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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

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U. S. Atomic Energy Commission

New York Operations Office

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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. Merrill 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

NOT RECORDED

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. Merrill 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.

*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.

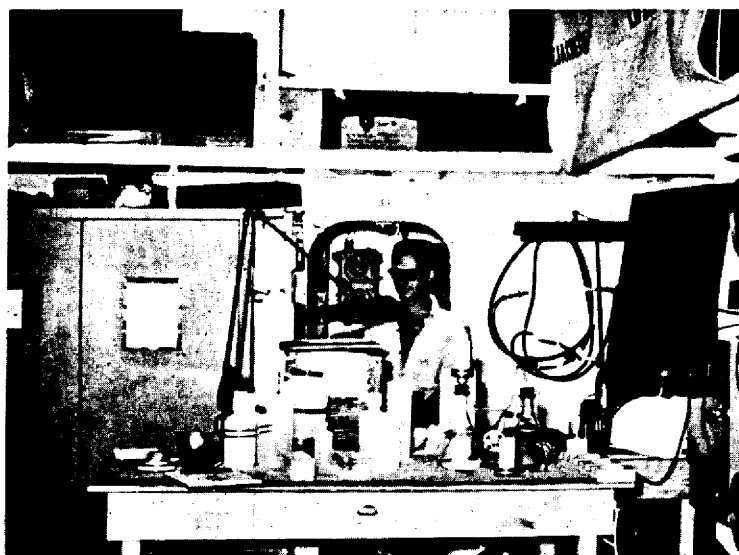


Figure 1. Radiochemical laboratory in the weather-balloon shelter on board the TANEY.

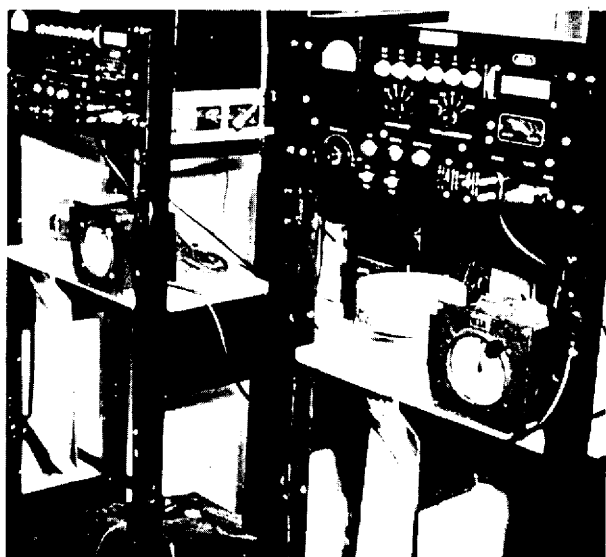


Figure 2. Counting equipment.

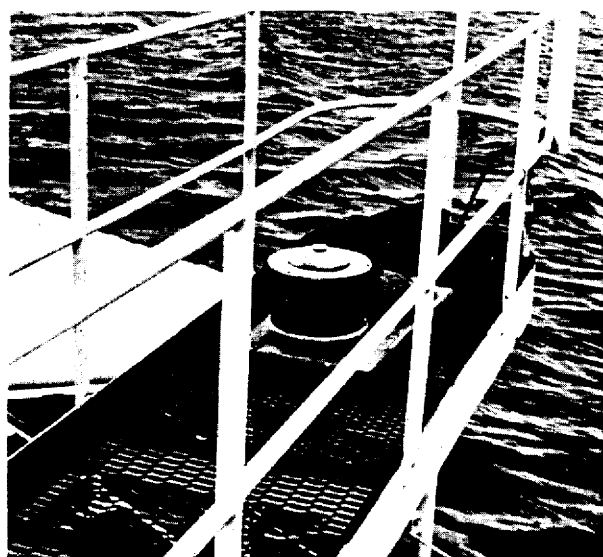


Figure 3. Muffle furnace.

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 $\pm 0.02^{\circ}\text{C}$.
- b) Salinity. Water samples were saved and subsequently titrated at the Scripps Institution. Salinity values are believed to be accurate to ± 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.

