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RADIOACTIVE PLANKTON FROM THE COLUMBIA RIVER

by

R. W. Coopey

March 29, 1951

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ABSTRACT

Plankton collections using a silk net were made from the Columbia River above and below the Hanford Works production area from February 1949 to February 1950.

The usual limnological chemical tests indicate a relatively stable river environment throughout the year with only small variations in pH, alkalinity, and per cent oxygen saturation. The overall view shows no conditions greatly different from those of other natural waters of this region. No significant influence on characteristics of the river due to the plant operation can be found from the measurements taken.

Activity density measurements at Hanford show a maximum plankton value of 7.9×10^{-3} $\mu c/gm$ wet weight during January, 1950. Activity density of water and plankton is inversely related to river flow volume, being lowest during the early summer freshet season and highest during the fall and winter minimal flow periods.

Plankton numerical abundance, with diatoms predominating, shows pulses of Asterionella, Melosira, and Fragilaria during the warmer months reaching a maximum in the May to August period followed by lesser abundance during the winter season.

Gravimetric analysis shows 1200 mg of wet weight plankton per cubic meter of river water at maximum. Plankton being carried by the river past Hanford is estimated at 5.2×10^5 kg (570 tons) per day during May while the radioactivity it contained averaged 0.6 curies per day in July.

Decay curve results indicate 5 to 30 per cent of the activity results from isotopes with half-lives near or longer than that of P^{32} while the remaining major portion is of shorter half-life material. A small proportion of activity persists after 600 days decay.

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RADIOACTIVE PLANKTON FROM THE COLUMBIA RIVER

INTRODUCTION

Previous results (1) based on fragmentary data, indicated that plankton organisms concentrated radioactive isotopes from the greatly diluted pile effluent water present in the Columbia River. As a consequence, plankton became a matter of radiobiological interest and the limited work carried on previously was expanded early in 1949 to permit more regulated sample collection in the immediate vicinity of Hanford Works.

Although the present program is admittedly incomplete in scope and in addition considerable work remains undone on the analyses of collections, the results presented here give a brief summary of the findings.

METHODS

Plankton samples were collected with a conical net of 23 centimeters (9 inches) aperture diameter constructed of No. 20 standard silk bolting cloth. At two collecting stations, one above the Hanford Works and another near Hanford, Washington, quantitative samples were obtained from pumping plants operating in connection with the production plant. Activity density samples were taken at these two stations by the same method as for quantitative samples, while at Hanford, Washington and McNary Damsite near Umatilla, Oregon, samples were obtained by suspending the nets in the river current near shore. From a measured water flow source, a definite quantity was allowed to filter through nets, which were suspended in water, at a rate of 25 to 50 liters per net per minute. Gravimetric samples were concentrated from 3000 to 5000 liters of water depending on the abundance of organisms whereas samples for numerical count were concentrated from between 200 and 300 liters. The plankton concentrate to be used for gravimetric determinations was washed into large-mouth jars and preserved with formalin for future processing. Samples used for determining the abundance of organisms were

counted soon after collection and before preservative was added. Large proportions of sand were collected with the samples particularly during the early summer freshet season. Gross separation was accomplished by allowing the samples to settle for 15 to 20 seconds and decanting off the plankton. The sand residue was washed twice to remove trapped plankton organisms. In spite of this precaution, varying amounts of fine sand and silt remained in the samples and contributed additional weight to the gravimetric results. The silt and sand is ignored in the numerical counting procedure and except for slight volumetric considerations, is not of importance.

Preliminary tests indicate that the method of sample collection at the pumping plants yields results which do not differ radically from samples collected directly from the river.

Numerical abundance was determined by the accepted procedures outlined by Welch (2) using a representative one milliliter portion of the mixed plankton concentrate in a Sedgewick-Rafter counting cell. A survey count of the entire cell was made for the larger organisms while an average of ten random fields covered by a Whipple ocular grid was used for the smaller organisms. Calculations of numbers per milliliter of river water were made from these figures based on the area and volume of the counting cell and the degree of concentration of the sample counted. Filaments or colonies of green, blue-green and red algae were counted as one unit. Filaments of diatoms were measured and expressed as individual cells by calculation from the average number of cells per unit length of filament.

