operation were Dr. John H. Harley, Chief, Analytical Branch, HASL, responsible for the over-all program and the radiochemical analyses in particular; Dr. Warren Wooster, Scripps Institution of Oceanography, responsible for the oceanographic data and collection of water and plankton samples; Allyn Seymour, University of Washington Applied Fisheries Laboratory, responsible for marine biological work; Robert Gilkey, Scripps Institution of Oceanography, Oceanographic Technician; Robert S. Morse, HASL Chemist; and Rudolph Anker, HASL Electronic Technician.

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*Measurements were made by coprecipitation with ferric hydroxide and barium sulfate. This procedure eliminates the natural K^{40} activity and loses certain fission products, such as Cs and some of the Ru and Nb.

In addition to the scientific group, Coast Guard personnel were used as laboratory technicians to assist in the sampling, processing, and counting.

Radiochemical Laboratory

The Radiochemical Laboratory was set up in the weather-balloon shelter on the observation deck of the ship and counting equipment was placed in the weather office immediately adjoining the laboratory. Ashing was carried out in a muffle furnace set up on the starboard catwalk where natural ventilation usually kept smoke and fumes from being objectionable. These three units are shown in Figures 1, 2, and 3.

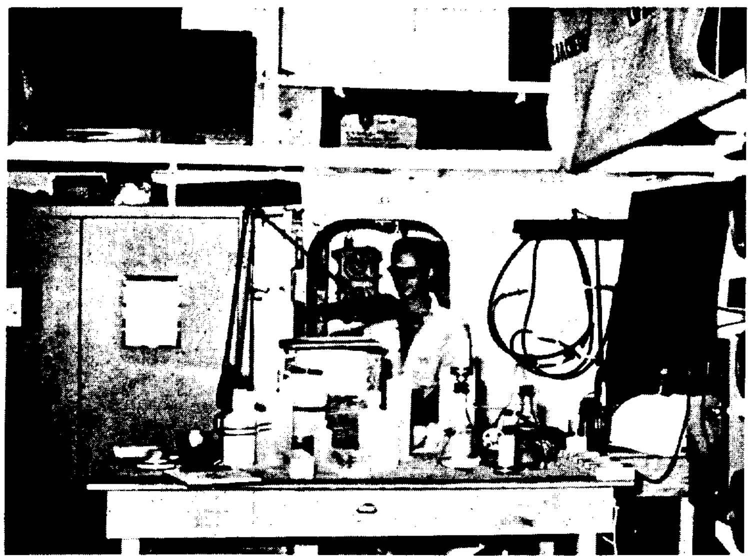

Figure 1. Radiochemical laboratory in the weather-balloon shelter on board the TANEY.

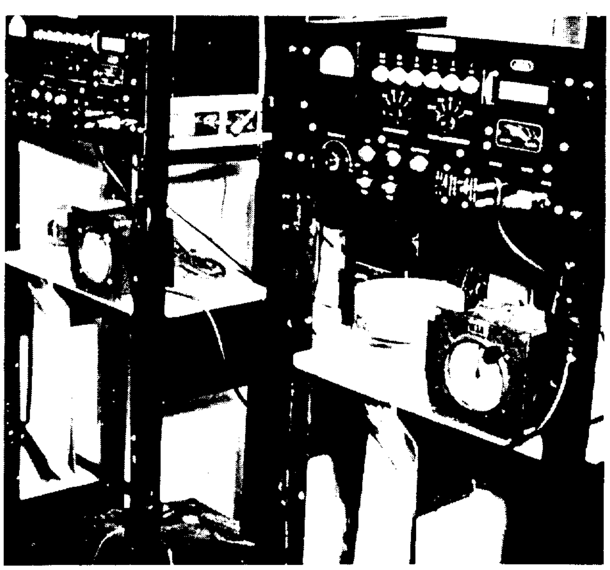

Figure 2. Counting equipment.

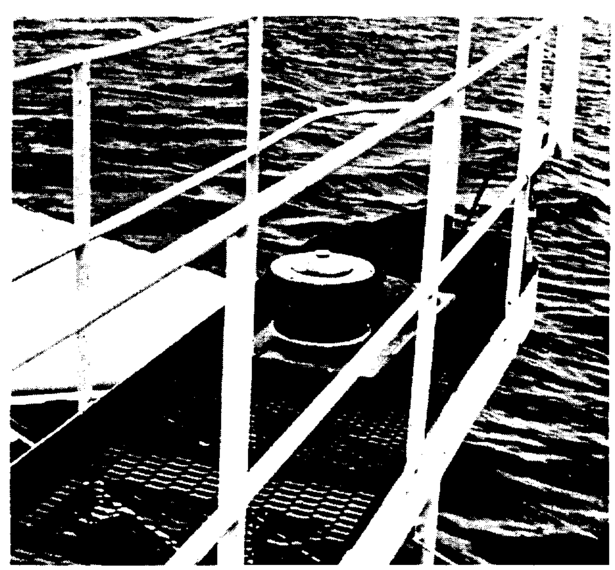

Figure 3. Muffle furnace.

Oceanographic Observations

Hydrographic Stations: Between Kwajalein and Yokosuka, 12 bottle casts to approximately 600 m were made at approximately 180 mile intervals (stations numbered 1, 2, 3, etc., see Figure eight and Appendix A for positions). On these stations, observations were taken at the following approximate depths: 0, 10, 25, 50, 75, 100, 150, 200, 300, 400, 500 and 600 m. On Stations 42 and 45 additional observations at 800, 1000 and 1200 m were taken. On each station at each depth, the following observations were taken:

a) Temperature. Subsurface temperature measurements were taken with protected reversing thermometers. Below 100 m, unprotected reversing thermometers were used to determine depths of observations. Reversing thermometer temperatures are believed to be accurate to $\pm 0.02^{\circ}C$.
b) Salinity. Water samples were saved and subsequently titrated at the Scripps Institution. Salinity values are believed to be accurate to $\pm$ 0.03 percent.
c) Radiochemistry. Water samples were collected for subsequent radiochemical analysis (see below).

Supplementary Stations: After Station 12, supplementary 4-bottle casts to approximately 400 m were made halfway between hydrographic stations (stations numbered 12A, 13A, etc.; see Figure eight and Appendix A for positions). On these stations observations were taken at the following approximate depths: 0 (bucket), 50, 100, 200, 400 m. No thermometers were used and depths were estimated from wire angle.

Bathythermograph Observations: Subsurface temperature measurements to about 250 m were taken every hour (at about 15 mi intervals) while underway, with the bathythermograph.

Surface Temperature: A continuous record of surface temperature was kept by means of a recording thermograph. The thermograph sensing element was located in a well in a sea chest in the engine room.

Biological Collections

Standard Net Tows: On all hydrographic stations, supplementary stations and between each hydrographic station prior to Station 12, standard oblique plankton tows were made. The nets used measured 1 m in diameter at the mouth and about 5 m in over-all length and were constructed of No. 30xxx grit gauze which retains organisms larger than about 0.5-mm diameter. An Atlas-type current meter fastened in the mouth of the net was used to measure the volume of water strained during the haul. Tows were made in the following manner: with the vessel steaming at 1-2 kts, the net was lowered at 50 m/min until 300 m of wire was out, then was retrieved at a steady rate of 30 m/min. It is believed that the collections represent a quantitative measure of zooplankton organisms larger than 0.5 mm present in the upper 200 m of water.

After collection, plankton samples were split, half being retained by Scripps for zoogeographical analysis, a quarter being used for shipboard radiochemical analysis, and a quarter being retained for radiochemical analysis at the Applied Fisheries Laboratory, University of Washington.

Microplankton Tows: After Station 23, on each hydrographic station a short vertical tow was taken with a 17-cm No. 20 net. Although they are nonquantitative, it is believed that the collections represent a sampling of small (larger than 0.1 mm) phytoplankton and zooplankton organisms living in the surface waters. These samples were used in entirety for shipboard radiochemical analysis.

Fish Collections: Although attempts were made to fish from the TANEY, only sharks and flying fish were secured. Three yellowfin (or big-eye) tuna were purchased from a Chinese fishing boat near Moratai Island. Reef fish were collected by means of rotenone poisoning at Truk, Guam, Parece Vela (Douglas Reef) and Okinawa. All fish samples were subjected to radiochemical analysis.

