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SURVEY OF RADIOACTIVITY IN THE SEA NEAR BIKINI AND ENIWETOK ATOLLS JUNE 11-21, 1956

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July 23, 1956

Applied Fisheries Laboratory
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Seattle, Washington

Technical Information Service Extension, Oak Ridge, Tenn.

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ABSTRACT

During the period of June 11 to 21, 1956, a survey party, operating from the USS Walton (DE 361), measured the radiation in plankton, water, and fish samples collected near Bikini and Eniwetok Atolls. Fifty-three stations between 10° 15' to 14° N and 159° to 166° E were covered during the 3,300-mile cruise. A continuous record of the radiation in the surface water was obtained with a probe. Plankton samples from oblique tows to a depth of 200 meters and water samples from the surface and from depths of 25, 50, 75, and 100 meters indicated radioactivity at each station. Highest radiation readings in plankton and water samples were from stations north of Bikini Atoll. Radiation decreased around the periphery of the survey area.

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INTRODUCTION

During the planning stage of Operation Redwing, discussions were held by staff members of the Atomic Energy Commission, Division of Biology and Medicine, and the Applied Fisheries Laboratory of the University of Washington on the probable need for biological surveys to define and evaluate the distribution of radioactive materials to be produced by the 1956 series of nuclear experiments.

Following these preliminary discussions, a tentative outline of studies to be pursued during and immediately following the test series was prepared by the Applied Fisheries Laboratory and submitted to the Division (UWFL-45)*. This proposed program contained, among other suggestions, one that called for a survey and evaluation of the radioactive content of the water, plankton, and fish from areas about the test site, following somewhat the plan of Operation Troll**.

The specific assignment of the Applied Fisheries Laboratory to the survey project was made in a letter of March 28, 1956, from Dr. Charles Dunham, Director of the Division of Biology and Medicine. This letter addressed to Lauren R. Donaldson stated in part:

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* Program of the Applied Fisheries Laboratory, University of Washington, for the 1956 Test Series at Bikini and Eniwetok Atolls, Marshall Islands. February 7, 1956.

** Harley, John H., Editor, Operation Troll, NYO-4656, March 1956.

The Division of Biology and Medicine has assigned the Applied Fisheries Laboratory the following operations during and following the forthcoming test series:

1. Conduct two marine biological open sea surveys, beginning June 10 and September 1.

   The primary mission of these two surveys is to ascertain (a) the levels of introduced radioactivity resulting from the tests in the water, plankton, and fish, and (b) how far the activity extends westward in the North Equatorial current. It has been recommended to the Task Force,

   (a) that the ship should operate from the area of highest average fallout to the westward fringe of the detectable introduced radioactivity in the water, and

   (b) that you or Allyn Seymour and the ship's captain be briefed as to the location where fallout from each shot fell into the sea, prior to each survey.

   Each cruise should include the following:

   (a) continuous water monitoring throughout the cruise. The New York Operations Office will construct and install the necessary instrumentation.

   (b) water samples should be taken at 0, 25, 50, 75 and below 100 meters at selected stations.

   (c) Plankton tows should be made in areas of both high and low activity.

   (d) Fish should be collected wherever and whenever feasible.

Preparations for undertaking these missions were made during April and May, when equipment was assembled and shipped to the Pacific Proving Ground and a schedule of staff assignments was worked out. The field group, which departed for Eniwetok early in June, included Lauren R. Donaldson, Allyn H. Seymour, Edward E. Held, Frank G. Lowman, Arthur D. Welander, Paul R. Olson, and Neal O. Hines.

The ship assigned by the Task Force to the first of the two surveys was the USS WALTON (Destroyer Escort 361), a 306-foot vessel whose range and accommodations were considered adequate for oceanographical work in open waters. The WALTON arrived at Eniwetok on June 5, and shortly thereafter the survey equipment was installed on board. The survey was begun on Monday, June 11, and completed on Thursday, June 21.

The success of the survey is attributable to the support of the Division of Biology and Medicine, particularly Dr. W. R. Boss, and to the coordinated assistance given to the field team by the operational groups within Joint Task Force 7, particularly Task Group 7.3 (Navy). Members of the staff are especially grateful for the intelligent interest in the project demonstrated by Commander Arthur T. Emerson, Jr., captain of the WALTON, and for the very great understanding and assistance afforded by officers and members of the crew of the vessel.

The probe for continuous water monitoring was developed and constructed by the Instruments Branch of the Health and Safety Laboratory, New York Operations Office, under the direction of Mr. Harris D. LeVine, Chief. The use at Eniwetok of a gamma ray spectrometer was made possible through the kindness of Mr. Robert Graveson, Chief Engineer of the Electronics Section, Instruments Branch, HASL, who also assisted and instructed members of the staff in its operation. The Eniwetok Marine Biological Laboratory of the Division of Biology and Medicine was used as a headquarters, and shared with HASL personnel who were most cooperative in the exchange of the use of equipment and supplies.

PLANS, EQUIPMENT AND OPERATIONS AT SEA

The marine survey whose results are reported herewith was one of two such projects set up by the Division of Biology and Medicine for the purpose of collecting information on the levels and distribution of radioactivity introduced into the waters of the Eniwetok-Bikini area by the atomic testing program of 1956. A more extensive survey is scheduled for September 1956.

As originally conceived, the survey was to be made "from the area of highest average fallout to the westward fringe of the detectable introduced radioactivity in the water." Final plans were made upon arrival in the field when a review of information available on fallout patterns indicated the desirability of a survey pattern that would provide ample sampling of water and plankton in the areas immediately about Eniwetok and Bikini as well as to the west of Eniwetok during the ten days granted for the survey.

The cruise pattern thus projected, coordinated with Task Group 7.3 and reported to the Division of Biology and Medicine, anticipated the coverage of fifty collecting stations on a grid extending from a line approximately 180 miles west of Eniwetok to a line 30 miles east of Bikini. The north and south boundary lines were 11° N and 14° N (Fig. 7). This pattern was somewhat modified during the course of the survey because of the testing program. The survey, however, actually covered fifty-three stations between Monday, June 11, and Thursday, June 21, on a track of 3,300 miles over 78,000 square miles of open sea (Fig. 8).

Preparations for the Field: Preliminary planning coordinated by the Division of Biology and Medicine and by Joint Task Force 7, specified that the survey vessel, the WALTON (DE 361), should report to Eniwetok on or about June 5 and that she should be available for the cruise for approximately ten days after June 10. The WALTON reported on schedule at Eniwetok, and was joined immediately thereafter by members of the survey party, who began the supervision of the installation of survey equipment.

Survey Equipment: The equipment used in collecting plankton, sampling water, and continuous monitoring of surface water, was installed on the afterdeck of the WALTON, approximately above the port screw. The counters, a recorder, and chemistry laboratory facilities were placed below decks in the after officers' quarters and in a crew's berthing compartment. Specifically, the major items of equipment were:

1. A continuous surface water monitoring probe with tank and water connections (Fig. 1), a unit designed and constructed by the HASL.

2. A power winch (Fig 2), feeding 3/16 inch steel cable over an A-frame and davit, for the use of plankton nets (Fig. 3) and water sampling bottles (Fig. 4).

3. A steel platform (Fig. 4) extending two feet over the port side of the ship to provide space for work with nets and water sampling bottles.

4. A temporary chemistry laboratory set up on sheet ply-

wood work tables fastened to existing bunk frames and supplied by electrical connections with 110 AC outlets (Fig. 5).

5. Two nuclear radiation detection instruments mounted on a temporary bench built into the wardrobe space of the after officers' quarters (Fig. 6).

6. A bathythermograph which was a part of the equipment of the ship.

Operation of the Ship: The projected cruise pattern presented to the commander of the WALTON unusual navigational and operational problems, and the mechanics of the sampling at the various stations required close cooperation between personnel of the ship and of the survey team.

It was calculated that to cover the fifty proposed stations in ten days, with a stop of approximately 30 minutes at each station, and with a pause for refueling at the midpoint, the ship would have to maintain a speed of advance of fifteen knots. As the operational procedure was worked out the ship steamed between stations at 18 knots, reduced the speed to 15 knots at survey time (ST) minus twenty-five minutes, and further reduced the speed to 10 knots for a bathythermograph drop at ST minus 10 minutes.* At ST the ship slowed to 5 knots and altered course to put wind 30 to 90 degrees on the port bow, the drop side, because the plankton net had the effect of a sea anchor. When the ship was steadied, the port screw was stopped and the starboard engine was slowed to rpm for approximately 4 knots, or to a

* From report of Commander A. T. Emerson to Commander Task Group 7.3 June 23, 1956.

speed that would maintain the plankton net towline at an angle of 45° with the surface of the water. For the subsequent drop of the water sampling bottles the starboard engine maintained rpm for speed of about 1 knot. After each drop the ship built up slowly to the 18-knot cruising speed to avoid unnecessarily great variations in boiler brickwork temperatures.

The WALTON reported to Eniwetok for refueling on Saturday, June 16, when approximately half of the survey had been accomplished. With additional fuel aboard, the cruise was resumed the same day.

THE SURVEY AREA

Delineation of Area and Proposed Track: The area to be included in the survey and the projected track of the ship were determined at a meeting on June 9 in the offices of Captain H. G. Munson, USN, representative of the commander of Task Group 7.3. Those present at the meeting included Captain Munson; Commander N. Purley, naval liaison officer, CTG 7.1; Commander Arthur T. Emerson, Jr., captain of the WALTON; Mr. Merril Eisenbud of the HASL; Dr. A. V. Shelton, of TG 7.1; and Lauren R. Donaldson and Allyn H. Seymour of TG 7.1 (Program 35).

Determinations of area and track were made after consideration of the elements of the problem, such as fallout patterns and estimated drifts of radioactive materials, and with knowledge of such operational factors as the overall time limit on the survey, the speed of the ship, and the need of the ship for additional fuel at some point during the 3,000-mile cruise.

The proposed track finally was laid out on a grid (Fig. 7) providing distances of 45 miles between stations. Track lines running northeast and southwest, although calling for longer runs between stations than on north-south or east-west tracks, were used (a) to give continuous water monitoring readings that were only 32 miles apart, and (b) to put the operations at sea on headings that would minimize the ship's roll.

The Actual Track: From the point of the initial drop to the return to Eniwetok for fuel on June 16, the WALTON followed rather closely the track that had been laid out in advance. During the second half of the cruise, however, it was necessary to modify the track to avoid possible contamination of the ship by tests scheduled in the area and to provide, in the vicinity of Bikini, a more complete coverage of the area contaminated by the drift of radioactive materials. The track actually accomplished by the WALTON is shown in Figure 8.

COLLECTION AND PREPARATION OF SAMPLES

Plankton, water, and fish samples and continuous measurements of the activity in the surface water were taken.