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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 Morotai 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

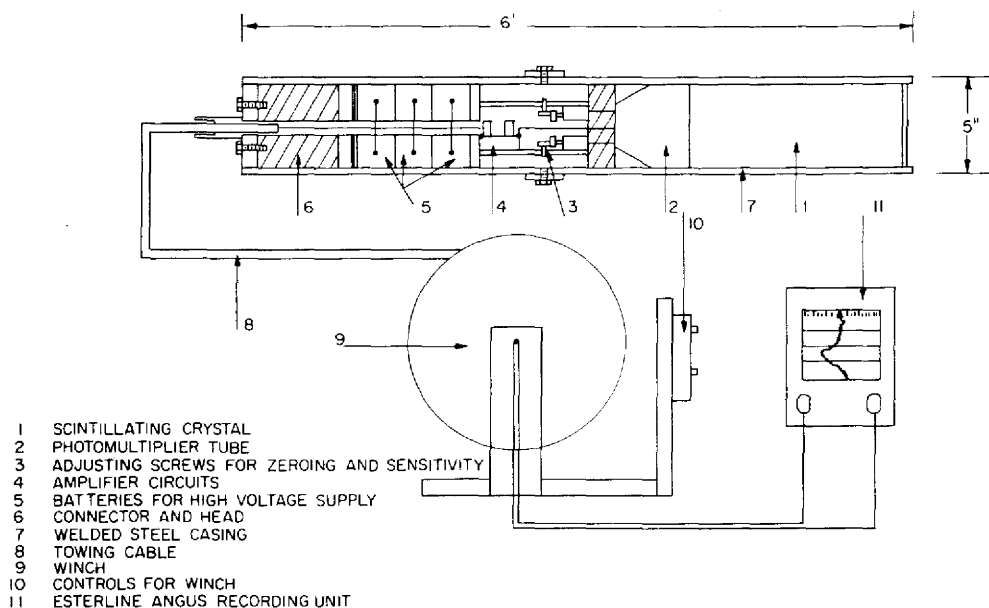


Figure 4. Assembly for the scintillation probe.

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.

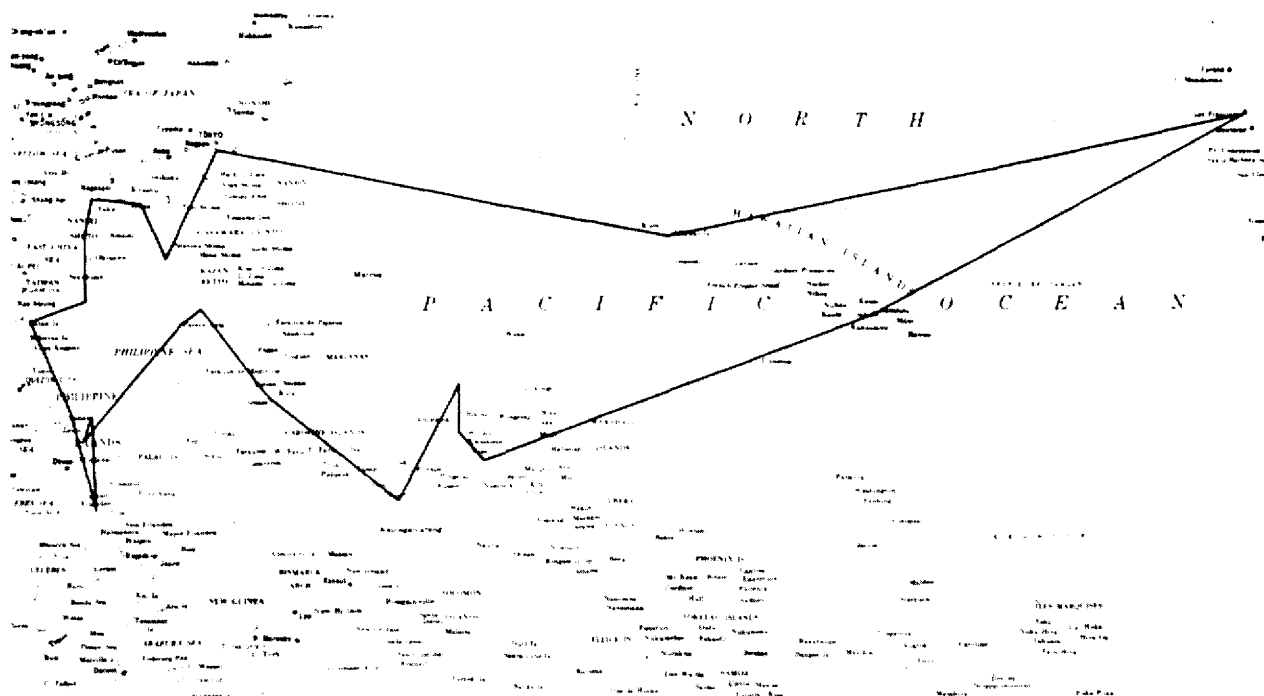


Figure 5. Track of the TANEY during Operation Troll.