Scintillation Probe

A scintillation probe was designed and built at HASL for continuous monitoring of radioactivity in sea water. A plastic phosphor, 3 in. in diameter and 30 in. long, was coupled to a 3-in. photomultiplier tube. The sensing element, circuitry and batteries were encased in a stainless steel housing about 7 ft long. The signal was carried by a cable to an Esterline-Angus recorder. A special winch allowed the probe to be towed while on course. The assembly is sketched in Figure 4. The winch was mounted on the quarter-deck about 15 ft from the port side where the probe was put into the water. The controlling switches were mounted on a vertical plate attached to the rear of the winch so that the operator had a good view of the operation. The towing cable came off the drum of the winch to a davit extending 6 ft out from the side of the ship. This davit was rigged with a meter block through which the towing cable passed. The probe

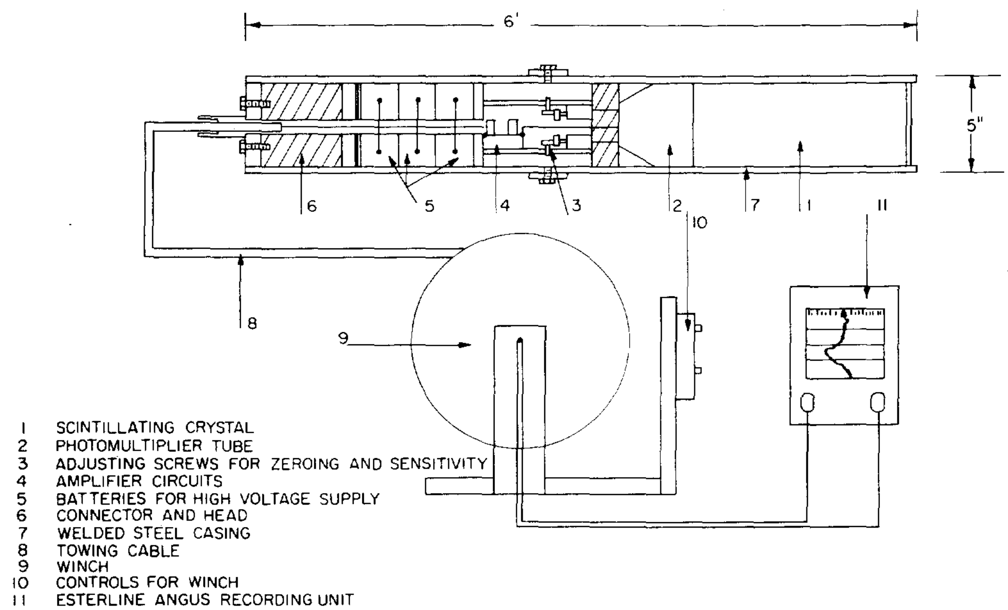

Figure 4. Assembly for the scintillation probe.

was lowered vertically in the water to a depth of about 200 m. As the ship got under way, the probe rode horizontally near the surface of the water almost 200 m astern of the ship. Another davit was set up near the stern of the ship, outboard, to prevent the towing cable from fouling the propellers.

Course and Itinerary

On February 25, 1955, the US Coast Guard Cutter TANEY departed from San Francisco for its survey of the Pacific. The track is shown in Figure 5.

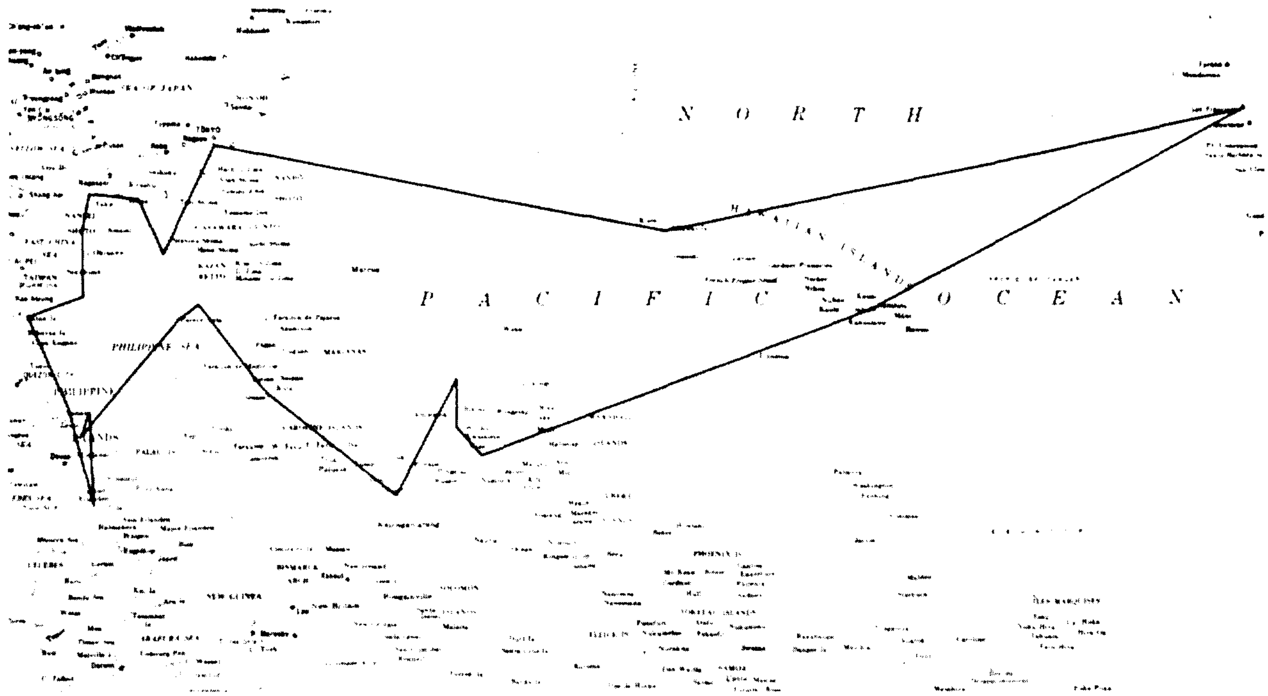

Figure 5. Track of the TANEY during Operation Troll.

The TANEY proceeded west-south-west on a straight course, and arrived at Honolulu on March 5. Two days were spent in refueling and rigging the ship for the survey. On March 7 the ship continued from Honolulu on the same west-south-west course. The survey of water and plankton samples began on March 9 at 12° N, 176° E and continued until arrival at Kwajalein on March 12. The TANEY refueled and on March 13 left Kwajalein to traverse the waters about Eniwetok and Bikini. The first samples of flying fish were obtained here in addition to the scheduled samples. On March 20 a small boat was put off and obtained samples of reef fish and coral from one of the northern islands of Truk Atoll.

The survey continued to Guam where the TANEY arrived on March 22. During March 22 and 23, reef fish were collected, and a preliminary report of the survey was written and sent to HASL. From Guam, the course was northwest to about 22° N, 139° E, then southwest. A collection of fish and invertebrates was made at Douglas Reef on March 27. From the Phillipine Coast, the ship cruised south to Moratai, then returned northward to Okinawa. Here, another collection of reef fish was made.

On April 9 the TANEY departed from Okinawa and its course lay north toward Japan. At Yokosuka, Japan, where the TANEY arrived on April 14, the scientists aboard went ashore to attend an informal meeting in Tokyo with some members of the Japanese Science Council to discuss some of the data from Operation Troll.

On April 21, the TANEY departed from Yokosuka, Japan, on an eastward course toward San Francisco. Samples of surface water were taken until the ship arrived at San Francisco on May 3.

Analytical Procedures

The analytical procedures were designed to be carried out aboard ship and, therefore, had to be extremely simple. All activity measurements were made on 2-in.

plastic ring and disc holders with a 2-in. flat Anton Geiger tube in a lead shield. The background of these counters was higher than expected and precision of measurement was therefore reduced. In spite of low precision, the data show considerable internal consistency and the average of group samples should be reliable.