Plankton Samples and Water Temperatures: Plankton samples were obtained by twenty-minute oblique tows from about 200 meters of depth using a 1-meter Michael Sars type net of No. 6 mesh (Fig. 3). No. 6 mesh is equivalent to seventy-four meshes per inch with apertures of 0.24 mm. This mesh retains some microplankton as well as larger forms. Organisms longer than approximately 2 cm were removed from the samples before processing. The plankton was filtered through No. 1 Whatman paper and about two grams were transferred to a 1.5-inch stainless steel planchet, dried with an infrared lamp, and then counted aboard ship. The remainder of the plankton sample was preserved for future use. Amounts of plankton were determined volumetrically. A 50 ml portion of sea water and plankton was poured into a Buchner funnel with No. 1 Whatman filter paper. The amount of plankton remaining on the filter paper was determined by subtracting the amount of filtrate from the original amount of sea water and plankton (50 ml). After returning to Eniwetok Marine Biological Laboratory the shipboard estimates of the volumes of the plankton samples were revised. The corrected volumes were calculated by multiplying the dried sample weight of the individual samples by the ratio of the average estimated volume to the average dry weight. Finally, volumes in ml were converted directly to wet weights in grams.

Bathythermograph casts were made by the ship's crew at each station during the cruise for the purpose of defining temperature change with depth.

Water Samples: Samples were collected at the surface by bucket and at 25, 50, 75 and 100 meters by means of a Nansen water bottle (Fig. 4). The surface water samples were processed aboard ship and the other samples at the EMBL.

One liter of surface water was passed through a Millipore filter using Millipore AA paper. The filter paper was saved and counted. From the filtrate two 100 ml samples were processed for counting and a 500 ml sample saved for possible future use. To each of the 100 ml samples 5 ml of saturated sodium carbonate was added. The precipitate was collected on 1½-inch Millipore HA paper in a Millipore filter and counted. By this method naturally occurring K^{40}, normally present in sea water to the extent of about 600 d/m, is eliminated from the portion which is counted. Radiocesium is also lost in the filtrate but accounts for less than one per cent of the total activity at the time of collection.

The water samples processed at EMBL were treated in a similar manner except that a 500 ml sample was filtered and only one 100 ml sample was prepared for counting.

Fish Samples: Time and facilities were not available to collect fish in numbers. However, three flying fish were found on deck and taken as samples. Larval forms and small fish were captured in the plankton nets but were not processed separately. In an attempt to increase the take of flying fish a section of white canvas was stretched on the starboard side near the after gun mount. A light was kept burning at night to illuminate the canvas.

The three flying fish were frozen aboard ship. The liver and muscle were processed at the EMBL. These tissues were dried for 12 hours at about 100°C on 1½-inch plates, ashed at 500°C (3 hours), slurried with alcohol and fixed to the plate with 0.5 per cent solution of formvar in ethylene dichloride, and then counted.

Continuous Monitoring of Water: A probe for continuously monitoring water was constructed by the HASL, NYOO. This installation differed from that used during Operation Troll* in that the probe was mounted in a cylindrical, rubber-lined tank, 4 feet in diameter and 6 feet long (Fig. 1). Water from the surface of the sea was passed through the tank at the rate of about 30 gallons per minute.

The sensing probe contained a plastic phosphor three inches in diameter and thirty inches long, a photomultiplier tube, and a battery-operated preamplifier. The probe unit was connected to a control box inside the ship by two coaxial lines, the high voltage line and the signal line. The control box contained an AC-operated high voltage supply and a DC amplifier with output scales of 5, 50, 500, and 5,000 microroentgens. The signal from the control box was fed into an Esterline Angus recorder which was operated at a chart speed of three inches per hour. The scintillation unit was operated throughout the duration of the trip.

METHODS OF ANALYSES

Preliminary analyses of the plankton and surface water were carried out on board the WALTON. Further determinations were made at the EMBL and at the Applied Fisheries Laboratory.

Counting Equipment: Samples were prepared on $1\frac{1}{2}$-inch stainless steel plates and counted with a 2 inch Anton tube in

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* Harley, John H., Editor, Operation Troll, NYO-4656, March 1956.

a 3-inch lead Anton pig with a Nuclear-Chicago Model 181 Scaler. Background varied from 18 to 32 c/min.

Correction Factors: To convert counts to disintegrations per unit volume or weight, corrections were made for sample size, self-absorption, geometry, backscatter and decay. The correction factor for counting efficiency, which includes self-absorption, geometry and backscatter, was determined from counting plates of known weights of potassium chloride with known disintegration rates for K^{40}. For plankton this factor ranged from 3.4 to 3.8; and was for filter paper, 3.3; and for water samples, 4.0. All samples counting background or less were taken as zero.

The samples counted aboard ship were counted within a few hours from time collected and therefore were not corrected for decay. The samples counted at EMBL were corrected to the day of collection. For samples collected west of Eniwetok (sections 1 to 5 inclusive) one decay curve was used and for sections 6 to 10 a second curve was used (Fig. 9). For the former the half life was less than two days for the early part of the curve and about six days for the end of the observation period. For the latter curve the half life was about four days. The maximum correction factor for decay was 15 but the factor usually was much less. Fish samples were corrected to the day of collection using the plankton decay curves and absorption factors.

Contours: Contours have been used to show distribution of radioactivity, but the contours have limited significance. The use of contours adequately shows the relationships between the radioactivity of the plankton and water samples, but the contours do not give the distribution of radioactivity at any one time for the entire survey area. As mentioned above, the values given are those at time of collection and can not be corrected readily to a common date because of the repeated addition to the waters being sampled of radioactive materials from the testing program.

Gamma Ray Spectra: Gamma ray spectra were run at the EMBL on a Gamma Spectrometer type TM-10-A developed by the Instruments Branch, HASL, NYOO.

RESULTS AND CONCLUSIONS

Plankton and Water Temperatures: The average value of radioactivity in plankton was 71,000 d/m/g(wet), with the range from 1,300 to 1,100,000 (Table 1). The average value for plankton was about 7,100 times the average value for surface water (10,000 d/m/l; Table 3). The minimum level of plankton activity, 1,300 d/m/g, was almost as high as the maximum level of 1,700 d/m/g found during the Troll survey, and indicates that the entire area covered by the WALTON survey was contaminated to some degree.

The contour curves of plankton activity, based on station values as of the day of collection (June 11 to June 21), are shown in Figure 10. Radioactivity was at a maximum in the region immediately north of Bikini Atoll and diminished rapidly southward and gradually northwestward, suggesting fallout to the north and northwest. There was a general decrease in activity westward from Bikini with the exception of a tongue of higher activity extending from Bikini to Eniwetok and continuing westward to the southwest corner of the sampling area. The highest levels along this line were greater than 50,000 c/m/g in the area from Eniwetok to about 35 miles westward. In the area surveyed, the lowest values were in the northwest quadrant, with the minimum value, 1,300 d/m/g, at the most northwesterly station, 1A, at 14° N - 159° E.

The plankton tows were made to a depth of about 200 meters, which assured complete sampling of the stirred layer. It is generally accepted that the stirred layer exists only above the thermocline, a region in which temperature decreases rapidly with increase in depth. Bathythermograph casts were made at each station to determine temperature changes with depth and from these data the area of the thermocline was determined. Examples of bathythermograph traces are shown in Figure 11. Surface temperatures were approximately 81° to 83°F and remained practically unchanged to a depth of about 300 feet; below 300 feet temperatures decreased, and at the 450 foot level were 70° to 74°F, indicating that, in general, the upper limit of the thermocline was just below 300 feet or about 100 meters.

Water: The radioactive content of the water samples from the fifty-three collecting stations is presented in Table 1. The sums of the values of radioactivity of the residue from one liter of sea water and of the filtered water, less K^{40}, for each station and depth are given in Table 2. Table 3 summarizes the percentage contribution of each component to the total radioactivity for all stations at each sample depth.

Measurable amounts of radioactive materials were found in the water at each station sampled. In general, the northwestern part of the area had the lowest values. The highest readings were from station 9D near the northwestern edge of Bikini Atoll.

The surface samples had a higher average value for total radioactivity, 10,000 d/m/l, than samples from other depths. This value is the average of the sums of the radioactivity of the residue on the filter paper and that in the filterable portion. Water samples obtained from the 100-meter depth had the lowest average radioactive content, 3,900 d/m/l.

The distribution of the radiation in the water at the depths sampled is illustrated in Figures 12 to 16. The highest radiation levels for each depth sampled were at station 9D, immediately north of Bikini Atoll. A second area of concentration was found in a limited region north and west of Eniwetok Atoll.

In only the surface samples did the particulate matter retained on the filter paper have a greater radioactive content than the filterable fraction (Table 3). In the surface samples sixty per cent of the activity was recovered in the carbonate precipitate. In samples obtained from the 25, 50, 75 and 100-meter depths, most of the radiation passed through the filter paper, indicating that it was in solution.

While radioactive materials were found at all sampling stations the decline of the amounts found around the edge of the area under study suggests that the regions of greatest contamination were included in the survey.

<u>Fish Samples</u>: Time and facilities made it impossible to collect large numbers of fish. Some larval fish and eggs were represented in the plankton catches, but these were not analyzed separately. Table 1 contains the results of the analyses of the three flying fish. The livers of the two fish caught northwest of Eniwetok had lower values (3200 and 6200 d/m/g) than that of the fish caught northeast of Eniwetok (22,000 d/m/g); the converse was true for muscle (680 and 1000 d/m/g vs. 210 d/m/g).

<u>Continuous Monitoring of Water</u>: The values from the chart record are plotted in Figure 17, line A. A measure of contamination in the probe tank is indicated by the increase in the readings in Eniwetok lagoon at the beginning, midpoint and end of the survey. These values were 2 microroentgens on June 11, 9 on June 16 and 125 on June 21. A correction for the increase in background radiation was made. This was based on the assumption that the contamination in the probe tank rose in a stepwise manner with an increase in background resulting from each encounter with radioactivity higher than the previous background level. The estimated background is shown in Figure 17, line B. The major increases in background were assumed to occur in the areas of stations 1c, 2c, 5c, 8a, 9c, and 7d.

The background line, B, in Figure 17 was then used as the zero line in Figure 18. The differences between the background values and the observed chart values were plotted and the resulting line is assumed to be a more accurate representation of the radiation levels (Fig. 18).

The circled points in Figure 18 represent the activity in d/m/l of the surface water (Table 1). The levels of radioactivity in the surface water samples in most instances exhibit approximately the same pattern as do the corrected values from the probe record, although in some cases differences do occur. The greatest variation between the two sets of data is found in the latter part of the trip after high levels of radioactivity had been encountered in the area of stations 9B, C and D.

The scintillation monitoring unit exhibited good stability of the electronic components. There were, however, three problems encountered in the operation of the instrument: (1) retention of contamination in the sea water system, (2) failure of the photomultiplier tube as a result of vibration, and (3) build-up of static charges in the sea water from pumping through plastic pipe. This was partially corrected by scraping away a small portion of the rubber lining of the tank.