Gravimetric results were obtained from formalin preserved samples by filtering through Whatman low ash paper in a Buchner suction funnel, drying at 60°C. for 24 hours in a constant temperature oven and ashing at 650°C. in an electric muffle furnace. The filter paper and the plankton were weighed at each step in the process and the results expressed in milligrams per cubic meter of river water strained through the net to obtain the original sample. Samples were weighed in all cases after heat treatment while the sample temperature was between 60° and 80°C. to minimize the effect of moisture absorbed from

the atmosphere. A torsion balance sensitive to 10 mg was used for weighing with a total dry weights ranging from 800 to 4800 mg. Since wet weights were used in obtaining activity density results the wet weights of plankton are also reported.

Plankton concentrates for determination of activity density were separated from the sand, filtered in a suction funnel on hard filter paper, weighed in 0.5 gram portions on 1-1/2 inch stainless steel plates, dried under infra-red lamps and covered with cellophane before being counted.

Chemical and temperature data on the water were obtained from the Technical Division which ran these samples routinely by the following methods: Hydrogen ion determinations were made with a Beckman electrometric pH meter. Methyl orange and phenolphthalein alkalinity were obtained by titrating 100 ml samples with 0.04 N sulphuric acid. Water temperatures were taken at the surface near the center of the river with a thermometer accurate to 0.1° C. Dissolved oxygen results were obtained by using an unmodified Winkler method. Since the elevation above mean sea level is approximately 325 feet in this section of the river, no correction to sea level is made in the figures.

All the data given represent the monthly averages of several samples. A period of thirteen months from February, 1949 through February, 1950 is represented in the data. The results for February, 1950, are included to provide a means for comparison with the same month in 1949.

All activity counts were made with samples 0.48 cm from the window of a mica end window G.M. tube. Conversion to d/m was made by correcting the counts per minute by the method outlined by Healy, Schwendiman, and Thorburn (3) with additional corrections for self-absorption and radioactive decay on all samples.

RESULTS AND DISCUSSION

The physical and chemical characteristics of the river are shown in Figure 1. From these data the following generalized statements may be made: Hydrogen ion concentrations remain relatively stable exhibiting a change of only two-tenths of a pH number during the course of the