Sea Water Analyses

Sea water samples were transferred from the Nansen bottles directly to polyethylene bottles. A 200-ml aliquot was measured in a graduate and poured into a 400-ml polyethylene beaker. A sufficient quantity of saturated sodium carbonate was added to precipitate all the calcium present and the precipitate collected on a 47-mm glass fibre filter. The precipitate and paper were covered with Mylar film of about 0.0005 in. thickness and mounted on a plastic ring and disc holder.

Tests were made to determine if potassium, normally present in sea water to the extent of 600-700 d/min/liter would co-precipitate. Normal potassium was added at a level of 6000 d/min/200 ml and the standard procedure carried out. No measurable increase in activity was found. It is believed that the interference of potassium is negligible.

One of the major constituents of mixed fission products more than a year old is cesium which should not be co-precipitated with calcium carbonate. Tests were run in the laboratory to check possible co-precipitation but as in the case of potassium, no detectable cesium was found.

The large amount of precipitate obtained in this procedure causes a considerable loss in measured activity by self-absorption. The data shown in Figure 6 were obtained by precipitating the calcium completely in various volumes of sea water after the addition of mixed fission products. Figure 6 indicates that self-absorption reduced the activity by a factor of 2. Comparison of the value extrapolated to zero absorption (3450 d/min) with that obtained by direct measurement of the spike (4500 d/min) indicates that 23 percent of the activity escapes precipitation.

The mixed fission products used in the spike were obtained from the Oak Ridge pile and were approximately 18 months old. The percentage of Cs^{137}-Ba^{137} activity in material of this age should be 5.4 percent. Other isotopes in aged fission products that partially escape precipitation are Ru^{106}-Rh^{106} and Nb^{95}. Their percentage in the Oak Ridge material should be 6.4 and 5.3 percent, respectively. Pm^{147}, at 9.8 percent, would not be counted efficiently. The total which might escape precipitation or counting could be as high as 27 percent, compared to 23 percent found.

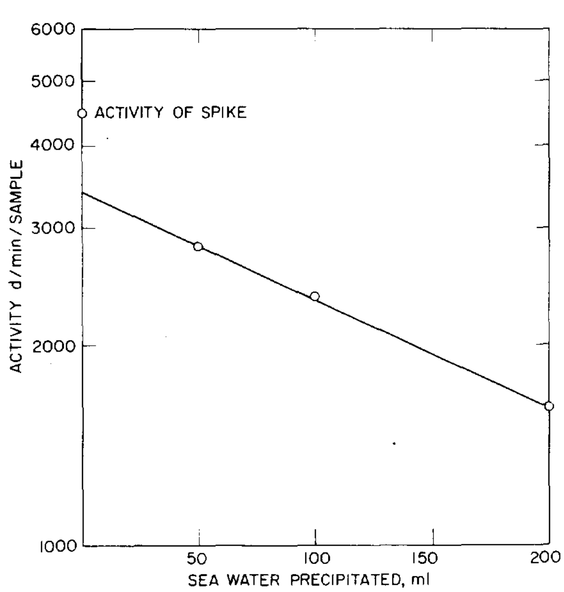

Figure 6.

Plankton Analyses

The plankton sample obtained from each net tow was quartered and one-quarter used for activity measurement. This was ordinarily contained in about 200 ml of water. The plankton was filtered off on a 47-mm Millipore filter and dried at 110°C. The dried sample was covered with Mylar and mounted on a plastic ring and disc. In each case the weight of the wet sample was estimated to the nearest 10th gram, on a Scripps electronic shipboard balance. The potassium activity of plankton is at most 5 d/min/g of wet material and should be considerably lower. No correction was made for this natural activity.

One-half of the original sample was retained by Scripps for biological examination and one-quarter was taken by the University of Washington for activity measurement in their laboratories.

Analyses of Fish Samples

Fish samples were identified and dissected when necessary by the marine biologist. Samples were ashed at 600°C in nickel crucibles and weighed portions of the ash taken for analysis. The ash was slurried with about 500 ml of dilute sodium carbonate solution in an attempt to remove the natural potassium activity and the residue filtered off on fibre glass. The samples were covered with Mylar and mounted on plastic rings and discs for counting.

When treated samples were analyzed by HASL by beta absorption techniques, it was apparent that the major portion of the activity was due to the natural potassium in most cases. This indicated poor separation by the method described and a number of samples were reanalyzed by dissolving the ash and reprecipitating carbonates. In addition, several samples were analyzed for individual fission products at the HASL laboratory.

Samples of all reef fish, flying fish and other biological specimens were taken back to the Applied Fisheries Laboratory for activity measurement. There, individual tissues were ashed and counted.

Counting Procedures

The beta counters described had an average background count of 18 to 20 cts/min. The procedure on all samples consisted of running alternate periods of 30 min on background and 60 min on the sample. The average background for the period before and after the sample reading was subtracted from the sample count to give the net count. The efficiency of the counters was measured with half-gram samples of potassium carbonate mounted and measured under the same conditions as the sample except that a 10-min counting period was used. The K^{40} activity was taken as 492 d/min/half-gram. This standardization is reasonable for mixed fission products, since the average energies of K^{40} and of MFP are very close. The average efficiency of the counters was 20 percent.

The counting statistics of all samples of one type are roughly equivalent. For water samples, the Poisson standard deviation is one count per minute per sample which becomes 25 d/min/liter. Plankton and fish samples were weighed, and in most cases, one gram samples were taken. This gives a standard deviation of 5 d/min/g unless stated otherwise in the results.

The only possibility of improving the counting statistics is the development of low background counters. It is not possible to handle larger samples of material nor is a counting time greater than one hour practical for field use. If a 2-in. diameter Geiger tube with a background of 10 cts/min were available, the standard deviation on a water sample would be reduced to 15 d/min/liter while a 5-cts/min background would reduce the standard deviation to 10 d/min/liter. It is apparent that even a marked background improvement does not eliminate the problems of low level counting. A reliable estimate is obtained only by combining results on a relatively large number of samples.

Water Data

The water samples collected in Nansen bottles were transferred to polyethylene bottles for storage until analysis. Only half of the samples from each station could be analyzed immediately aboard ship because of limited facilities. Therefore, alternate samples from the 12 Nansen bottles were analyzed at the time and the others were analyzed later in the course or in the New York laboratory. All the samples from the intermediate stations were analyzed immediately, while the surface samples taken with each BT measurement were analyzed in port, or upon return to the United States.

The analytical procedure suffers from poor counting statistics for most of the samples taken. Therefore, a high degree of confidence cannot be placed in individual samples and conclusions should be drawn only on the basis of the broad pictures involving the average of many samples. The complete water data are given in Appendices B and C which cover the surface samples and Appendix D which covers the samples taken at various stations. The calculations show some negative values, that is, the sample count was less than the current background count. In all cases, these negative values have been used in averaging.

As Miyake showed, most of the activity in sea water samples is due to material in solution. Although the zooplankton activity appears to be 300 times the activity of sea water per unit weight, the zooplankton organisms are present in great dilution (2 to 56 g per 10^6 liters on Troll stations) and the Nansen bottle is a notoriously poor sampler of zooplankton organisms. Filtration of 83 sea water samples through a Millipore filter (0.5-μ pore size) showed on the average 9.6 percent of the activity retained by the filter. This activity can probably be attributed to microphytoplankton organisms which do not evade the Nansen bottle and appear to have a very high specific activity.

The average surface activity along the entire track was 93 d/min/liter, with a maximum of 450 d/min/liter. Low values were found on the return trip from Japan, the average for 29 values between Yokosuka and Midway being 49 d/min/liter, the

Table 1

Distribution of Activity in Sea Water

	Surface Samples*		Station Samples**		
Stations	No. of Values	Average	No. of Values	Average	Region
4-15	109	49	144	64	North Equatorial
16	9	72	11	88	Transition
17-21	46	118	60	95	Dubious
22-27	63	115	71	110	North Equatorial
28-31	48	107	48	72	Counter Current
32-33	24	134	24	74	North Equatorial
34-38	54	146	60	89	Kuroshio
39-40	17	166	24	70	Cold Area
41-44	45	45	48	45	Kuroshio
45-46	15	13	24	40	Cold Area
Total	430	93	514	78	

*All surface samples at stations and BT stops.
**Depth samples to 600 m, 12 per cast.

Plankton Data

The high specific activity of plankton compared with sea water makes it a simple measure of the distribution of activity (see Figure 9). It is not completely quantitative; the amount of water swept out is not accurately known, nor are the source and history of any sample known. However, there is definite correlation between the macroplankton and sea water samples.