Before the unit is used in subsequent operations it is suggested that the following changes be made:

1. Install a self-priming heavy duty pump with a capacity of 30-40 gallons per minute immediately ahead of the tank.

2. Use only metal pipe, not lined with plastic or rubber.

3. Install grounding bars inside the tank for discharge of static charges in the water.

4. Direct the incoming stream of water downward inside the tank from a pipe parallel to and within three inches of the bottom of the tank.

5. Install a three-inch valve on the bottom of the tank

to facilitate draining and decontaminating the interior.

6. Shock-mount the probe with at least one inch of sponge rubber.

7. Add range scales to the control unit with the following ranges: 5, 30, 50, 300, 500, and 3000 microroentgens.

Gamma Ray Spectra. Plankton sample 9D was first analyzed, unashed, on June 22, ashed and analyzed on June 23, and allowed to decay until July 2, when it was again analyzed.

The results are shown in Table 4. Both the gamma peaks for I^{131} (.32 and .66 Mev) and Ru^{103} (.23 Mev) exhibited marked reduction in intensity after ashing. The I^{131} peak, accounting for most of the iodine activity (.32 Mev, 85 per cent), had disappeared by July 2.

The gamma spectrum curves give good indications for the presence of Mo^{99}, Ru^{103}, I^{131}, Ba^{140} and La^{140}. The presence of Zr^{95} and Ce^{141} is questionable.

Fig. 1. Tank Containing Probe for Monitoring Water.

Fig. 2. Power Winch and A-frame.

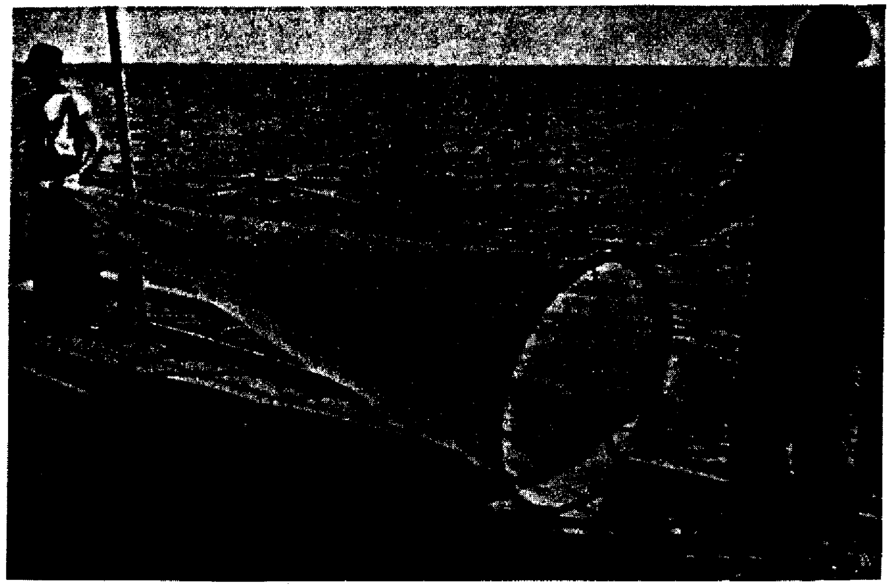

Fig. 3. One-Meter Plankton Net.

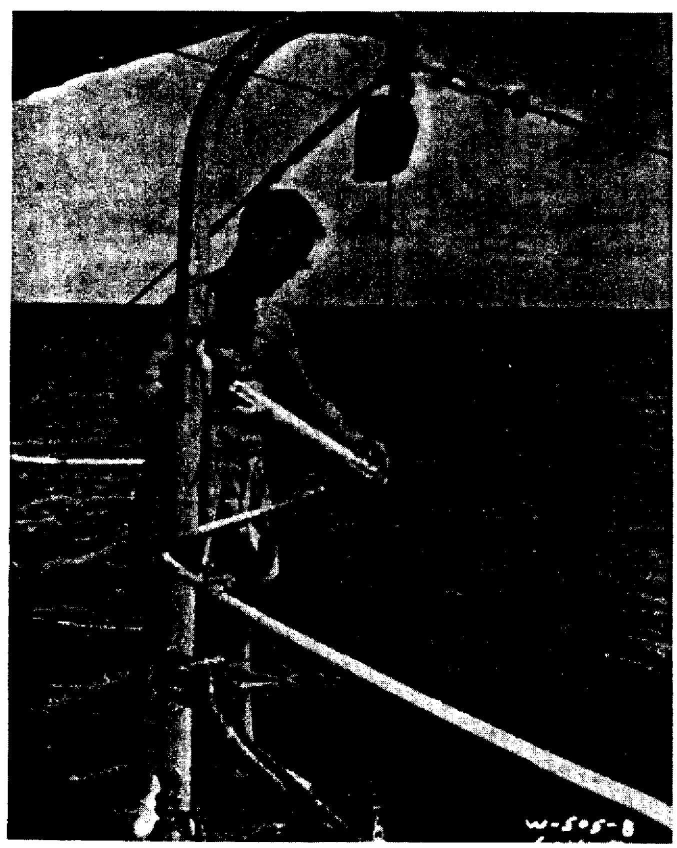

Fig. 4. Davit, Meter Block, Water Bottle and Platform.

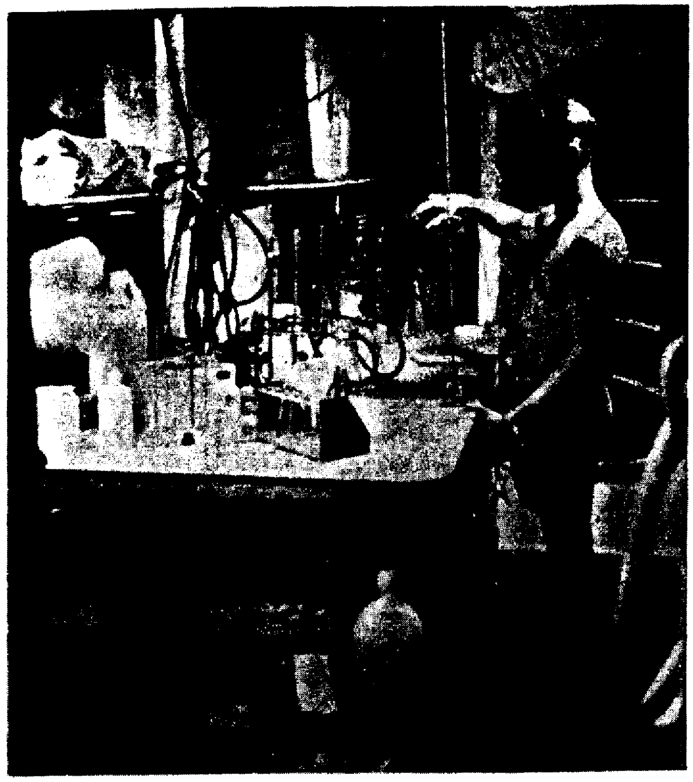

Fig. 5. Temporary Chemistry Laboratory in Crew's Quarters.

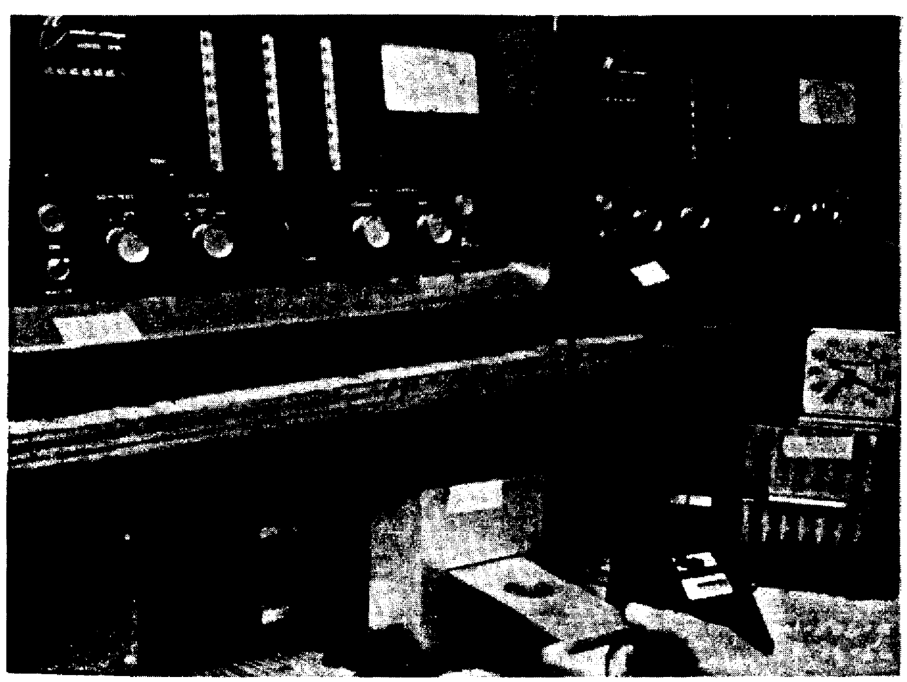

Fig. 6. Counters and Scalers Installed in After Officers' Quarters.