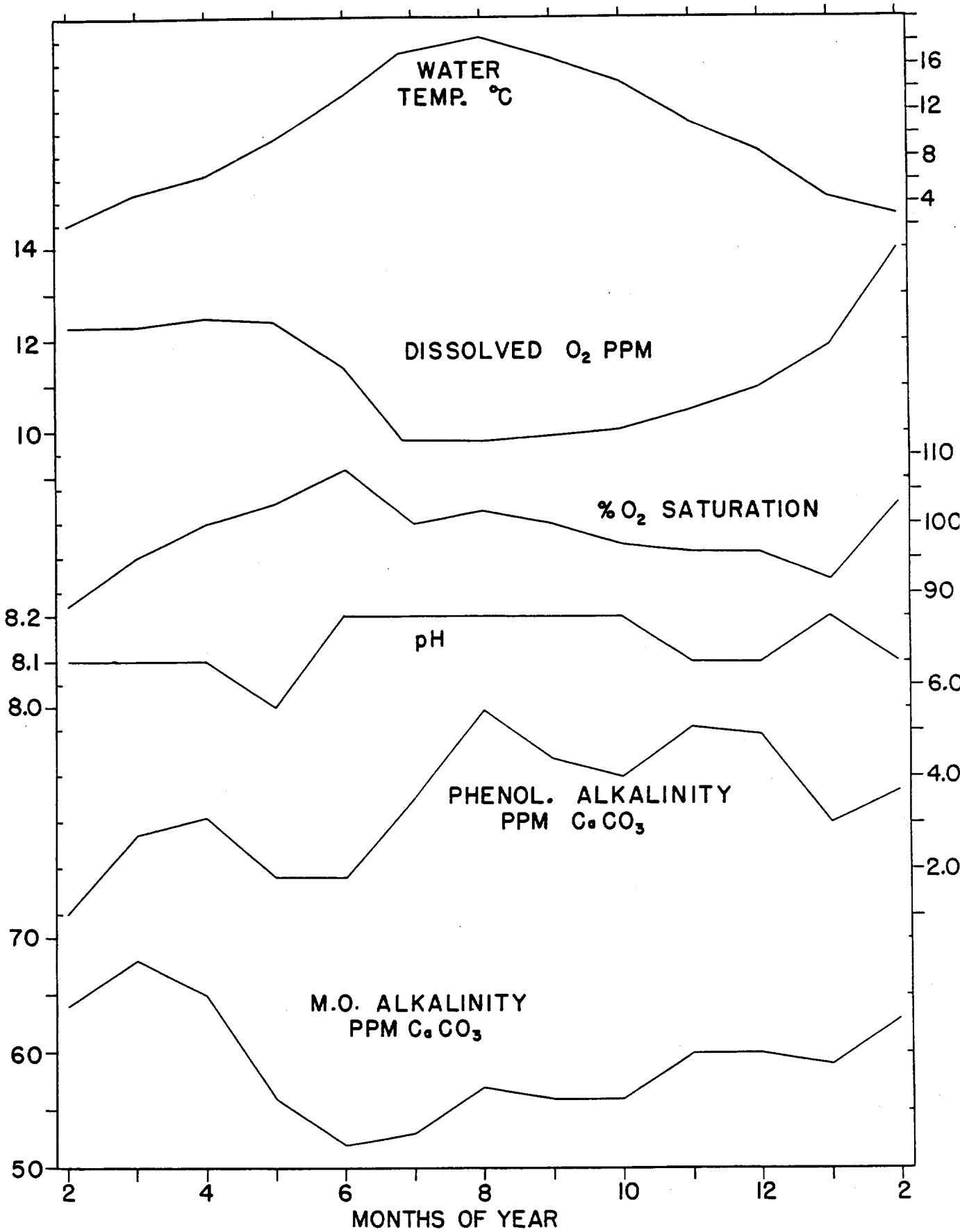

FIG. 1 COLUMBIA RIVER DATA FEB. 1949 TO FEB. 1950

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year. Methyl orange and phenolphthalein alkalinities are moderate and are commensurate with values found in comparable waters of this vicinity. The total alkalinity dropped perceptibly during the freshet season as is commonly observed in rivers. The phenolphthalein alkalinity increased slightly with a decrease in bicarbonate content during the summer season. Free carbon dioxide was absent during the period covered. Water temperatures followed the expected seasonal pattern of surrounding air temperatures. Dissolved oxygen content fluctuated inversely with water temperatures but remained in the vicinity of the saturation value throughout the year. A rise to a saturation value near 108 per cent during June 1949 may be attributed to the growth of diatoms at this time with the consequent photosynthetic release of oxygen to the water. All in all, the chemical data from the river show no features different from those which might be expected in similar bodies of water in this region.

Although these samples were taken at a point up-river from the Hanford Works, other samples were also routinely collected at Richland. Variations from the above results are only slight and without uniformity, indicating no demonstrable change in these chemical characteristics in this section of the river due to the operation of the Hanford Works.

Volume-of-flow data shown in Figure 2 were obtained from the Power Division of Hanford Works and show a pattern of increased water volume during the early summer period when melting mountain snows increased the run-off. Minimal flows occur during the fall and winter seasons when precipitation in the form of snow was accumulating at higher elevations.

The quantities of beta radioactivity contained by the plankton and the river water are given in Figure 2 for the Hanford samples. The general pattern of plankton and water activity density follows inversely that of the river flow fluctuations because a lower dilution factor for the pile effluent isotopes exists during low water periods while the converse is true at times of high water. In addition, the presence of considerable amounts of silt during the May, June, and July freshet season may have an effect, unevaluated at present, in further reducing the plankton activity density per unit weight of material.