A comparison between the results obtained on corresponding samples of macroplankton measured at the Applied Fisheries Laboratory and HASL is shown in Appendix F. Statistical tests show the two sets of values to be indistinguishable. Comparison of Troll samples with comparable samples from other areas is shown in Appendix I.

Table 2

Macroplankton Activity

Based on one gram wet weight

Station	Total d/min	No. of Samples	Ave d/min/g
0A-3A	170	7	24
4-15A	740	24	31
16-16A	111	2	56
17-21A	350	10	35
22-27A	615	11	56
28-31A	288	7	41
32-33A	220	4	55
34-38A	379	8	47
39-40A	48	3	16
41-44A	92	7	13
45-46A	10	2	5
	3023	85	35.6

A few samples of microplankton were taken with a 17-cm No. 20 net dragged from 20 m to the surface. These samples showed even higher specific activity than the macroplankton, as shown in Appendix G.

A breakdown of plankton samples by current region is shown in Table 2, corresponding to Table 1 for water samples.

The only marked change is the drop after Station 38A; it corresponds more closely to the change in surface activity than the depth activity.

Radiochemical analysis of the plankton showed 80-90 percent of the activity to be Ce^{144} with its Pr^{144} daughter. The remainder was chiefly Sr^{90}, but small amounts of other isotopes may be present. Cs^{137} should be retained in the procedure, but was not detected.

Fish Data

None of the edible portions of fish collected on Operation Troll showed activity levels that would be of concern. In addition, the activity levels were so low that radiochemical analyses were not possible.

The controlling activity in the hazard from mixed fission products is the Sr^{90}-Y^{90} pair. The maximum permissible level for food may be taken as that for drinking water, 8×10^{-7} μc Sr^{90}-Y^{90} per milliliter or per gram. This is equivalent to 2×10^{-5} μc MFP/g at one year, or 45 d/min/g. For populations, the maximum permissible level is considered to be 1/10 of the industrial level, or 4.5 d/min/g. This is about 500 d/min/g of ash, the basis of reporting used here.

For the analyses of fish reported in Appendix H, the maximum activity found in tuna muscle was 132 d/min/g ash. However, these analyses were in error due to incomplete removal of potassium. Table 3 shows comparative values of shipboard and laboratory analyses for mixed fission products.

The maximum values from the laboratory measurements for tuna fish are 3.5 d/min/g ash, or less than 1 percent of the conservative permissible level.

Table 3

Comparison of Shipboard and Laboratory Analyses for MFP

Sample No.	Type	d/min/g Ash TANEY	HASL
547	Tuna I - Skin	0.2	0±0.5
548	- White Muscle	94	3.6±0.6
549	- Red Muscle	132	3.4±0.6
550	- Bone	6.2	1.1±0.5
553	Tune II - Skin	7	0.5±0.5
568	- White Muscle	69	2.3±0.6
554	- Red Muscle	--	3.5±0.5
555	- Bone	2.4	1.4±0.5
63	Shark - Cartilage	45	11±0.5
158	Shark - Cartilage	5	8±1.2
567	Remora - Entire	18	10±0.4

Although the activity level was too low for accurate radiochemical analysis, the Sr^{90} level in the edible portion was shown to be less than 2 percent of the permissible level for this isotope. This estimate of hazard is of course based on the fish as the only food intake.

The results obtained on individual tissues of fish taken on Troll upon analysis at the Applied Fisheries Laboratory are shown in Appendix I. The Troll fish collection included 19 flying fish, 6 shark, 3 yellowfin tuna and reef fishes from Truk, Guam, Douglas Reef and Okinawa. Invertebrates and algae were also collected with the reef fishes and on four occasions from floating objects at sea.

Values in d/min/g(wet) for samples of these organisms and for comparable samples from other areas are also included in Appendix I. No correction has been made for potassium. The following conclusions were drawn from these data:

1. Values for plankton, fish, invertebrates and algae were usually several to many times greater than comparable samples from Puget Sound, an area considered to be free of fission product contamination.

2. The contamination was considerably less than at Bikini or Eniwetok, usually by a factor of 10 to 20 or greater.

3. Of the reef collections, the highest average values were obtained at Guam, the lowest at Okinawa, with Douglas Reef (Parece Vela) and Truk intermediate.

Probe Measurements

No significant measurements were made with the probe, since the activity levels encountered were generally below the sensitivity of the instrument. In addition, operational difficulties allowed use of the probe for only small portions of the track. These flaws in the experimental model can be corrected, and it is felt that the probe would be of considerable value in assessing sea water activity shortly after a detonation.

Probe operations were complicated by the possibility of tangling if two cables were over the side at the same time. Therefore, the probe had to be brought on deck at each station and tow. This extra handling plus the relative fragility of the conducting cable required considerable time and resulted in many cable failures.

Five men were required for the operation: one officer in phone contact with the bridge and engine room regulated course and speed to keep the probe clear of the screws, one HASL man operated the winch and another the winch brake, the boatswain handled the lines to the cable from the boom and brought the probe aboard with the help of a seaman. The meter block had to be removed from the davit and the hydrographic cable installed for Nansen sampling and plankton tows. The removal and replacement of the probe required about 45 min.

From the winch drum, the cable went through a meter wheel block on the davit, and was held clear of the port screw by a boom near the stern. About 150-200 m of cable were required to give an estimated probe depth of 5-10 ft when cruising at 17 knots. During bathythermograph measurements, the probe sank somewhat (speed 3-4 knots) and gave a lower reading on the chart. Most of the problems encountered would not arise in continuous monitoring at slower speeds.

Conclusions

1. Sea water and plankton samples show the existence of widespread low-level activity in the Pacific Ocean. Water activity ranged from 0-570 d/min/liter and plankton from 3-140 d/min/g wet weight.
2. There is some concentration of the activity in the main current streams, such as the North Equatorial Current. The highest activity was off the coast of Luzon, averaging 190 d/min/liter down to 600 m (April 1, 1955).
3. Analyses of fish indicate no activity approaching the maximum permissible level for foods. The highest activity in tuna fish was 3.5 d/min/g ash, less than 1 percent of the permissible level.
4. Measurements of plankton activity offer a sensitive indication of activity in the ocean.
5. Similar operations would be valuable in assessing the activity from future tests and in gathering valuable data for oceanographic studies.