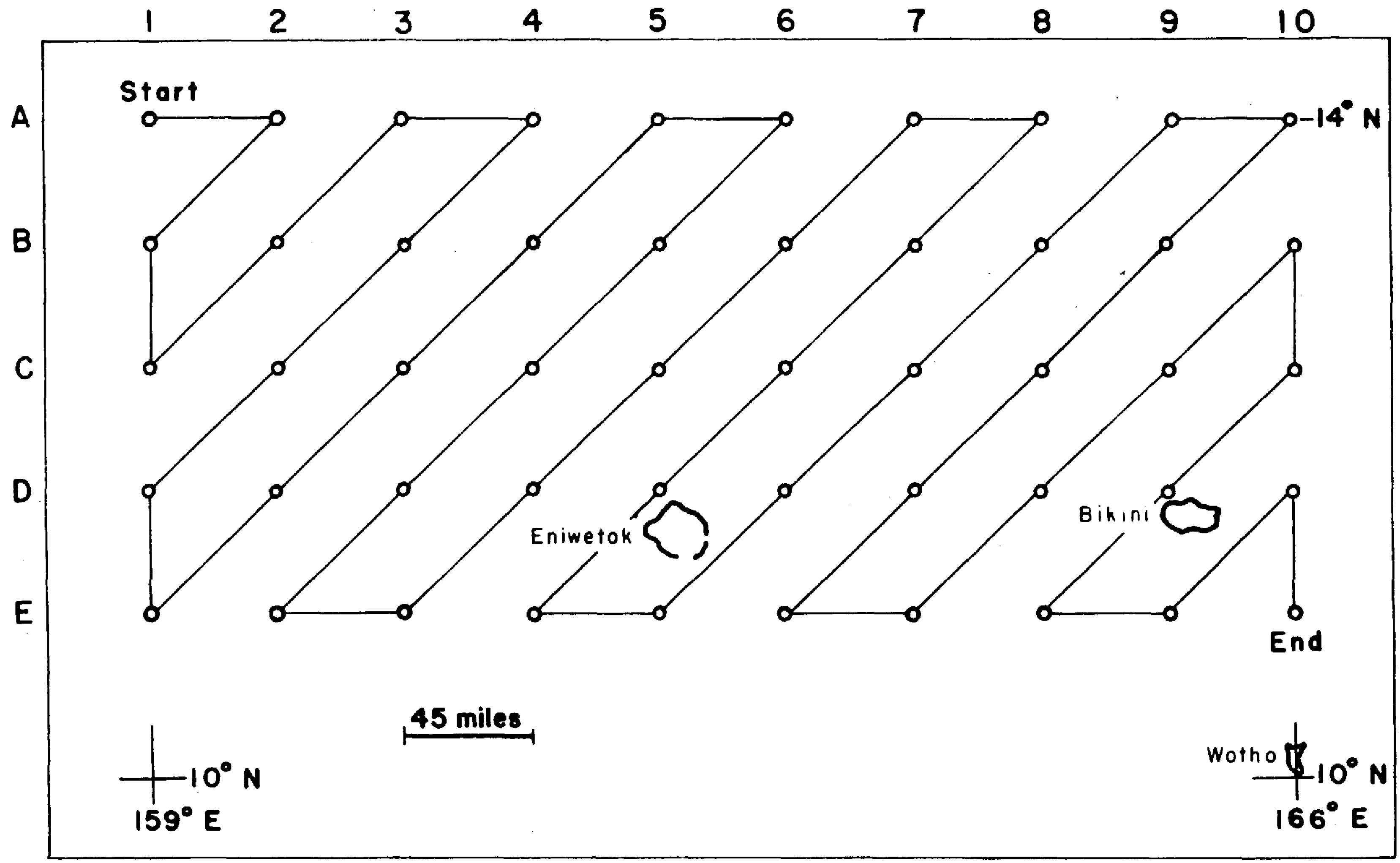

FIG. 7. PROPOSED TRACK OF THE WALTON - JUNE 1956

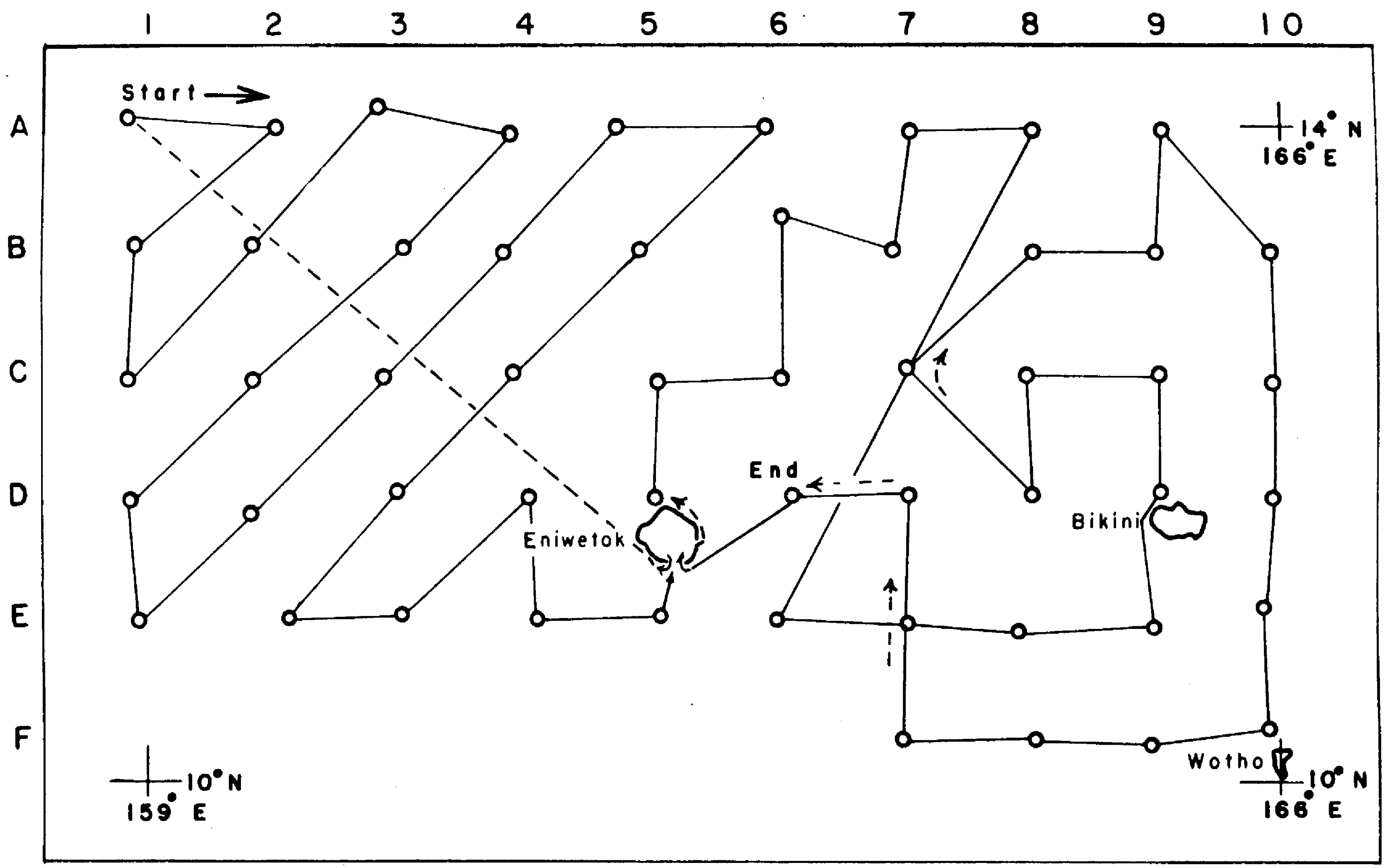

FIG. 8. TRACK OF THE WALTON - JUNE 11-21, 1956

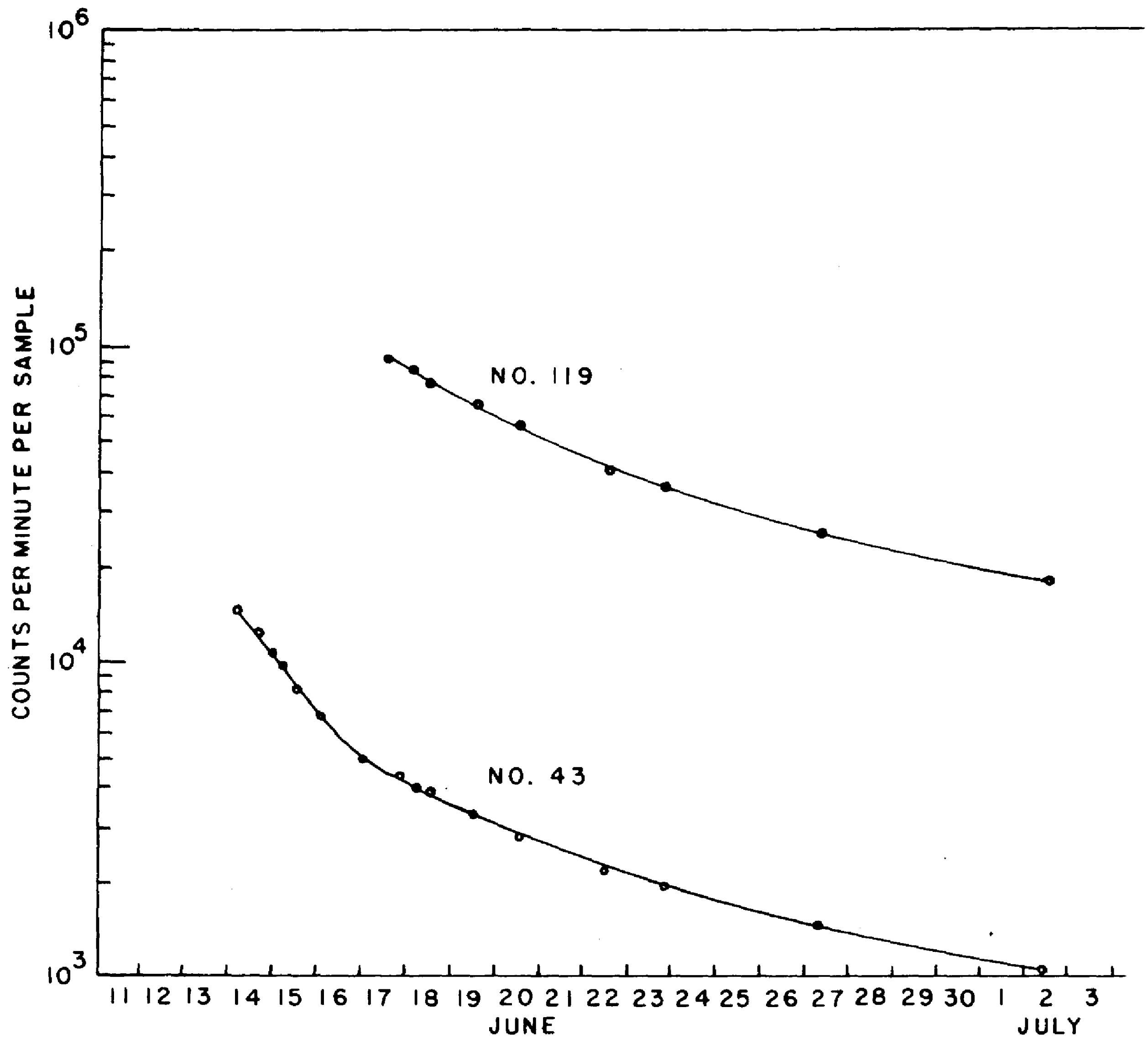

FIG. 9 RADIOACTIVE DECAY OF PLANKTON SAMPLES

NO. 43 USED FOR CORRECTING SAMPLES FROM SECTIONS I TO

NO. 119 " " " " " " 6 TO

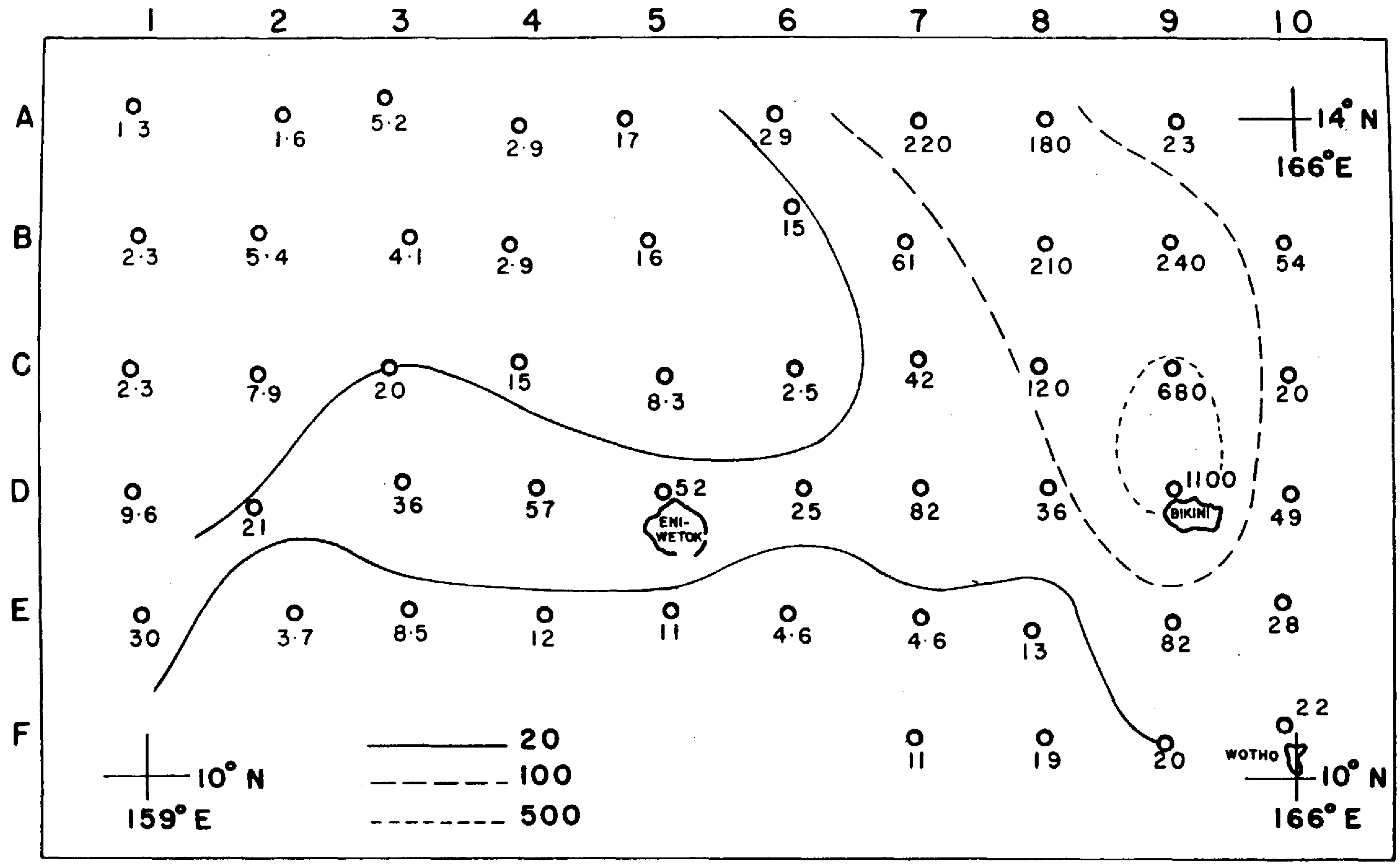