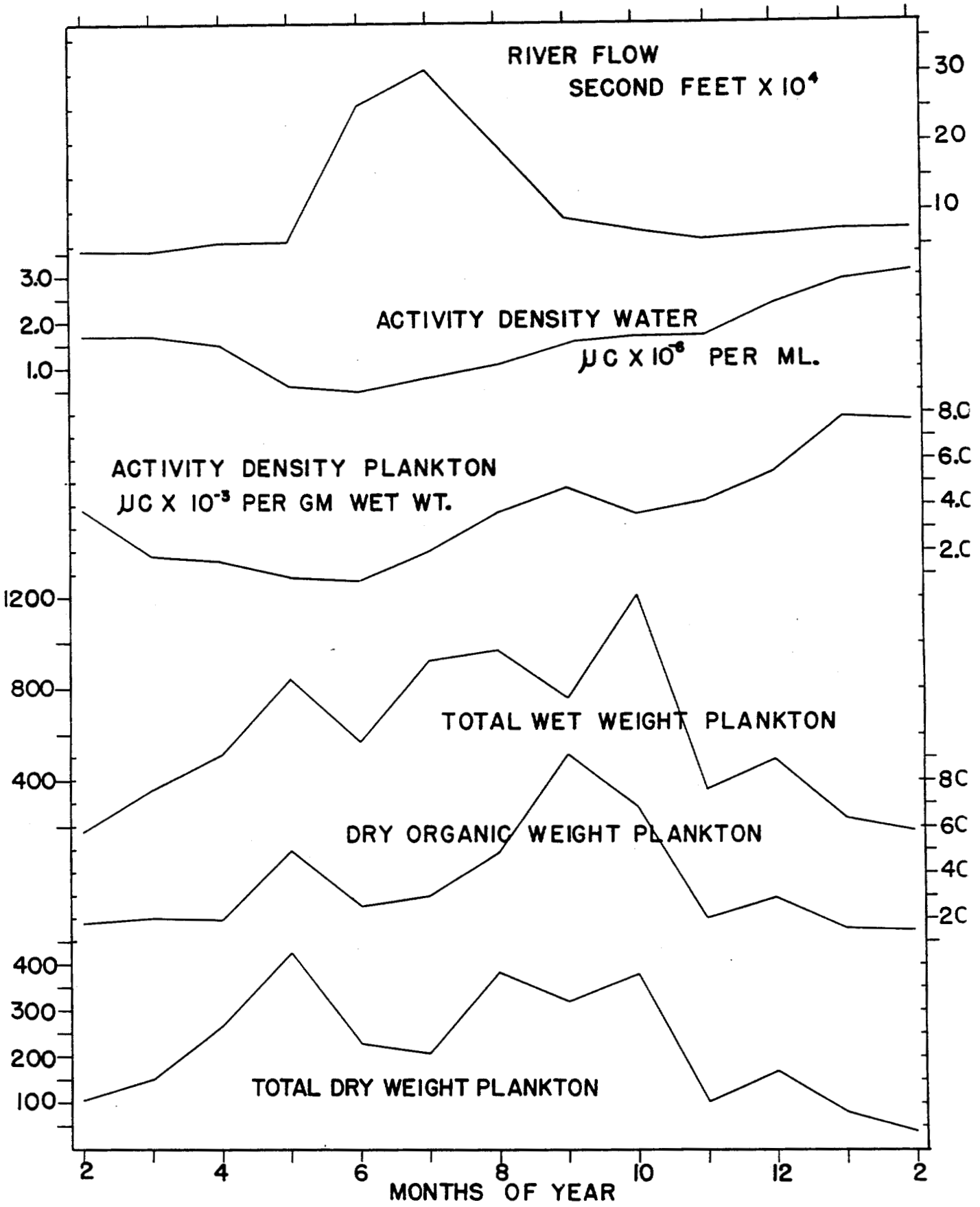

FIG. 2 COLUMBIA RIVER DATA FROM FEB. 1949 TO FEB. 1950. PLANKTON WEIGHTS IN MGM PER CUBIC METER

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The table below showing average values for the thirteen months period, indicates the increase in activity levels of both water and plankton at Hanford over those of the station above Hanford Works. It likewise indicates the rate of pick-up of the isotopes by the plankton if the average river flow of 2-3 miles per hour is taken into consideration. Since Hanford is approximately 21 miles below the first sampling station, the time lapse for water passage between these two points, disregarding any lag in eddy or slough areas, is 5 to 7 hours.

	Activity density $\mu c \times 10^{-3}$	
	per gm plankton	per ml water
Above Hanford Works	0.01	.00001
Hanford, Washington	3.70	.002
*McNary Damsite	0.10	.0002

McNary station located some 60 miles below Hanford gives an approximation of the decrease in plankton activity through radioactive decay, dilution and other factors as the plankton and water proceed downstream. The few data from Bonneville Dam roughly 200 miles below Hanford show plankton activity density to be less than $.02 \times 10^{-3}$ $\mu c/gm$.

In general, the doubling of plankton activity density occurring between February 1949 and February 1950 reflects a corresponding increase in water activity during this same period.