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 Morotai, 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.

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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.

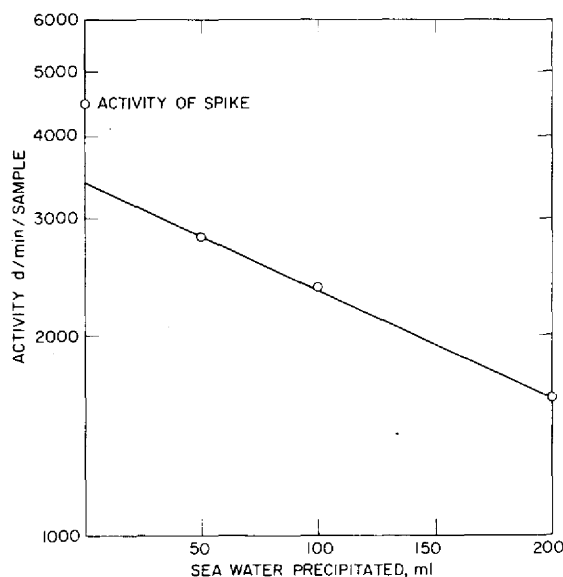


Figure 6.

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

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

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.

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, $8 \times 10^{-7} \mu c$ Sr^{90} - Y^{90} per milliliter or per gram. This is equivalent to $2 \times 10^{-5} \mu c$ 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	Tuna 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	Date	Hour	d/min/liter
March 11	2240	30		0230	(-54)
12	0030	18		0330	30
13	0030	130		0430	(-60)
	Net 2A	130		Net 5A	170
	0230	-		0630	78
	0330	66		0730	(-39)
	0430	63		0830	
	0530	42		0930	
	0630	(-9)		1030	-
	0730	120		1130	
	0830	100		1230	
				1330	
	Station 3	60		Station 6	66
	1230	(-15)		1630	
	1330	33		1730	-
	1430	96		1830	
	1530	(-39)		1930	
	1630	100		2030	
	1800	84		2130	
	Net 3A	75		Net 6A	33
	1930	42		2330	
	2030	63	March 16	0030	
	2130	78		0130	
	2230	48		0230	
	2330	69		0330	
March 14	0030	-			
	Station 4	36		Station 7	66
	0530	-		0730	
	0630	69		0830	
	0730	48		0930	
	0830	-		1030	
	0930	39		1130	
	1030	6		1230	
	1130	36			
	Net 4A	63		Net 7A	(-24)
	1330	-		1430	-
	1430	-		1530	
	1530	93		1630	
	1630	(-39)		1730	
	1730	78		1830	
	1830	30		1930	
	1930	110			
	Station 5	51		Station 8	66
March 14	2230	93		2230	-
	2330	180		2330	
March 15	0030	-	March 17	0030	33
	0130	(-45)		0130	33
				0230	(-100)

Date	Hour	d/min/liter	Date	Hour	d/min/liter
March 18	Net 8A	30	March 20	Station 12	81
	0330	(-24)		2130	-
	0530	57		0330	-
	0630	160		0430	21
	0730	6		0530	-
	0830	(-51)		0630	-
	0930	-		0730	54
	1030	33		0830	27
	Station 9	87	March 21	Net 12A	100
	1330	0		1030	-
March 19	1430	0		1130	(-9)
	1530	110		1230	110
	1630	18		1330	150
	1730	90		1430	-
	Net 9A	72	March 21	Station 13	75
	2030	(-45)		1830	140
	2130	-		1930	100
	2230	-		2030	87
	0150	-		2130	9
March 19	0230	6		2230	120
	0530	96	March 21	Net 13A	90
	0630	-		0130	-
	0730	30		0230	69
	0830	63		0330	99
	Station 10	(-39)		0430	84
	1330	66		0545	93
	1430	18	March 21	Station 14	250
	1530	(-24)		0830	-
	1630	(-60)		0930	-
	1730	48		1030	69
	1830	190		1130	6
March 19	Net 10A	54		1230	(-39)
	2030	6	March 24	1330	-
	2130	6		1430	-
	2230	-		Net 14A	150
	2330	0		1730	66
	0030	15		1830	0
	0130	(-24)		1930	81
	Station 11			2030	48
	0430	(-15)		2130	81
	0530	18		2230	57
	0630	0	March 24	Station 15	
	0730	33		Station 15R	
	0830			0430	130
March 19	Net 11A	51		0530	72
	1130	-		0630	87
	1230	54		0730	100
	1330	(-66)		0830	150
	1430	33		Net 15A	140
	1530	69		1030	90
	1730	(-15)			