FIG. 10. RADIOACTIVITY OF PLANKTON IN THOUSANDS OF DISINTEGRATIONS PER MINUTE PER GRAM

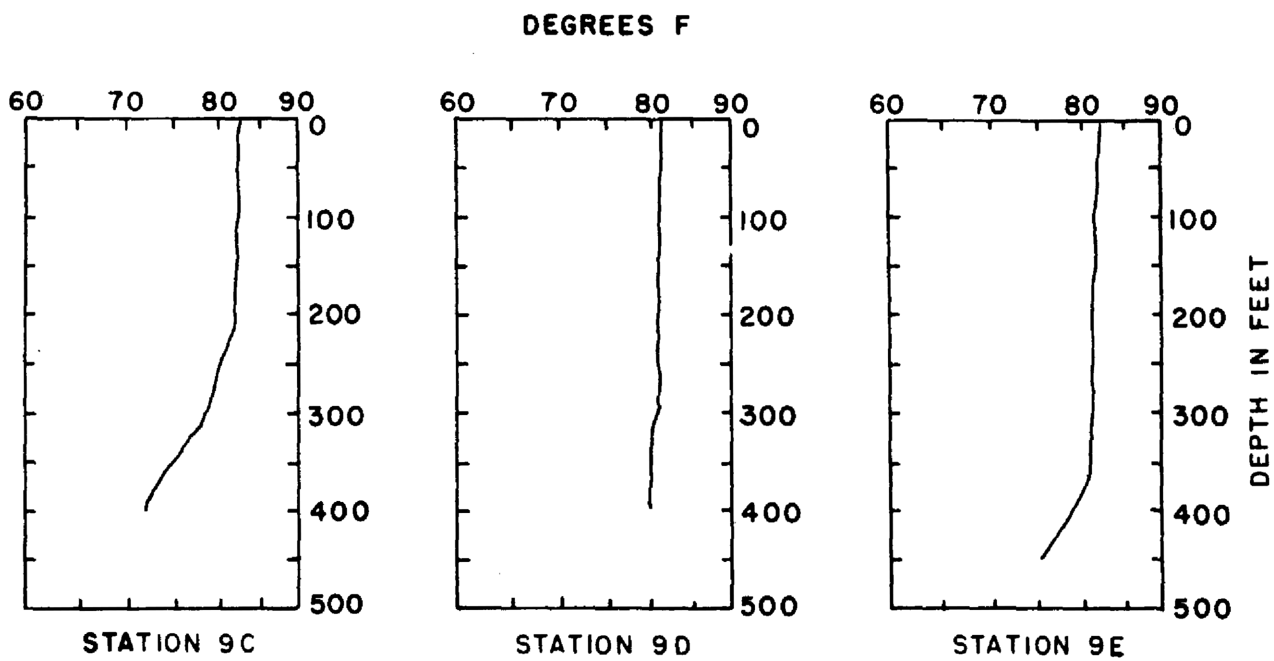

FIG. 11 EXAMPLES OF PLOTS FROM BATHYTHERMOGRAPH TRACES

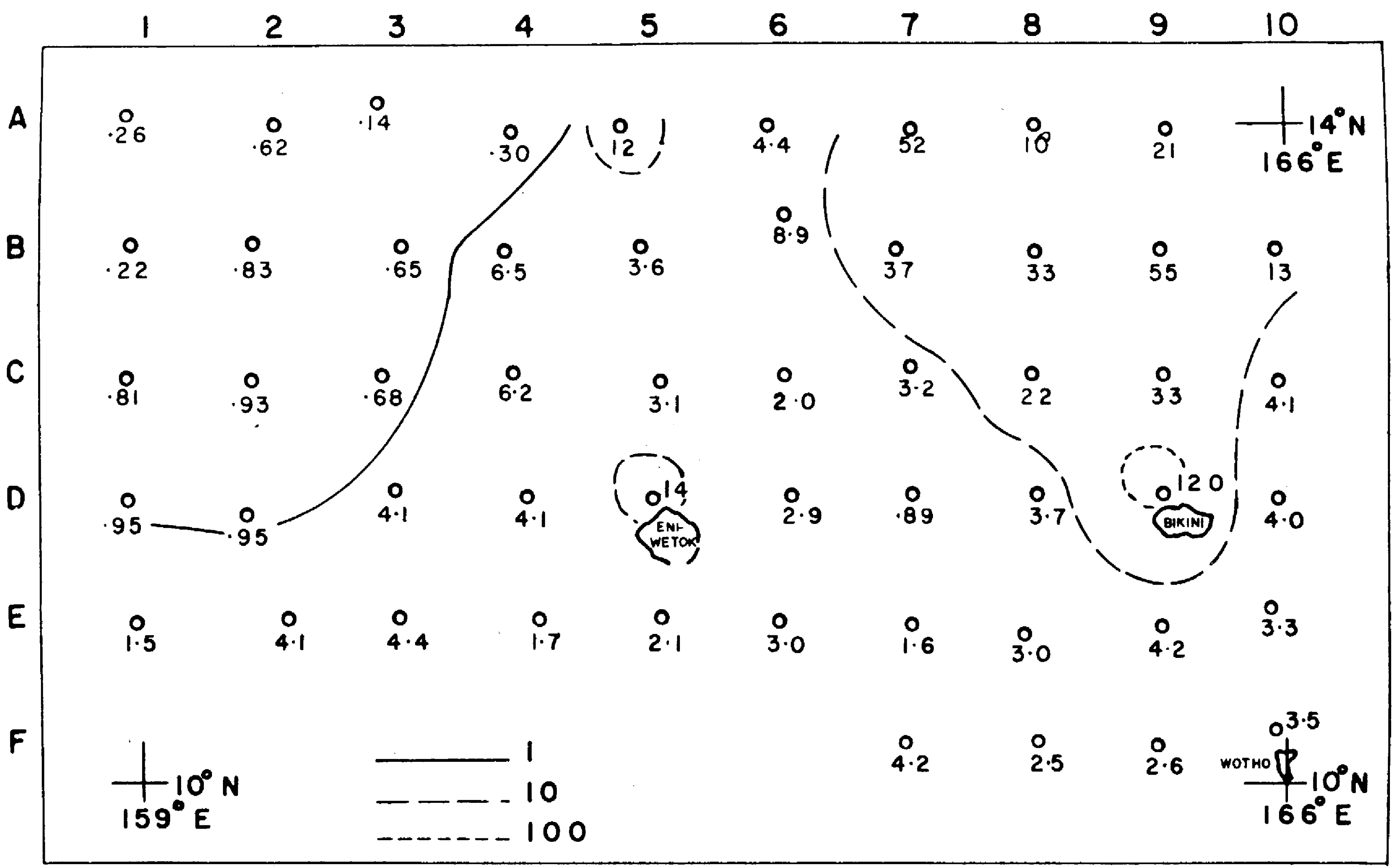

FIG. 12. RADIOACTIVITY OF SURFACE WATER IN THOUSANDS OF DISINTEGRATIONS PER MINUTE PER LITER

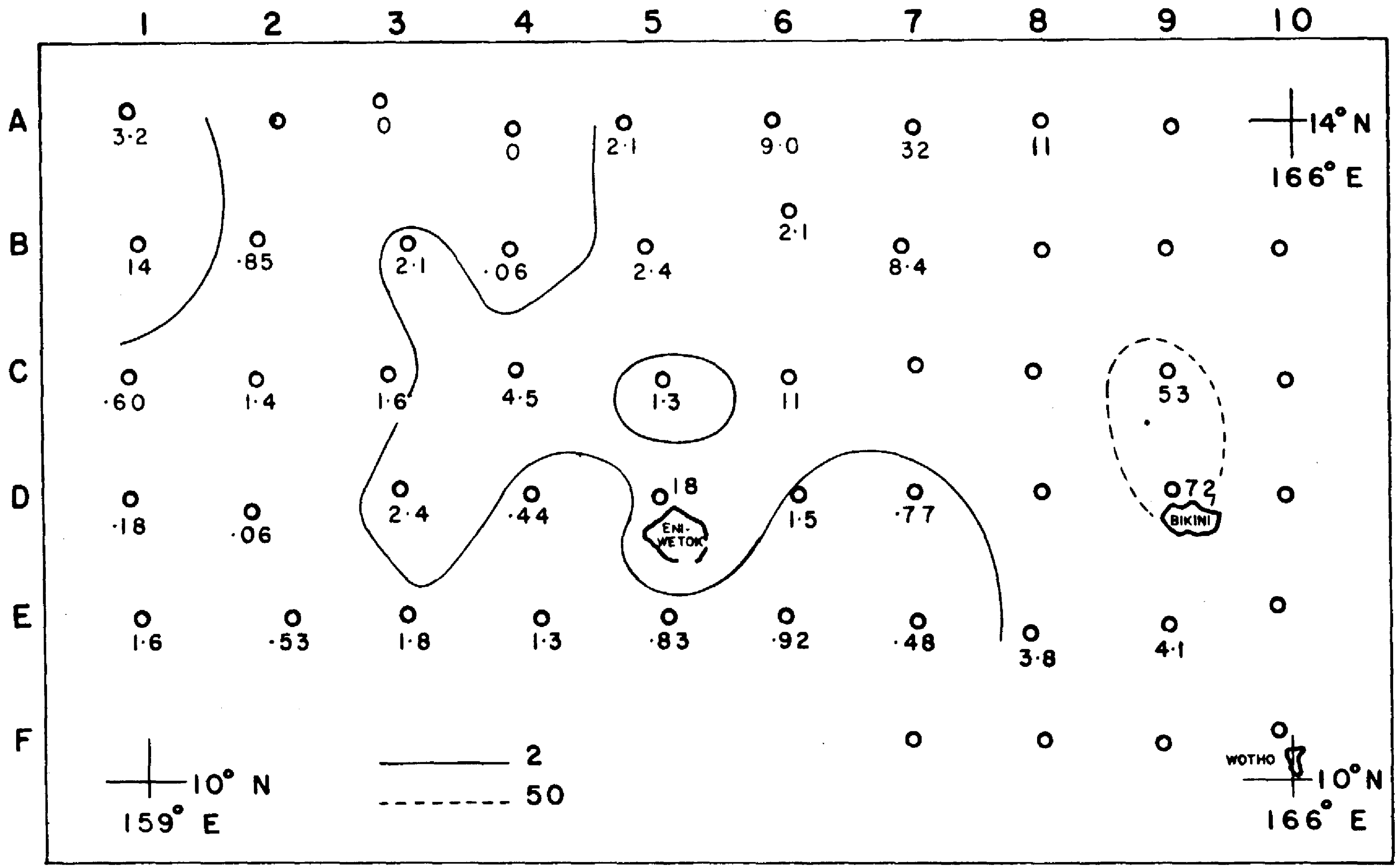