Numerical abundance results for the Hanford samples are given in Figure 3. Because the plankton consists of more than 90 per cent diatoms of the genera Asterionella, Melosira, and Fragilaria, the

---

* Six samples were collected at McNary Dam between August and November 1949. These results which ranged between 0.095 and 0.246×10^{-3} $\mu c/gm$ are indicated here on a comparative basis. This assumes that the ratio of activity density between McNary and Hanford was the same for the period February 1949 to February 1950 as it was for the period August to November 1949.

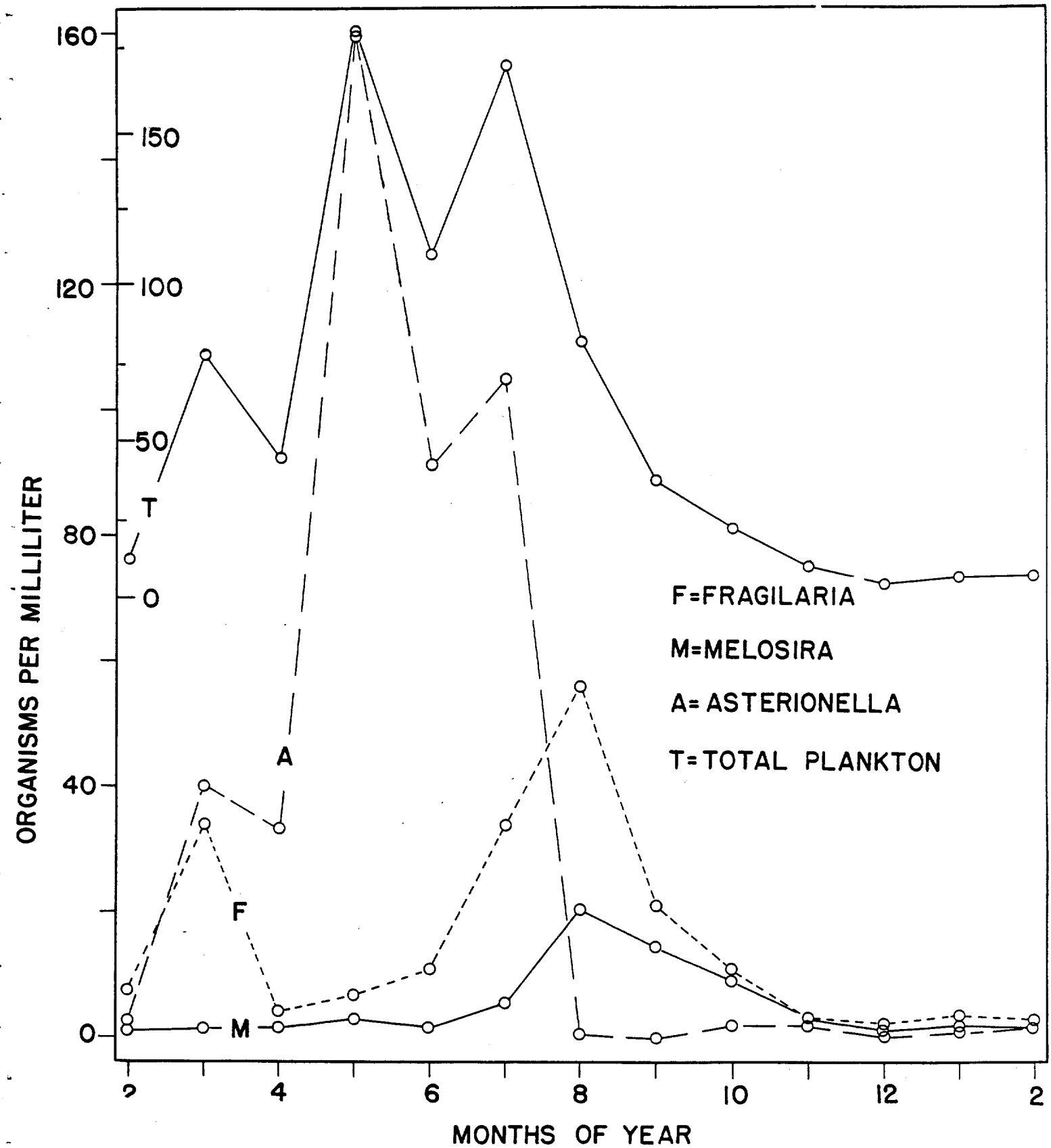

FIG. 3 SEASONAL CHANGES IN PRINCIPAL DIATOMS AND TOTAL PLANKTON FROM FEB. 1949 TO FEB. 1950

combined numerical abundance of these three genera is for all intents and purposes the same as the total count results. A period of great abundance from March through August with minimal numbers during the colder months is the most pronounced feature. Superimposed on this major trend are fluctuations in the three diatom major genera. Fragilaria and Asterionella showed an increase during March; Asterionella produced a pronounced pulse in May, June and July; while a decrease in Asterionella from its maximum abundance masked an increase of Melosira and Fragilaria in July and August.

Although Melosira at no time shows abundance comparable to the maxima exhibited by the other two genera, it is consistantly present in modest numbers throughout the year. The details of abundance of other phytoplankton and of zooplankton which, as previously mentioned, are in the minority compared to the above three diatom genera, are reserved for a more strictly limnological presentation at a later time.

A comparison of the results from the station above the production area with those from near Hanford shows no decrease in the abundance of plankton organisms in a down-river direction. It may be said then that at the present stage of the program, no deleterious effect is evident on the abundance of plankton due to the operation of the Hanford Works.

Gravimetric data presented in Figure 2, although not reflecting all changes evident in the numerical abundance graph, exhibit in a general way these same pulses. Since the total wet weights are influenced by the amount of silt or clay present because of their added water holding properties, and it is difficult to standardize accurately the amount of water removed by suction filtration, these results should only be considered in a general manner. On the other hand, the dry organic weight was obtained by standardized procedures and may be regarded with a greater degree of confidence.

Difficulties in standardizing the collection of quantitative samples make it desirable to improve the quantitative collection equipment and methods. A boat which has been obtained for this and other work should aid materially. Additional data on the activity density of stations below