APPENDIX A

Troll Station List

Station	Date	Lat. (N)	Long. (E)	Station	Date	Lat. (N)	Long. (E)
0A	9 III 55	13°01'	179°09'	22	28 III 55	15°55.5'	132°27'
1	10 III 55	11°58'	176°08'	22A	28 III 55	14°47'	131°21'
1A	10 III 55	10°57'	173°26.5'	23	28 III 55	13°40'	130°15.5'
2	11 III 55	9°58'	170°36'	23A	28 III 55	12°38'	129°16.5'
2A	13 III 55	8°41'	167°00'	24	29 III 55	11°40'	128°19'
3	13 III 55	8°20'	165°26'	24A	29 III 55	10°19'	127°21'
3A	13 III 55	7°54'	163°54'	25	29 III 55	9°14'	126°30.5'
4	14 III 55	9°23'	163°36'	25A	30 III 55	10°19.5'	126°59'
4A	14 III 55	10°48'	163°20.5'	26	30 III 55	11°36.5'	127°27'
5	14 III 55	12°15.5'	163°06.5'	27	30 III 55	9°01'	127°41.5'
5A	15 III 55	13°37'	162°59'	27A	31 III 55	7°37'	127°56'
6	15 III 55	15°02'	163°04'	28	31 III 55	6°09'	128°09.5'
6A	15 III 55	13°43'	162°20'	28A	31 III 55	4°28'	128°20.5'
7	16 III 55	12°17'	161°28'	29	1 IV 55	3°01'	128°28.5'
7A	16 III 55	10°52.5'	160°35'	30	1 IV 55	5°58'	127°22.5'
8	16 III 55	9°29'	159°45.5'	30A	1 IV 55	7°28'	126°48.5'
8A	17 III 55	8°12'	159°10'	31	2 IV 55	8°57.5'	126°29'
9	17 III 55	6°49'	158°32'	31A	2 IV 55	10°35'	126°17.5'
9A	17 III 55	5°32'	157°52.5'	32	3 IV 55	12°00'	126°03'
10	18 III 55	4°00'	157°00'	32R	3 IV 55	12°23'	125°51'
10A	18 III 55	4°55'	155°54'	32A	3 IV 55	13°37'	125°10'
11	19 III 55	5°43.5'	154°48'	33	3 IV 55	15°16.5'	124°17'
11A	19 III 55	6°33'	153°46'	33A	4 IV 55	16°50'	123°22.5'
12	19 III 55	7°29'	152°27.5'	34	4 IV 55	18°30'	122°29.5'
12A	20 III 55	8°35'	150°49'	35	4 IV 55	20°01'	121°54'
13	20 III 55	9°31'	149°46.5'	35A	5 IV 55	20°42.5'	123°29'
13A	20 III 55	10°28'	148°36'	36	5 IV 55	21°30'	124°44.5'
14	21 III 55	11°25'	147°26'	36A	6 IV 55	22°17'	126°12'
14A	21 III 55	12°19'	145°55'	37	6 IV 55	22°59'	127°36'
15	22 III 55	13°25.5'	144°31'	37A	6 IV 55	24°23.5'	127°33'
15 (Repeat)	24 III 55	13°25'	144°31.5'	38	6 IV 55	25°46.5'	127°29'
15A	24 III 55	14°28'	143°47'	38A	9 IV 55	27°39'	127°39.5'
16	24 III 55	15°34'	143°00.5'	39	9 IV 55	29°34'	128°14'
16A	24 III 55	16°43'	142°10.5'	40	10 IV 55	31°10'	128°48'
17	25 III 55	17°49.5'	141°25.5'	40A	10 IV 55	30°55'	130°02'
17A	25 III 55	18°38'	140°52'	41	10 IV 55	30°57.5'	131°42'
18	25 III 55	19°55.5'	139°59'	41A	10 IV 55	29°53.5'	132°45'
18A	26 III 55	21°11'	139°09'	42	11 IV 55	28°19'	134°02.5'
19	26 III 55	22°12'	138°26.5'	43	11 IV 55	27°00'	135°01'
19A	26 III 55	21°13.5'	137°12'	43A	11 IV 55	28°28'	135°52'
20	26 III 55	20°15'	136°01'	44	12 IV 55	29°55'	136°29'
20A	27 III 55	19°03'	135°08'	44A	12 IV 55	31°17'	137°29'
21	27 III 55	17°59'	134°24'	45	13 IV 55	33°05'	138°09'
21A	27 III 55	16°57.5'	133°24.5'	46	13 IV 55	34°21.5'	138°29'

APPENDIX B

Surface Samples, Kwajalein to Yokosuka

Date	Hour	d/min/liter
March 11	2240	30
12	0030	18
13	0030	130
	Net 2A	130
	0230	-
	0330	66
	0430	63
	0530	42
	0630	(-9)
	0730	120
	0830	100
	Station 3	60
	1230	(-15)
	1330	33
	1430	96
	1530	(-39)
	1630	100
	1800	84
	Net 3A	75
	1930	42
	2030	63
	2130	78
	2230	48
	2330	69
March 14	0030	-
	Station 4	36
	0530	-
	0630	69
	0730	48
	0830	-
	0930	39
	1030	6
	1130	36
	Net 4A	63
	1330	-
	1430	-
	1530	93
	1630	(-39)
	1730	78
	1830	30
	1930	110
March 14	Station 5	51
	2230	93
	2330	180
March 15	0030	-
	0130	(-45)

Date	Hour	d/min/liter
	0230	(-54)
	0330	30
	0430	(-60)
	Net 5A	170
	0630	78
	0730	(-39)
	0830	
	0930	
	1030	-
	1130	
	1230	
	1330	
	Station 6	66
	1630	
	1730	-
	1830	
	1930	
	2030	
	2130	
	Net 6A	33
	2330	
March 16	0030	
	0130	
	0230	
	0330	
	Station 7	66
	0730	
	0830	
	0930	
	1030	
	1130	
	1230	
	Net 7A	(-24)
	1430	-
	1530	
	1630	
	1730	
	1830	
	1930	
	Station 8	66
	2230	-
	2330	
March 17	0030	33
	0130	33
	0230	(-100)

Date	Hour	d/min/liter
	Net 8A	30
	0330	(-24)
	0530	57
	0630	160
	0730	6
	0830	(-51)
	0930	-
	1030	33
	Station 9	87
	1330	0
	1430	0
	1530	110
	1630	18
	1730	90
	Net 9A	72
	2030	(-45)
	2130	-
	2230	-
March 18	0150	-
	0230	6
	0530	96
	0630	-
	0730	30
	0830	63
	Station 10	(-39)
	1330	66
	1430	18
	1530	(-24)
	1630	(-60)
	1730	48
	1830	190
	Net 10A	54
	2030	6
	2130	6
	2230	-
	2330	0
March 19	0030	15
	0130	(-24)
	Station 11	
	0430	(-15)
	0530	18
	0630	0
	0730	33
	0830	
	Net 11A	51
	1130	-
	1230	54
	1330	(-66)
	1430	33
	1530	69
	1730	(-15)

Date	Hour	d/min/liter
	Station 12	81
	2130	-
March 20	0330	-
	0430	21
	0530	-
	0630	-
	0730	54
	0830	27
	Net 12A	100
	1030	-
	1130	(-9)
	1230	110
	1330	150
	1430	-
	Station 13	75
	1830	140
	1930	100
	2030	87
	2130	9
	2230	120
March 21	Net 13A	90
	0130	-
	0230	69
	0330	99
	0430	84
	0545	93
March 21	Station 14	250
	0830	-
	0930	-
	1030	69
	1130	6
	1230	(-39)
	1330	-
	1430	-
	Net 14A	150
	1730	66
	1830	0
	1930	81
	2030	48
	2130	81
	2230	57
	Station 15	
	Station 15R	
March 24	0430	130
	0530	72
	0630	87
	0730	100
	0830	150
	Net 15A	140
	1030	90

Date	Hour	d/min/liter
	1130	63
	1230	-
	1330	27
	1430	-
	Station 16	84
	1730	87
	1830	60
	1930	150
	2030	140
	Net 16A	(-60)
	2330	200
March 25	0030	180
	0130	180
	0230	160
	Station 17	300
	0630	-
	0730	160
	0830	78
March 25	Net 17A	24
	1130	160
	1230	140
	1330	120
	1430	190
	1530	110
	Station 18	230
	1930	-
	2030	190
	2130	-
	2230	30
	2330	130
	Net 18A	250
March 26	0230	110
	0330	66
	0430	(-30)
	0530	63
	Station 19	160
	0830	140
	0930	75
	1030	-
	1130	110
	1230	-
	Net 19A	(-15)
	1530	-
	1630	48
	1730	87
	1830	60
	1930	-
	Station 20	160
March 27	0330	120

Date	Hour	d/min/liter
	0430	81
	0530	39
	0630	21
	0730	63
	Net 20A	160
	1030	-
	1130	100
	1230	130
	1330	21
March 27	Station 21	140
	1630	130
	1730	200
	1830	51
	1930	93
	Net 21A	230
	2230	170
	2330	180
March 28	0030	210
	0130	180
	0230	72
	Station 22	72
	0530	130
	0630	260
	0730	99
	0830	57
	Net 22A	210
	1130	
	1230	66
	1330	0
	1430	87
	1530	160
	Station 23	360
	1830	100
	1930	200
	2030	33
	2130	170
	Net 23A	160
March 29	0040	140
	0130	140
	0230	69
	0330	200
	Station 24	150
	0630	96
	0730	30
	0830	96
	1030	120
	1130	99
	Net 24A	130
	1430	130

Date	Hour	d/min/liter
	1530	120
	1630	160
	1730	48
March 29	Station 25	240
	2030	130
	2130	39
	2230	15
	2330	(-39)
March 30	0030	75
	Net 25A	210
	0230	96
	0330	93
	0430	(-39)
	0530	180
	0630	48
	0730	180
	Station 26	48
	1030	100
	1130	140
	1230	110
	1330	170
	1430	78
	1530	220
	1630	42
	1730	63
	Station 27	27
	2130	-
	2230	72
	2330	15
March 31	0050	-
	0130	90
	Net 27A	150
	0330	130
	0430	150
	0530	39
	0630	39
	0730	290
	0830	51
	Station 28	260
	1130	200
	1230	160
	1330	150
	1430	120
	1530	0
	1630	(-39)
March 31	Net 28A	6
	1930	33
	2030	110
	2130	(-84)
	2230	(-39)
	2330	(-75)