Date	Hour	d/min/liter	Date	Hour	d/min/liter
	1130	63		0430	81
	1230	-		0530	39
	1330	27		0630	21
	1430	-		0730	63
	Station 16	84		Net 20A	160
	1730	87		1030	-
	1830	60		1130	100
	1930	150		1230	130
	2030	140		1330	21
	Net 16A	(-60)	March 27	Station 21	140
March 25	2330	200		1630	130
	0030	180		1730	200
	0130	180		1830	51
	0230	160		1930	93
	Station 17	300		Net 21A	230
	0630	-		2230	170
	0730	160		2330	180
	0830	78	March 28	0030	210
March 25	Net 17A	24		0130	180
	1130	160		0230	72
	1230	140		Station 22	72
	1330	120		0530	130
	1430	190		0630	260
	1530	110		0730	99
	Station 18	230		0830	57
	1930	-		Net 22A	210
	2030	190		1130	
	2130	-		1230	66
	2230	30		1330	0
	2330	130		1430	87
	Net 18A	250		1530	160
March 26	0230	110		Station 23	360
	0330	66		1830	100
	0430	(-30)		1930	200
	0530	63		2030	33
	Station 19	160		2130	170
	0830	140		Net 23A	160
	0930	75	March 29	0040	140
	1030	-		0130	140
	1130	110		0230	69
	1230	-		0330	200
	Net 19A	(-15)		Station 24	150
	1530	-		0630	96
	1630	48		0730	30
	1730	87		0830	96
	1830	60		1030	120
	1930	-		1130	99
	Station 20	160		Net 24A	130
March 27	0330	120		1430	130

Date	Hour	d/min/liter	Date	Hour	d/min/liter
	1530	120	April 1	Station 29	130
	1630	160		0230	24
	1730	48		0330	6
March 29	Station 25	240		0430	-
	2030	130		0530	150
	2130	39		0630	48
	2230	15		0730	-
	2330	(-39)		0830	100
March 30	0030	75		0930	54
	Net 25A	210		1030	-
	0230	96		1130	-
	0330	93		1230	120
	0430	(-39)		1330	96
	0530	180		1430	-
	0630	48		Station 30	160
	0730	180		1730	-
	Station 26	48		1830	230
	1030	100		1930	63
	1130	140		2030	150
	1230	110		2130	110
	1330	170		2230	120
	1430	78	April 2	Net 30A	100
	1530	220		0130	69
	1630	42		0230	240
	1730	63		0330	81
	Station 27	27		0430	290
	2130	-		0530	220
	2230	72		0630	160
	2330	15		0730	100
March 31	0050	-		Station 31	90
	0130	90		1130	-
	Net 27A	150		1230	160
	0330	130		1330	-
	0430	150		1430	190
	0530	39		1530	180
	0630	39		1630	99
	0730	290	April 2	Net 31A	120
	0830	51		1930	200
	Station 28	260		2030	-
	1130	200		2130	84
	1230	160		2230	130
	1330	150		2330	69
	1430	120	April 3	0030	-
	1530	0		Station 32	120
	1630	(-39)		0330	75
March 31	Net 28A	6		Station 32R	190
	1930	33		0545	-
	2030	110		0630	130
	2130	(-84)		0730	24
	2230	(-39)		0830	-
	2330	(-75)		0930	84