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Hanford together with quantitative information on this section of the river as well as improved quantitative data on the river above Hanford would be desirable when facilities become available.

A lack of agreement between the abundance of organisms in Figure 3 and their corresponding weights in Figure 2 should be mentioned. For example, the dry organic weight in May was 49 mg per cubic meter while in September and October it was 93 and 69 mg respectively. The abundance of organisms during this same period showed a downward trend from the maximum in May.

A total dry weight in May of 430 mg per cubic meter was composed of 89 per cent ash while a decreasing trend during the summer resulted in a dry weight of 380 mg per cubic meter in October but with an ash content of 82 per cent. Also during this period the predominant diatom genera changed (Figure 3) from Asterionella in May to a combination of Fragilaria and Melosira in October.

Three possible explanations are suggested. First, the weight ratio between the silica in the diatom shell and the inclosed organic material changed during the season. Second, the individual diatoms were heavier in October than in May. Third, other non-silicious plankton organisms were influencing the amount of organic material present. The fact that Fragilaria and especially Melosira, the predominant October forms, are more robust than Asterionella, lends support to the first two possibilities. The fact that diatoms are the predominant plankton form throughout the year contradicts the third. The high percentage of water in organic materials reflected in increased wet weights during the warmer months likewise indicates a greater organic component at this time.

In the following table are given the quantity of plankton moving past Hanford and the amount of radioactivity it contains. Because the present results deal with water near shore and do not claim a uniform distribution of either plankton quantity or plankton activity density across the river, the figures may be regarded as approximations. The average

plankton activity density across the river at Hanford is estimated to be two-thirds that of the south bank on the basis of river-water activity density cross section data [4, 5, 6, 7].

Average Quantity and Activity Density of Hanford Plankton

Date	Wet weight kg x 10^3 per 24 hours	μc x 10^3 per 24 hours
February, 1949	27	67
March	52	62
April	73	78
May	520	330
June	450	230
July	450	630
August	210	520
September	140	430
October	180	430
November	50	140
December	80	290
January, 1950	44	230
February	33	170

It is evident from this that although the maximum and minimum quantities of plankton flow per 24 hour period are in May and February, 1949, the largest and smallest amounts of contained radioactivity are in July and March, 1949, respectively.