Date	Hour	d/min/liter
April 1	Station 29	130
	0230	24
	0330	6
	0430	-
	0530	150
	0630	48
	0730	-
	0830	100
	0930	54
	1030	-
	1130	-
	1230	120
	1330	96
	1430	-
	Station 30	160
	1730	-
	1830	230
	1930	63
	2030	150
	2130	110
	2230	120
April 2	Net 30A	100
	0130	69
	0230	240
	0330	81
	0430	290
	0530	220
	0630	160
	0730	100
	Station 31	90
	1130	-
	1230	160
	1330	-
	1430	190
	1530	180
	1630	99
April 2	Net 31A	120
	1930	200
	2030	-
	2130	84
	2230	130
	2330	69
April 3	0030	-
	Station 32	120
	0330	75
	Station 32R	190
	0545	-
	0630	130
	0730	24
	0830	-
	0930	84

Date	Hour	d/min/liter
	Net 32A	-
	1230	(-9)
	1330	42
	1430	72
	1530	190
	1630	180
	1730	170
	1830	270
	Station 33	260
	2130	-
	2230	290
	2230	290
	2330	290
April 4	0030	21
	0130	140
	0230	87
	Net 33A	140
	0430	180
	0530	200
	0630	99
	0730	-
	0830	270
	0930	210
	1030	240
	Station 34	270
	1330	-
	1430	270
	1530	-
April 4	1630	84
	1730	230
	1830	0
	1930	180
	2030	-
	Station 35	230
April 5	0030	45
	0130	90
	0230	140
	0330	160
	0430	220
	0530	180
	0630	130
	0730	160
	Net 35A	240
	0930	220
	1030	120
	1130	120
	1230	99
	1330	200
	Station 36	450
	1830	-
	1930	170
	2030	290
	2130	160
	2230	260
	Net 36A	170
April 6	0130	190
	0230	(-54)
	0330	51
	0430	260
	0530	(-75)
	Station 37	180
	0830	-
	0930	57
	1030	260
	1130	220
	1230	93
	Net 37A	(-24)
	1530	72
	1630	160
	1730	(-9)
	1830	-
	1930	66
	Station 38	54
April 9	0130	-
	0230	120
	0330	30
	0430	(-30)
	0530	84
	Net 38A	110
	0830	84
	0930	110
	1030	210
	1130	110
	1230	220
	1330	380
	Station 39	110
	1830	-
	1930	190
	2030	120
	2130	180
	2230	150
	2330	9
April 10	Station 40	230
	0230	250
	0330	280
	0430	57
	Net 40A	150
	0730	36
	0830	110
	0930	93

Date	Hour	d/min/liter	Date	Hour	d/min/liter
	1030	110		Net 43A	180
	1130	-		2330	18
			April 12	0030	(-45)
	Station 41	90		0130	200
	1530	250		0230	-
	1630	87		0330	160
	1730	15		0800	100
	1830	24			
	1930	72		Station 44	0
				1130	110
	Net 41A	230		1230	(-99)
	2230	0		1330	(-30)
	2330	93		1430	0
April 11	0030	(-60)		1530	6
	0130	(-270)		1630	24
	0230	30			
	0330	(-45)		Net 44A	140
	0430	(-39)		1930	6
				2030	66
April 11	Station 42	48		2130	(-45)
	0830	0		2230	(-15)
	0930	30		2330	(-75)
	1030	24	April 13	0030	30
	1130	-		0130	(-84)
	1230	210		0230	6
	1330	42			
				Station 45	72
	Station 43	96		0630	(-69)
	1630	140		0730	36
	1730	(-51)		0830	(-24)
	1830	120		0930	81
	1930	30		1030	30
	2030	(-130)			
	2130	(-130)		Station 46	180

APPENDIX C

Surface Samples, Yokosuka to Alameda

Sample No.	Lat.	Long.	d/min/liter	Sample No.	Lat.	Long.	d/min/liter
1	34°44'	140°17'	0	39	29°55'	174°45'	120
2	33'	141°31'	45	40	58'	172°50'	42
3	19'	143°10'	15	41	30°26'	171°21'	81
4	12'	53'	(-9)	42	54'	170°29'	66
5	05'	144°54'	0	43	31°19'	169°06'	39
6	33°55'	146°11'	No sample	44	38'	168°37'	(-9)
7	48'	147°22'	110	45	32°02'	167°08'	12
8	36'	148°41'	39	46	19'	166°14'	20
9	22'	150°02'	0	47	42'	164°30'	(-15)
10	13'	151°17'	75	48	33°07'	163°10'	69
11	05'	152°28'	(-15)	49	31'	161°54'	110
12	32°47'	153°47'	6	50	57'	160°38'	84
13	34'	155°09'	0	51	34°31'	159°20'	84
14	27'	156°18'	No sample	52	33'	158°00'	24
15	16'	158°37'	90	53	51'	156°40'	33
16	5'	57'	110	54	35°03'	155°20'	9
17	31°56'	159°52'	48	55	27'	153°56'	33
18	39'	161°04'	24	56	42'	152°44'	0
19	04'	162°20'	(-9)	57	58'	151°35'	110
20	30°58'	163°20'	90	58	36°16'	150°11'	54
21	39'	164°27'	84	59	27'	148°45'	(-9)
22	37'	165°43'	99	60	36'	147°11'	(-75)
23	23'	167°00'	160	61	48'	145°55'	81
24	12'	168°06'	170	62	37°00'	144°28'	39
25	03'	169°22'	96	63	14'	143°03'	15
26	29°51'	170°36'	36	64	22'	141°37'	39
27	40'	171°50'	0	65	28'	140°08'	(-9)
28	29'	173°04'	75	66	23'	139°00'	39
29	10'	174°13'	110	67	28'	137°12'	(-39)
30	28°53'	175°23'	(-39)	68	31'	136°06'	(-75)
31	47'	176°34'	36	69	34'	134°40'	(-15)
32	29'	177°45'	(-30)	70	38'	133°11'	6
33	24'	178°59'	(-9)	71	42'	131°43'	Lost
34	17'	179°29'	6	72	45'	130°14'	"
35	11'	178°35'	54	73	42'	128°42'	"
36	08'	177°30'	100	74	42'	127°34'	"
37	32'	176°23'	120	75	41'	126°04'	"
38	29°02'	175°47'	160	76	42'	124°30'	"

Stations	Sample No.	Depth, m	d/min/liter
	260	281	-
	261	401	54
	262	506	63
	263	621	160
15A	265	0	140
	266	53	180
	267	105	100
	268	199	100
	269	391	(-24)
16	275	0	84
	276	11	-
	277	32	78
	278	63	130
	279	90	180
	280	127	160
	281	189	78
	282	247	0
	283	361	110
	284	473	63
	285	596	0
	286	722	90
16A	290	0	(-60)
	291	47	160
	292	92	160
	293	169	(-15)
	294	327	78
17	296	0	300
	297	10	270
	298	30	260
	299	61	100
	300	86	130
	301	120	100
	302	177	9
	303	236	120
	304	352	69
	305	461	(-72)
	306	581	87
	307	707	90
17A	309	0	24
	310	58	24
	311	112	30
	312	217	42
	313	415	9
18	315	0	230
	316	10	120
	317	29	84
	318	54	93
	319	78	69
	320	106	84
	321	133	170
	322	199	60
	323	296	0
	324	398	48
	325	500	(-36)
	326	612	110
18A	328	0	250
	329	60	9
	330	118	84
	331	229	0
	332	442	18
19	334	0	160
	335	10	150
	336	28	110
	337	53	93
	338	78	120
	339	105	36
	340	154	(-110)
	341	204	(-18)
	342	306	100
	343	410	18
	344	514	60
	345	632	0
19A	348	0	-15
	349	56	100
	350	113	(-140)
	351	213	0
	352	421	0
20	354	0	160
	355	11	160
	356	32	190
	357	59	87
	358	85	140
	359	117	84
	360	172	100
	361	226	0
	362	337	150
	363	349	(-45)
	364	559	120
	365	674	30
20A	367	0	170
	368	53	110
	369	105	18
	370	199	110
	371	391	39
21	373	0	140
	374	10	230
	375	31	160
	376	57	66
	377	83	190
	378	114	72
	379	168	100
	380	222	45
	381	328	120
	382	434	42