FIG. 13. RADIOACTIVITY OF WATER FROM 25 METER DEPTH IN THOUSANDS OF DISINTEGRATIONS PER MINUTE PER LITER.

THOUSANDS OF DISINTEGRATIONS PER MINUTE PER LITER.

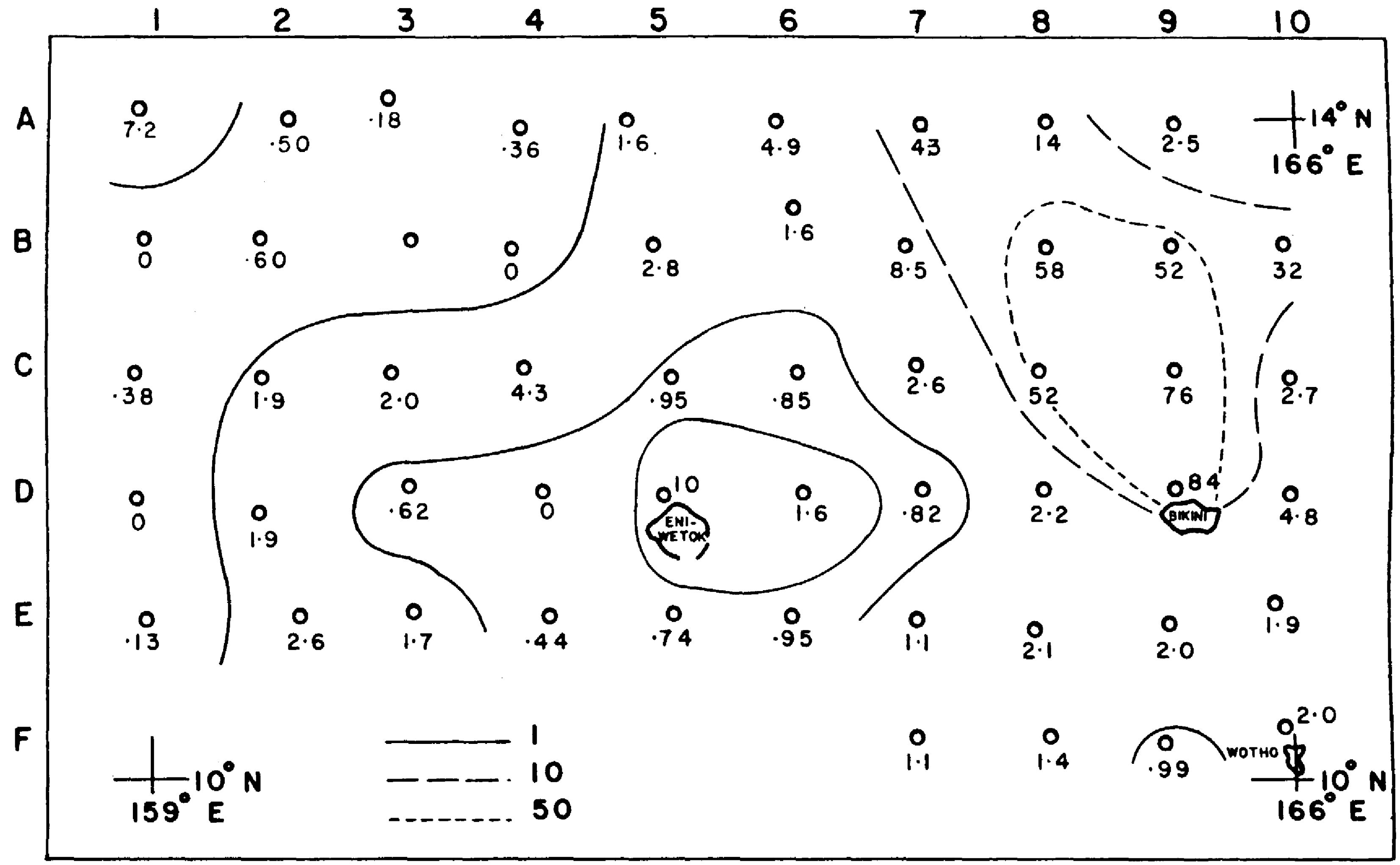

FIG. 14 RADIOACTIVITY OF WATER FROM 50 METER DEPTH IN THOUSANDS OF DISINTEGRATIONS PER MINUTE PER LITER.

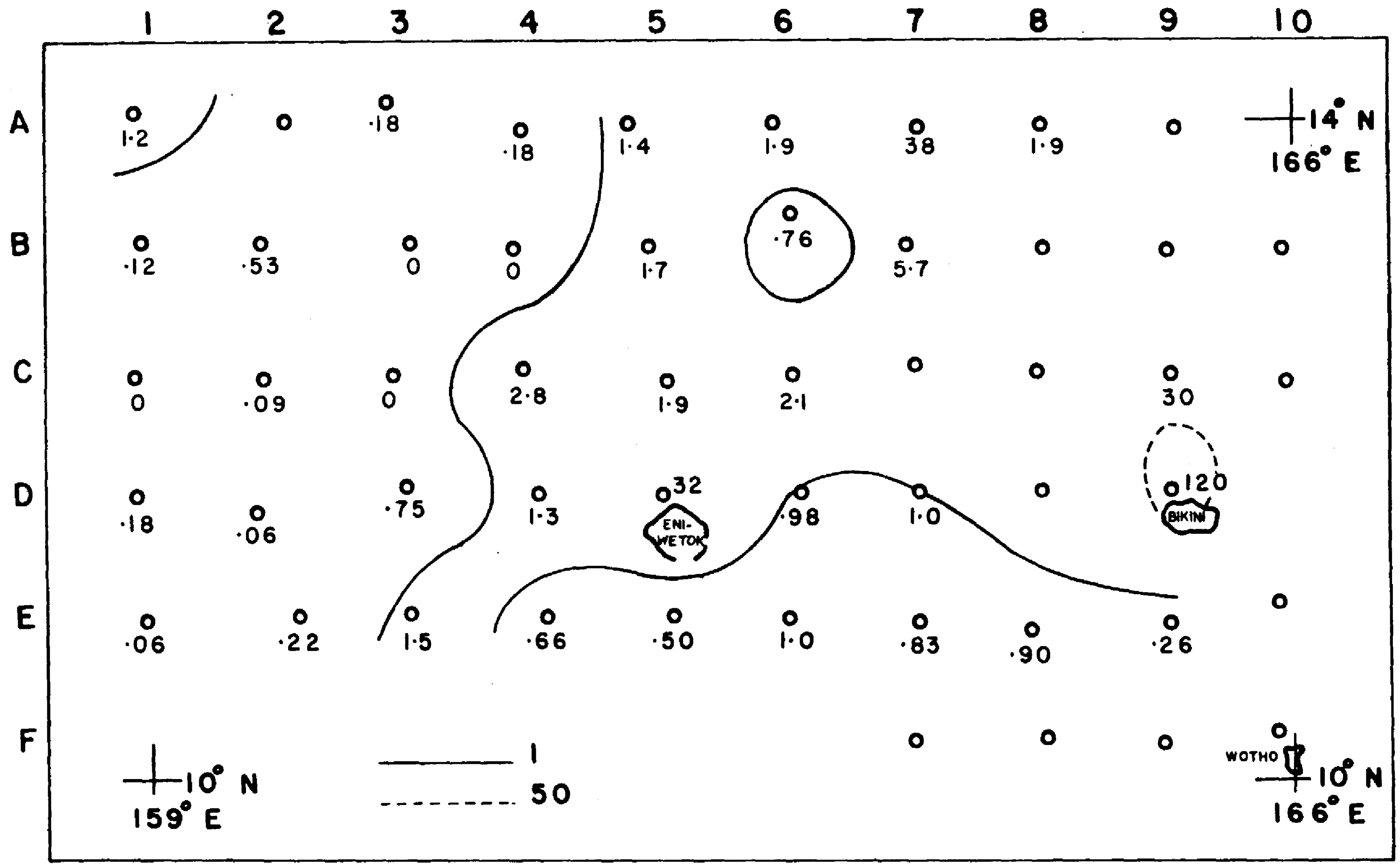

FIG. 15. RADIOACTIVITY OF WATER FROM 75 METER DEPTH IN THOUSANDS OF DISINTEGRATIONS PER MINUTE PER LITER.