A plankton sample collected on October 5, 1950, was analyzed on October 8, 1950, by standard radiochemical techniques for total beta emitters. The results of this analysis are tabulated below. When possible, chemical results were confirmed by absorption and decay curves. It should be noted that the short-lived isotopes would contribute at zero time a much higher percentage of the spectrum of beta emitters, but because of technical difficulties, an analysis on October 5, 1950, was not possible.

Radioelement	Per Cent of total beta emitters
P^{32}	40
Cu-As isotopes	5
Fe^{59}	30
Rare earths	15
Zn-Co isotopes	10

Tests for alkali metals and alkaline earths gave negative results, as did tests for metals of the silver group.

A decay curve run on a sample collected on January 19, 1949 is shown in Figure 4. The curve was obtained from 1 gm of wet plankton. Three arbitrary components, each of which represents a group of elements, have been approximated from the curve. First, a group of one-day or less half-life which is likely to include Na^{24}, Mn^{56} and one or more of the short-lived copper and arsenic isotopes. This complex constitutes the major share of the radioactivity of the plankton and is estimated to be responsible for 70 - 95 per cent of the counts per minute. Since only small residues remained at the time of the radiochemical analysis given above, this component is lacking in those data. Second, a complex which includes P^{32} together with several possible isotopes among Fe, Ca, Zn, and the rare earths. Indications point to a sizable proportion of P^{32}. Finally, a small but detectable count persisting at the end of 600 days decay is evidently made up of materials of 400 or more days half-life. This is thought to be contributed largely by the rare earths Pm^{147} and Eu^{155} together with Fe^{55}. A very small but undetermined amount of the naturally occurring isotope K^{40} contributes a slight count (probably not exceeding 2 c/m) in this region of the curve.

Although the medium- and long-lived components, are of minor significance as compared to the short-lived components on the basis of the amount of radioactivity contributed, they are, nevertheless, of primary biological importance in the Columbia River for two reasons. First, the half-lives of the elements are sufficiently long to make them detectable some distance below the Hanford project and second, several of the elements are incorporated into the plankton of the river and transmitted to the higher organisms as a consequence of food chain relationships.

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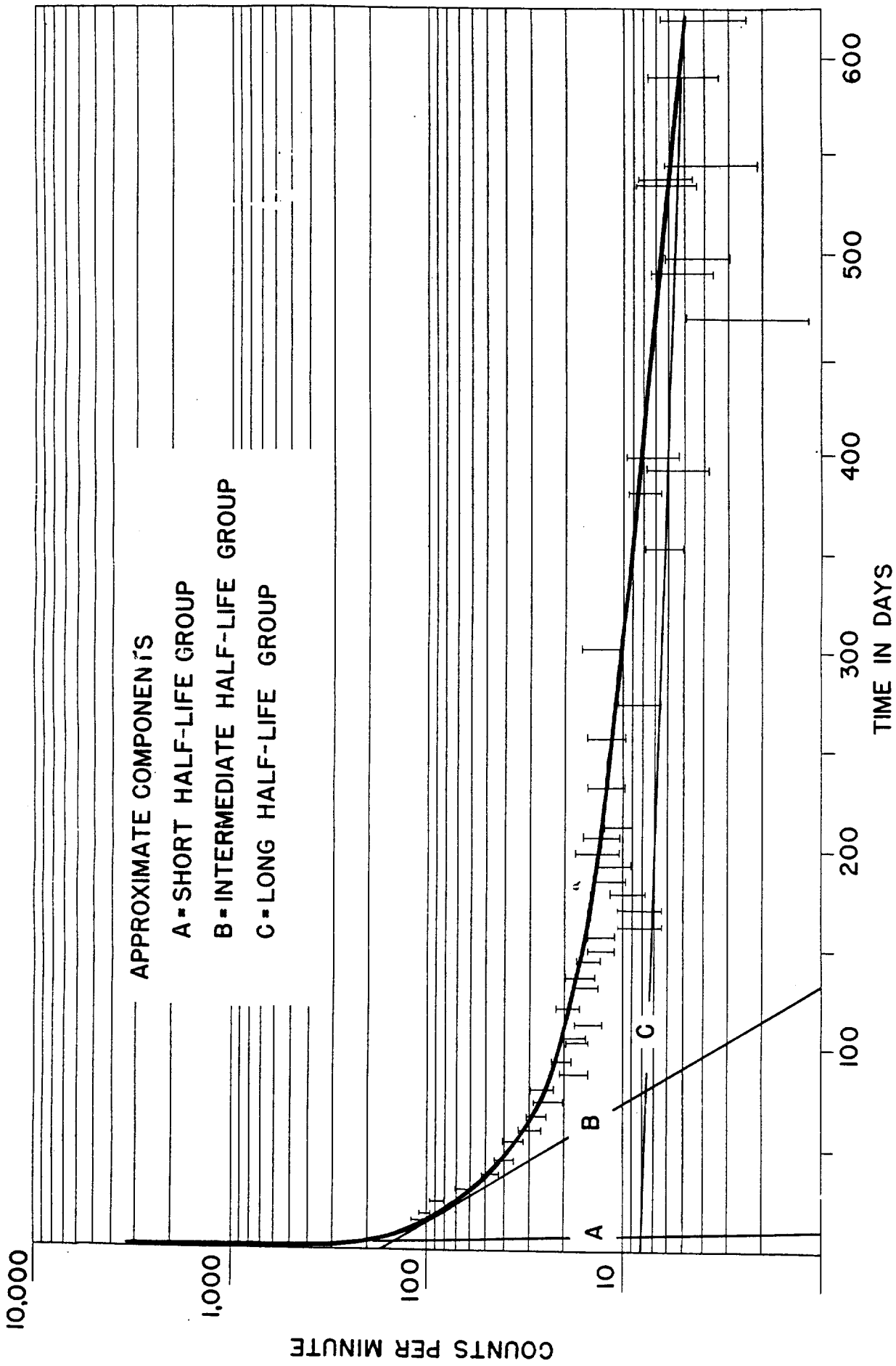