Stations	Sample No.	Depth, m	d/min/liter
	383	539	75
	384	658	27
21A	390	0	230
	391	55	210
	392	110	18
	393	209	42
	394	413	130
22	398	0	72
	399	10	190
	400	29	240
	401	53	21
	402	77	330
	403	104	54
	404	153	0
	405	201	48
	406	300	100
	407	404	(-18)
	408	508	96
	409	621	54
22A	412	0	210
	413	54	190
	414	108	220
	415	203	0
	416	402	90
23	418	0	360
	419	10	130
	420	29	280
	421	53	272
	422	77	260
	423	104	210
	424	151	93
	425	199	150
	426	296	(-27)
	427	386	120
	428	482	(-150)
	429	597	0
23A	431	0	160
	432	53	230
	433	103	-36
	434	195	36
	435	379	120
24	439	0	150
	440	9	150
	441	27	180
	442	46	170
	443	69	160
	444	92	0
	445	135	27
	446	174	96
	447	254	-
	448	341	45
	449	432	54
	450	542	(-36)
24A	453	0	130
	454	51	110
	455	99	54
	456	185	(-15)
	457	360	54
25	459	0	240
	460	10	180
	461	31	320
	462	57	570
	463	84	430
	464	116	130
	465	170	18
	466	221	180
	467	324	18
	468	427	18
	469	536	63
	470	653	110
25A	473	0	210
	474	58	190
	475	116	110
	476	222	0
	477	435	-36
26	479	Doubtful Cast	48
	480		120
	481		54
	482		170
	483		110
	484		39
	485		63
	486		(-45)
	487		45
	488		30
	489		81
	490		66
27	493	0	30
	494	9	140
	495	26	200
	496	48	130
	497	68	72
	498	98	(-9)
	499	136	0
	500	178	(-36)
	501	305	(-18)
	502	356	140
	503	454	36
	504	558	(-36)
27A	507	0	150
	508	59	84
	509	116	66
	510	224	63
	511	439	(-6)
	513	0	260
	514	11	130

Stations	Sample No.	Depth, m	d/min/liter
	515	31	220
	516	57	250
	517	84	(-18)
	518	114	100
	519	166	120
	520	220	(-130)
	521	330	54
	522	442	48
	523	554	0
	524	674	(-54)
28A	527	0	6
	528	59	(-30)
	529	117	100
	530	227	(-15)
	531	444	36
29	533	0	130
	534	11	81
	535	32	(-81)
	536	59	66
	537	84	9
	538	114	0
	539	165	90
	540	219	(-63)
	541	329	190
	542	437	0
	543	548	(-36)
	544	669	(-45)
30	569	0	160
	570	11	130
	571	31	81
	572	57	(-45)
	573	83	81
	574	113	(-9)
	575	165	45
	576	218	(-63)
	577	325	72
	578	434	48
	579	543	90
	580	663	84
30A	583	0	100
	584	59	260
	585	116	6
	586	224	60
	587	439	230
31	589	0	90
	590	11	220
	591	31	150
	592	58	250
	593	86	200
	594	116	78
	595	170	(-9)
	596	218	84
	597	322	120
	598	428	140
	599	538	36
	600	655	110
31A	603	0	120
	604	59	160
	605	117	(-15)
	606	227	(-60)
	607	444	(-6)
32	609	0	190
	610	11	9
	611	32	(-63)
	612	59	150
	613	84	230
	614	118	42
	615	168	(-120)
	616	219	24
	617	326	150
	618	436	0
	619	546	(-120)
	620	665	18
32A	623		84
	624		240
	625		99
	626		(-15)
	627		42
33	629	0	260
	630	11	200
	631	31	260
	632	58	90
	633	84	120
	634	116	140
	635	170	51
	636	222	99
	637	327	36
	638	432	33
	639	542	9
	640	660	(-24)
33A	643	0	140
	644	56	240
	645	112	140
	646	212	120
	647	419	42
34	649	0	276
	650	9	27
	651	26	240
	652	52	140
	653	73	296
	654	100	48
	655	142	(-27)
	656	179	(-9)
	657	245	69
	658	313	0

Stations	Sample No.	Depth, m	d/min/liter
	659	382	(-51)
	660	452	(-57)
35	662	0	230
	663	9	300
	664	28	81
	665	36	180
	666	79	130
	667	108	160
	668	156	(-130)
	669	204	0
	670	298	(-36)
	671	367	81
	672	409	(-130)
	673	471	150
35A	676	0	240
	677	62	280
	678	122	6
	679	236	42
	680	462	30
36	682	0	450
	683	11	290
	684	32	290
	685	64	200
	686	91	160
	687	128	140
	688	190	72
	689	251	110
	690	368	27
	691	479	170
	692	600	72
	693	726	72
36A	697		170
	698		57
	699		0
	700		(-15)
	701		18
	703	0	180
	704	10	200
	705	31	36
	706	62	75
	707	87	100
	708	123	(-120)
37	709	180	121
	710	236	(-42)
	711	351	36
	712	460	(-66)
	713	580	96
	714	701	(-51)
37A	719	0	(-24)
	720	62	(-30)
	721	123	42
	722	239	(-66)
	723	466	78
38	725	0	54
	726	10	140
	727	28	200
	728	57	72
	729	81	6
	730	112	6
	731	164	6
	732	216	100
	733	317	48
	734	414	150
	735	523	(-60)
	736	644	0
38A	740	0	110
	741	59	(-9)
	742	116	96
	743	224	33
	744	439	84
39	746	0	110
	747	11	63
	748	32	54
	749	59	180
	750	86	0
	751	117	0
	752	173	93
	753	228	(-81)
	754	337	130
	755	447	(-30)
	756	559	(-60)
	757	679	15
40	760	0	230
	761	11	160
	762	32	130
	763	59	54
	764	86	15
	765	116	130
	766	170	160
	767	225	78
	768	335	99
	769	447	87
	770	559	110
	771	679	(-24)
40A	774	0	150
	775	53	63
	776	105	120
	777	202	150
	778	398	18
41	780	0	90
	781	11	200
	782	31	69
	783	57	170
	784	83	84
	785	114	81
	786	165	140

Stations	Sample No.	Depth, m	d/min/liter
	787	213	60
	788	310	21
	789	408	100
	790	510	57
	791	624	(-45)
41A	794	0	230
	795	56	(-15)
	796	117	130
	797	213	30
	798	421	(-54)
42	800	0	48
	801	11	87
	802	31	9
	803	57	6
	804	84	110
	805	114	51
	806	168	27
	807	218	(-24)
	808	323	15
	809	428	30
	810	536	(-24)
	811	657	18
	812	612	30
	813	820	66
	814	1018	0
	815	1226	45
	818	0	96
	819	11	60
	820	32	100
	821	59	15
	822	86	15
	823	118	0
	824	175	(-9)
	825	231	30
	826	337	30
	827	445	18
	828	554	120
	829	674	45
43A	833	0	180
	834	59	(-210)
	835	118	(-81)
	836	226	(-15)
	837	442	100
44	839	0	0
	840	11	57
	841	32	24
	842	59	42
	843	86	(-69)
	844	117	30
	845	171	0
	846	224	(-45)
	847	334	72
	848	445	54
	849	555	(-9)
	850	676	120
44A	853	0	140
	854	57	24
	855	118	120
	856	219	(-15)
	857	429	24
45	860	0	72
	861	11	150
	862	31	(-30)
	863	62	48
	864	88	57
	865	124	39
	866	179	24
	867	233	(-54)
	868	343	0
	869	446	100
	870	562	(-15)
	871	683	120
	872	610	(-15)
	873	820	48
	874	1015	(-9)
	875	1230	0
46	878		180
	879		42
	880		15
	881		42
	882		57
	883		0
	884		(-24)
	885		27
	886		15
	887		63
	888		63
	889		0

APPENDIX E

Water Samples

Station No.	No. of Values	Average d/min/liter	Station No.	No. of Values	Average d/min/liter
1	6	57	24	11	90
2	6	61	25	12	189
3	6	42	26	12	65
4	12	50	27	12	55
5	12	65	28	12	82
6	12	52	29	12	28
7	12	52	30	12	56
8	12	64	31	12	122
9	11	57	32	12	42
10	11	40	33	12	105
11	10	35	34	12	79
12	11	48	35	12	85
13	12	35	36	12	172
14	12	99	37	12	48
15	6	155	38	12	60
15 (Repeat)	11	118	39	12	40
16	11	88	40	12	102
17	12	123	41	12	85
18	12	87	42	12	29
19	12	60	43	12	44
20	12	98	44	12	23
21	12	106	45	12	46
22	12	99	46	12	40
23	12	158			

APPENDIX F

Comparative Measurements on Activity of Macroplankton Samples.
Disintegrations per Minute per Gram Wet.