THOUSANDS OF DISINTEGRATIONS PER MINUTE PER LITER.

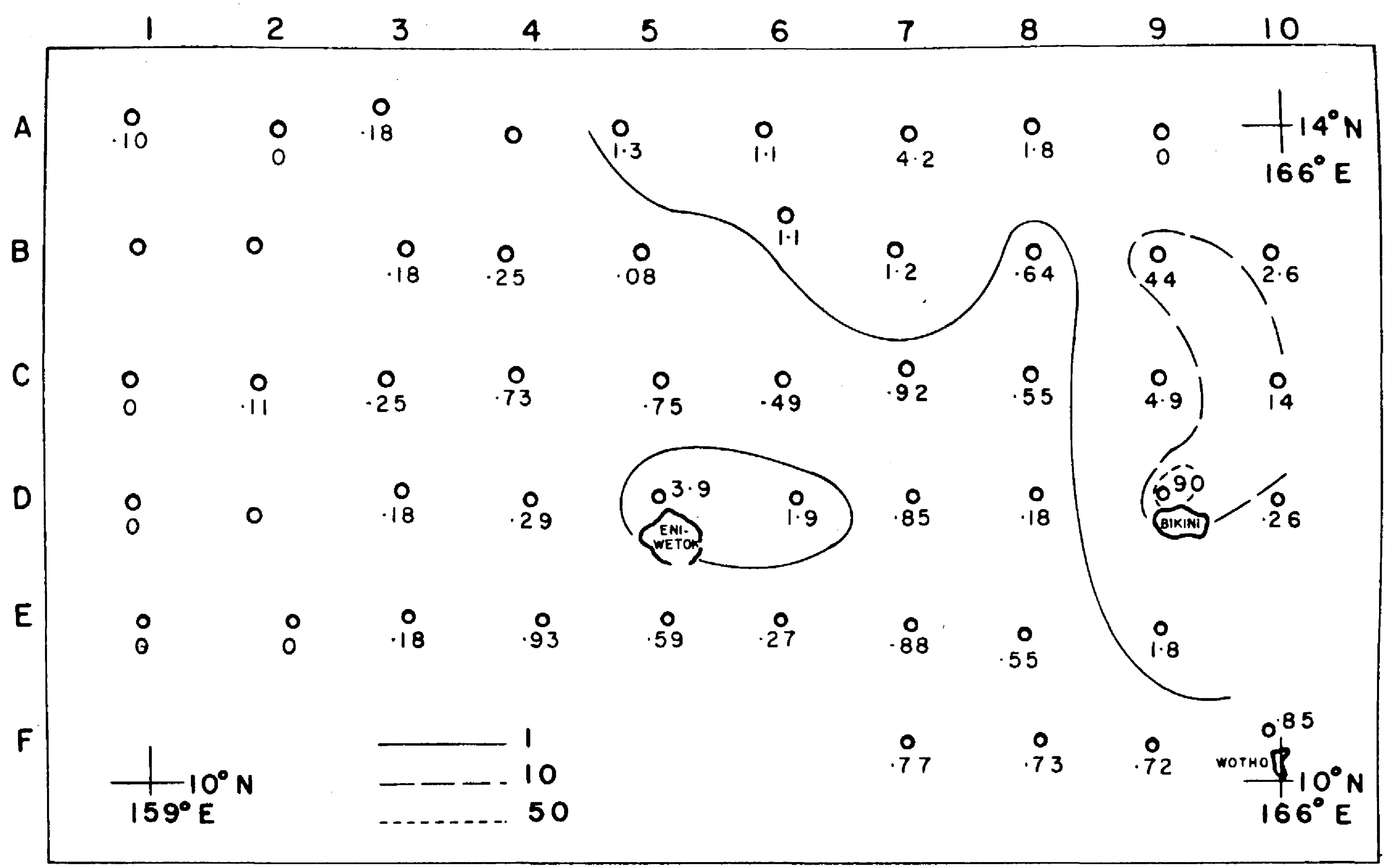

FIG. 16. RADIOACTIVITY OF WATER FROM 100 METER DEPTH IN THOUSANDS OF DISINTEGRATIONS PER MINUTE PER LITER.

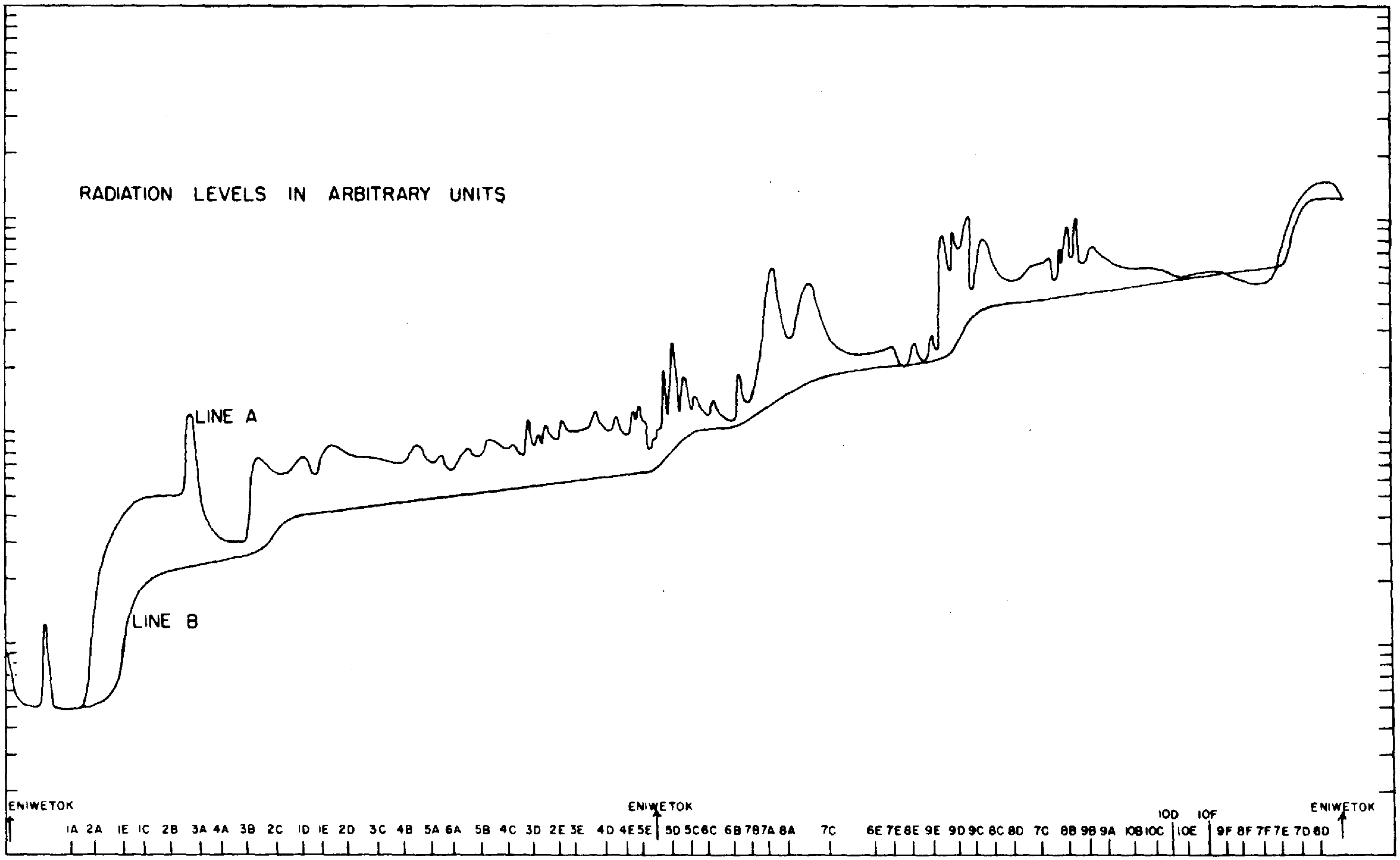

FIG. 17 PLOT FROM PROBE TRACE, LINE A. ESTIMATED INCREASE IN BACKGROUND FROM CONTAMINATION, LINE B.

FIG. 17 PLOT FROM PROBE TRACE, LINE A. ESTIMATED INCREASE IN BACKGROUND FROM CONTAMINATION, LINE B.