FIG. 4 DECAY CURVE OF PLANKTON COLLECTED AT HANFORD JAN. 19, 1949

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SUMMARY

Weekly plankton net collections covering a period from February 1949 to February 1950 were made from the river above and below Hanford Works.

Methyl orange and phenolphthalein alkalinity, pH, and per cent saturation of dissolved oxygen, showed only slight variations during the course of the year. Values obtained are commensurate with those of other natural waters of this region. Water temperatures varied from 2.0° C. in February 1949 to 18.4°C. in August 1949. No observable influence of the plant operations on the chemical characteristics of the water was found.

A maximum value of 7.9×10^{-3} μc/gm for plankton at Hanford was found during January 1950. Eleven months previously in February 1949 the figure was 3.8×10^{-3} μc/gm demonstrating a two-fold rise in activity density.

A decrease in both water and plankton activity density coincided with increased river flow during the summer freshet season. Greater dilution of the pile effluent water together with an increase in the amount of silt admixed with the plankton were influential in this.

Numerical abundance of the various plankton organisms showed Asterionella, Melosira, and Fragilaria to constitute more than 90 per cent of the total. The plankton appeared in greatest abundance during the warmer months reaching a maximum following the spring freshet season. A decline to minimal numbers in late fall and winter correlated with decreasing water temperatures.

Gravimetric results of plankton analyses followed a pattern similar to that of numerical counts. A maximum of 1200 mg and a minimum of 180 mg of wet weight plankton per cubic meter occurred in October, 1949, and February, 1950, respectively. Estimates indicate that 5.2×10^{5} kg (570 tons) of plankton moved past Hanford each day during May. Similar estimates indicate 0.6 curies of radioactivity was carried by the plankton each day during July.

Decay durve data showed 70 to 95 per cent of the plankton activity to be composed of elements with half-lives of less than one day while the

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remaining 5 to 30 per cent is composed of 14.7 day (P^{32}) or isotopes of longer half-life. Radiochemical analysis results supplement the decay curve data by indicating a great variety of isotopes present with Pm^{147}, Eu^{155}, and Fe^{55} contributing toward a small long-lived component persisting beyond 600 days.

ACKNOWLEDGEMENTS

The writer expresses gratitude to all who aided in carrying out this work. The collection of samples and the numerical counting procedure was initiated by Virginia C. Madden and carried on later by Nancy C. Mandell. R. G. Genoway assisted in the preparation of gravimetric and activity density samples. All members of the Aquatic Biology Unit, aided in one way or another in carrying out the program. Radiochemical analysis data were supplied by R. C. Thorburn and A. C. Case of the Analysis Group.

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