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

Date	Hour	d/min/liter	Date	Hour	d/min/liter
April 11	1030	110	April 12	Net 43A	180
	1130	-		2330	18
	Station 41	90		0030	(-45)
	1530	250		0130	200
	1630	87		0230	-
	1730	15		0330	160
	1830	24		0800	100
	1930	72		Station 44	0
	Net 41A	230		1130	110
	2230	0		1230	(-99)
	2330	93		1330	(-30)
	0030	(-60)		1430	0
	0130	(-270)		1530	6
	0230	30		1630	24
	0330	(-45)	April 13	Net 44A	140
	0430	(-39)		1930	6
April 11	Station 42	48		2030	66
	0830	0		2130	(-45)
	0930	30		2230	(-15)
	1030	24		2330	(-75)
	1130	-		0030	30
	1230	210		0130	(-84)
	1330	42		0230	6
	Station 43	96		Station 45	72
	1630	140		0630	(-69)
	1730	(-51)		0730	36
	1830	120		0830	(-24)
	1930	30		0930	81
	2030	(-130)		1030	30
	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	Stations	Sample No.	Depth, m	d/min/liter
	260	281	-		324	398	48
	261	401	54		325	500	(-36)
	262	506	63		326	612	110
	263	621	160				
15A	265	0	140	18A	328	0	250
	266	53	180		329	60	9
	267	105	100		330	118	84
	268	199	100		331	229	0
	269	391	(-24)		332	442	18
16	275	0	84	19	334	0	160
	276	11	-		335	10	150
	277	32	78		336	28	110
	278	63	130		337	53	93
	279	90	180		338	78	120
	280	127	160		339	105	36
	281	189	78		340	154	(-110)
	282	247	0		341	204	(-18)
	283	361	110		342	306	100
	284	473	63		343	410	18
	285	596	0		344	514	60
	286	722	90		345	632	0
16A	290	0	(-60)	19A	348	0	-15
	291	47	160		349	56	100
	292	92	160		350	113	(-140)
	293	169	(-15)		351	213	0
	294	327	78		352	421	0
17	296	0	300	20	354	0	160
	297	10	270		355	11	160
	298	30	260		356	32	190
	299	61	100		357	59	87
	300	86	130		358	85	140
	301	120	100		359	117	84
	302	177	9		360	172	100
	303	236	120		361	226	0
	304	352	69		362	337	150
	305	461	(-72)		363	349	(-45)
	306	581	87		364	559	120
	307	707	90		365	674	30
17A	309	0	24	20A	367	0	170
	310	58	24		368	53	110
	311	112	30		369	105	18
	312	217	42		370	199	110
	313	415	9		371	391	39
18	315	0	230	21	373	0	140
	316	10	120		374	10	230
	317	29	84		375	31	160
	318	54	93		376	57	66
	319	78	69		377	83	190
	320	106	84		378	114	72
	321	133	170		379	168	100
	322	199	60		380	222	45
	323	296	0		381	328	120
					382	434	42

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

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

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

Stations	Sample No.	Depth, m	d/min/liter	Stations	Sample No.	Depth, m	d/min/liter
	787	213	60	44	839	0	0
	788	310	21		840	11	57
	789	408	100		841	32	24
	790	510	57		842	59	42
	791	624	(-45)		843	86	(-69)
41A	794	0	230		844	117	30
	795	56	(-15)		845	171	0
	796	117	130		846	224	(-45)
	797	213	30		847	334	72
	798	421	(-54)		848	445	54
					849	555	(-9)
42	800	0	48		850	676	120
	801	11	87	44A	853	0	140
	802	31	9		854	57	24
	803	57	6		855	118	120
	804	84	110		856	219	(-15)
	805	114	51		857	429	24
	806	168	27				
	807	218	(-24)	45	860	0	72
	808	323	15		861	11	150
	809	428	30		862	31	(-30)
	810	536	(-24)		863	62	48
	811	657	18		864	88	57
	812	612	30		865	124	39
	813	820	66		866	179	24
	814	1018	0		867	233	(-54)
	815	1226	45		868	343	0
					869	446	100
	818	0	96		870	562	(-15)
	819	11	60		871	683	120
	820	32	100		872	610	(-15)
	821	59	15		873	820	48
	822	86	15		874	1015	(-9)
	823	118	0		875	1230	0
	824	175	(-9)	46	878		180
	825	231	30		879		42
	826	337	30		880		15
	827	445	18		881		42
	828	554	120		882		57
	829	674	45		883		0
43A	833	0	180		884		(-24)
	834	59	(-210)		885		27
	835	118	(-81)		886		15
	836	226	(-15)		887		63
	837	442	100		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		Total d/min	Station	Total Weight*	Plankton		Total d/min
		AFL**	NYO†				AFL**	NYO†	
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 (K⁴⁰ 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 K⁴⁰.

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			