Station	Total Weight*	Plankton AFL**	NYO†	Total d/min	Station	Total Weight*	Plankton AFL**	NYO†	Total d/min
0A	6.0	11	13	76	22	4.8	72	83	400
1	8.8	13	16	139	22A	6.0	78	121	728
1A	7.2	5	31	220	23	23.2	57	75	1748
2	8.8	16	43	381	23A	8.0	4	32	254
2A	8.8	11	16	144	24	18.0	23	23	420
3	18.0	8	18	316	24A	9.6	36	39	378
3A	8.8	8	37	328	25	15.2	102	118	1788
4	9.6	8	17	163	25A	9.2	36	37	343
4A	10.4	19	20	206	26	18.4	30	31	576
5	5.6	35	23	131	27	34.4	17	16	566
5A	4.8	10	29	138	27A	8.4	35	39	327
6A	4.8	20	35	166	28	28	27	28	778
7	4.4	25	39	173	28A	22	13	18	389
7A	13.6	44	20	276	29	17.6	19	13	225
8	12.0	24	32	383	30	16.4	44	21	341
8A	5.2	10	13	68	30A	10.8	83	80	868
9	9.2	9	16	150	31	12.8	77	61	783
9A	22	4	5	107	31A	12.0	84	69	824
10	12.8	8	18	227	32	11.6	71	40	464
10A	2.0	10	12	24	32A	11.6	43	36	416
11	8.0	9	46	371	33	12.4	110	87	1076
11A	6.0	11	46	278	33A	8.0	46	57	458
12	12	24	58	693	35	7.2	47	51	370
12A	12.8	11	16	209	35A	6.8	100	62	419
13	14.0	26	31	432	36	6.8	73	140	928
13A	10.8	28	20	215	36A	7.6	46	48	367
14	16.8	27	16	262	37	3.6	56	35	126
14A	5.6	73	55	306	37A	15.2	12	9	142
15	6.4	61	39	250	38	9.2	21	23	210
15R	3.6	51	60	216	38A	16.8	17	14	242
15A	7.2	86	72	517	39	22.4	26	28	636
16	10.8	78	67	725	40	27.6	9	10	286
16A	5.6	68	44	247	40A	7.6	12	10	74
17	4.8	18	28	134	41	56	22	23	1264
17A	5.6	50	64	357	41A	14.8	24	27	395
18	9.2	63	44	400	42	19.2	12	11	203
18A	4.8	24	19	92	43	28	12	12	340
19	9.6	14	11	106	43A	18	12	9	165
19A	8.8	22	10	91	44	37.2	9	9	349
20	6.8	34	51	345	44A	16.0	4	3	43
20A	4.8	23	19	93	45	14.4	4	6	94
21	15.2	18	42	644	46	36.8	4	4	143
21A	9.2	28	62	568					

*These quantities represent the complete tow and not the one-quarter fraction taken for counting.
**Counted at the Applied Fisheries Laboratory (RaD and E standard).
†Counted aboard the "TANEY" by NYO (K^{40} standard).

APPENDIX G

Microplankton - Macroplankton Comparison.
Disintegrations per Minute per Gram Wet.

Station	Macroplankton Activity	Microplankton Activity	Microplankton Weight
24	23	42	0.2
25	118	420	0.1
26	31	56	0.3
27	16	124	0.3
28	28	15	0.8
29	13	12	0.7
30	21	37	0.6
31	61	52	0.5
32	40	91	0.4
33	87	157	0.5
34	-	214	0.7
35	51	45	1.1
36	140	226	0.3
37	35	12	0.8
38	23	48	0.7
39	28	1000	0.2
40	10	300	0.3
41	23	320	0.7
42	11	34	0.5
43	12	40	0.7
44	9	80	0.2
45	6	22	1.0
46	4	8	2.1

The weight of microplankton is given to indicate possible inaccuracies due to weighing. The balance sensitivity was about 0.1 g.

APPENDIX H

Activity of Fish Samples Counted Aboard Ship.
These Results Include K^{40}.

Nearest Station	Sample No.	Type	d/min/g ash
2A	31	Flying - Gut	38
4A	62	- Gut	1200
	63	Shark - Cartilage	45
7A	111	Flying - Gut	640
10	158	Shark - Cartilage	5
11A	174	Flying - Gut	12
12	190	- Gut	2600
	191	- Bone	50
Truk	192	Trigger - Bone	1
Guam	271	Squirrel - Bone	4.5
	272	- Gut	1100
	273	- Soft Tissue	28
15A	274	Shark - Cartilage	3
Parece Vela	386	Squirrel - Gut	300
	387	Grouper - Bone	12
	388	- Gut	370
21A	396	Flying - Gut	1200
	397	- Bone	56
23A	437	Flying - Gut	1900
	438	- Bone	14
29	547	Tuna I - Skin	0.2
	548	- White Muscle	94
	549	- Red Muscle	132
	550	- Bone	6.2
	553	Tuna II - Skin	7
	568	- White Muscle	69
	554	- Red Muscle	-
	555	- Bone	2.4
	558	Tuna III - Skin	8
	559	- White Muscle	61
	560	- Red Muscle	54
	561	- Bone	2.3
	564	Shark - Muscle	58
	565	- Cartilage	2.8
	567	Remora - Entire	18
37A	717	Flying - Gut	1600
	718	- Bone	37
Okinawa	739	Squirrel - Gut	34

APPENDIX I

Summary of Activity Measurements on Biological Specimens Run at the Applied Fisheries Laboratory.

Average Values of the Radioactivity of Tissues of Reef Fishes from the "TANEY" Collections and Other Areas. Values in Disintegrations per Minute per Gram of Wet Tissue.

	Skin	Muscle	Bone	Liver	Viscera	No. of Specimens
Truk	27	11	29	87	39	12
Guam	28	16	33	126	480	10
Parece Vela	8	12	32	49	48	9
Okinawa	9	12	12	10	19	10
Puget Sound	7	7	11	4	9	10
Marshall Is.*	337	91	528	5608	5348	61

*From Rongelap, Rongerik, Eniwetok during late January, February, and March, 1955 and of species comparable to those in the "TROLL" collections.

Radioactivity by Tissues of Flying Fish Samples from the "TROLL" and the Rongerik Area. Values in Disintegrations per Minute per Gram of Wet Sample.

Station	Scales Skin	Muscle	Bone	Liver	G.I. Tract	Gonad	Spleen	Kidney
3A	36	19	4	40		18		
3A	22	10	17	167	118			
7-2	84	24	21	144		27		
10A	36	16	10	24	14	43		
11A	102	20	84	297	50		194	
11A-6	48	19	10	150	72		396	
11A-6	54	19	0	155	49			
12A-2	42	7	28	18	86			
13	38	17	44	173	48			
13	72	10	33	119	44			
14	173	16	28	231	333			163
14	172	11	29	62	66			60
19A-5	256	20	34	22	70			
21A	250	45	63	359	386			
23-2	49	17	49	77	56		113	
30	66	13	8	101	75			
34/35	18	13	6	82	112			
36	134	31	82	329	462			
37-5	33	18	51	43	45			
Average	89	18	32	136	123			
Rongerik	109	38	68	208	115			
	336	32	78	241	320			
Average	222	35	73	224	218			