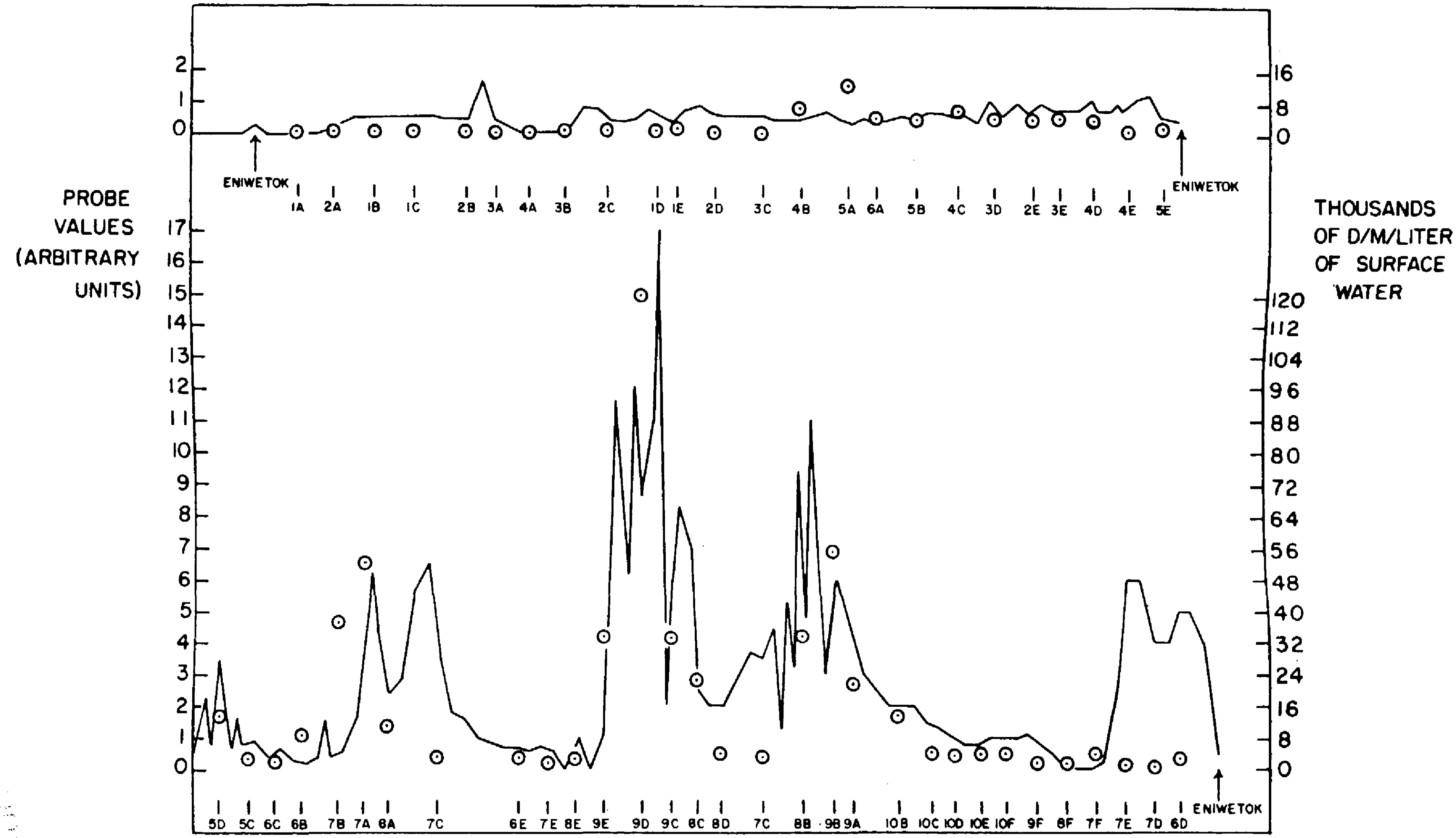

FIG. 18. CORRECTED RADIATION PLOT FROM PROBE TRACE. CIRCLED POINTS SHOW RADIOACTIVITY OF SURFACE WATER.

Table 1. Radioactivity of Plankton, Filter Paper with Residue from Water and Filtered Water (less K^{40}).

Plankton in d/m/g wet
Filter Paper with Residue in d/m/liter of water
Water in d/m/liter

	Plankton	Filter Paper					Water				
Station		Surface	25m.	50m.	75m.	100m.	Surface	25m.	50m.	75m.	100m.
1A	1300	23	0	7200	100	100	240	3200	0	1100	0
B	2300	120	0	0	120	-	100	14000	0	0	-
C	2300	490	0	380	0	0	320	600	0	0	0
D	9600	670	180	0	180	0	280	0	0	0	0
E	30000	1100	130	130	62	0	400	1500	0	0	0
2A	1600	110	-	500	-	0	510	-	0	-	0
B	5400	440	0	180	530	-	390	850	420	0	-
C	7900	560	89	180	89	110	370	1300	1700	0	0
D	21000	650	63	440	62	-	300	0	1500	0	-
E	3700	2300	92	180	0	0	1800	440	2400	220	0
3A	5200	40	0	180	180	180	100	0	0	0	0
B	4100	190	440	-	0	180	460	1700	-	0	0
C	20000	63	130	190	0	250	620	1500	1800	0	0
D	36000	2700	180	180	92	180	1400	2200	440	660	0
E	8500	2200	46	180	0	180	2200	1800	1500	1500	0
4A	2900	250	0	360	180	-	48	0	0	0	-
B	2900	6100	63	0	0	250	380	0	0	0	0
C	15000	3400	340	290	250	130	2800	4200	4000	2600	600
D	57000	1900	0	0	0	0	2200	440	0	1300	2900
E	12000	1100	230	0	0	46	580	1100	440	660	880
5A	17000	8000	0	63	190	62	4300	2100	1500	1200	1200
B	16000	1600	210	42	84	84	2000	2200	2800	1600	0
C	8300	1500	120	62	120	160	1600	1200	890	1800	590
D	52000	5100	1100	400	1700	62	8800	17000	10000	30000	3800
E	11000	1600	93	0	62	0	520	740	740	440	590

Table 1 (continued)

Station	Plankton	Filter Paper Surface	Filter Paper 25m.	Filter Paper 50m.	Filter Paper 75m.	Filter Paper 100m.	Water Surface	Water 25m	Water 50m.	Water 75m.	Water 100m.
6A	29000	2500	1100	2300	0	200	1900	7900	2600	1900	930
B	15000	7500	100	0	100	0	1400	2000	1600	660	1100
C	2500	680	210	34	1000	0	1300	980	820	1100	490
D	25000	2200	60	360	120	300	740	1400	1200	860	1600
E	4600	1300	0	39	77	0	1700	920	920	920	270
7A	220000	33000	1500	10000	2100	540	19000	30000	33000	36000	3700
B	61000	34000	270	620	230	230	3200	8100	7900	5500	920
C	42000	640	-	0	-	160	2600	-	2600	-	760
D	82000	490	0	54	640	210	400	770	770	380	640
E	4600	620	0	34	34	240	1000	480	1100	800	640
F	11000	3700	-	140	-	0	500	-	1000	-	770
8A	180000	5800	540	1200	77	150	4500	10000	13000	1800	1700
B	210000	12000	-	9600	-	32	21000	-	48000	-	610
C	120000	4500	-	10000	-	0	17000	-	42000	-	550
D	36000	1400	-	0	-	0	2300	-	2200	-	180
E	13000	690	370	170	100	67	2300	3400	1900	800	480
F	19000	1700	-	210	-	220	780	-	1200	-	510
9A	23000	19000	-	170	-	0	2400	-	2300	-	0
B	240000	25000	-	6100	-	10000	30000	-	46000	-	34000
C	680000	12000	180	20000	7300	1900	21000	53000	56000	23000	3000
D	1100000	85000	2500	20000	33000	26000	37000	70000	64000	91000	64000
E	82000	3000	420	150	77	500	1200	3700	1800	180	1300
F	20000	1800	-	220	-	210	780	-	770	-	510
10B	54000	2300	-	1000	-	260	11000	-	31000	-	2300
C	20000	2400	-	0	-	6200	1700	-	2700	-	7300
D	49000	2600	-	140	-	0	1400	-	4600	-	260
E	28000	1900	-	210	-	-	1400	-	1700	-	-
F	22000	2700	-	140	-	210	800	-	1900	-	640

Flying fish	Spec.#	Location	Organ	d/m/g
	58	Between Eniwetok & 2A	muscle	680
	58	" " "	liver	3200
	59	Between 7C & 8B	muscle	210
	59	" " "	liver	22000
	60	Near 4C	muscle	1000
	60	" "	liver	6200

Table 2. Sums of Values of Radioactivity of Residue from Water and Filtered Water (less K^{40}).

Station	Surface	25m	50m	75m	100m
1A	260	3200	7200	1200	100
B	220	14000	0	120	-
C	810	600	380	0	0
D	950	180	0	180	0
E	1500	1600	130	62	0
2A	620	-	500	-	0
B	830	850	600	530	-
C	930	1400	1900	89	110
D	950	63	1900	62	-
E	4100	530	2600	220	0
F					
3A	140	0	180	180	180
B	650	2100	-	0	180
C	680	1600	2000	0	250
D	4100	2400	620	750	180
E	4400	1800	1700	1500	180
F					
4A	300	0	360	180	-
B	6500	63	0	0	250
C	6200	4500	4300	2800	730
D	4100	440	0	1300	2900
E	1700	1300	440	660	930
F					
5A	12000	2100	1600	1400	1300
B	3600	2400	2800	1700	84
C	3100	1300	950	1900	750
D	14000	18000	10000	32000	3900
E	2100	830	740	500	590
F					

Station	Surface	25m	50m	75	100m
6A	4400	9000	4900	1900	1100
B	8900	2100	1600	760	1100
C	2000	11000	850	2100	490
D	2900	1500	1600	980	1900
E	3000	920	950	1000	270
7A	52000	32000	43000	38000	4200
B	37000	8400	8500	5700	1200
C	3200	-	2600	-	920
D	890	770	820	1000	850
E	1600	480	1130	830	880
F	4200	-	1100	-	770
8A	10300	11000	14000	1900	1800
B	33000	-	58000	-	640
C	22000	-	52000	-	550
D	3700	-	2200	-	180
E	3000	3800	2100	900	550
F	2500	-	1400	-	730
9A	21000	-	2500	-	0
B	55000	-	52000	-	44000
C	33000	53000	76000	30000	4900
D	120000	72000	84000	120000	90000
E	4200	4100	2000	260	1800
F	2600	-	990	-	720
10A		-			
B	13000	-	32000	-	2600
C	4100	-	2700	-	14000
D	4000	-	4800	-	260
E	3300	-	1900	-	-
F	3500	-	2000	-	850

Table 4. Gamma Energies by Spectrometry from Plankton Sample 9D.

Sample 9D unashed counted 6/22/56		Sample 9D ashed counted 6/23/56		Sample 9D ashed counted 7/2/56		Possible Isotopes
energy	intensity	energy	intensity	energy	intensity	
.06	strong	.06	strong	.06	strong	Unknown
.15	strong	.15	strong	.15	weak	Mo^{99} Ce^{141}
.23	weak	.23	very weak	.23	very weak	Ru^{103}
.33	medium	.32	weak	.32	absent	I^{131}
.51	strong	.51	strong	.51	medium	Ba^{140} La^{140}
.66	strong	.66	medium	.66	weak	I^{131}
.74	strong	.74	strong	.76	medium	Zr95 Mo99 La^{140}
.92	weak	.92	absent	.92	absent	Unknown
1.1	weak	1.1	absent	1.1	absent	Unknown
1.2	weak	1.2	absent	1.2	absent	Unknown
1.3	weak	1.3	absent	1.3	absent	Unknown
1.55	weak	1.55	weak	1.55	weak[x]	La^{140}
1.55-3	absent	1.55-3	absent	1.55-3	absent	

[x] Not weaker than intensities of 6/22 and 6/23.

Good indication of Mo^{99}, Ru^{103}, I^{131}, Ba^{140} and La^{140}.

Possible presence of Zr^{95} and Ce^{141}.

SUMMARY

A survey to determine the amount of radioactivity in the waters about Bikini and Eniwetok Atolls was made during the period June 11 to 21, 1956.

A grid of stations about 45 miles apart covering 78,000 square miles of ocean between 10° 15' N to 14° N and 159° to 166° E was covered by the survey. The distance traveled was 3,300 miles.

Radioactive materials were found in the plankton samples from every station. The highest plankton counts, 1,100,000 d/m/g (wet weight) were obtained near Bikini Atoll, and the lowest, 1,300 d/m/g, in the northwestern part of the survey area.

The average value for plankton was 71,000 d/m/g which was 7,100 times the average surface water value.

Water samples were collected at surface and at depths of 25, 50, 75 and 100 meters.

The average radioactivity of water was 10,000 d/m/l at the surface and 3,900 d/m/l at 100 meters.

A scintillation probe was used to continuously record the radioactivity of the surface water. This method has interesting possibilities if problems of contamination, vibration, and static electricity can be overcome.

The survey successfully demonstrated the usefulness of the various methods in evaluating the amount and distribution of radioactivity in the sea.