

Total plankton respiration*

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(Received 11 March 1966)

Abstract—Total plankton was gently concentrated from sea water, using a membrane filter, and its rate of respiration was quickly measured. Comparable measurements of respiration were made on plankton concentrated with a No. 2 net in a 12-in Clarke-Bumpus sampler. Organisms too small to be retained in the net accounted for 94–99% of the total respiration. In the Gulf Stream and Sargasso Sea flagellates usually appeared to be the most important metabolic component of the plankton.

PLANKTON small enough to pass through a net frequently make up more than half of the total plankton (BANSE, 1964). Because metabolic rate per unit mass increases with decreasing size (JOHANNES, 1964; 1965) the organisms missed by nets should be important movers of energy and materials in the sea. We have gently concentrated total plankton and rapidly measured its respiration, comparing it with the respiration of zooplankton taken in a No. 2 net ($< 366 \mu$) from the same stations.

Total plankton was concentrated with a membrane filter of 0.8μ porosity, using a filtration method like that described by DODSON and THOMAS (1964), with a pressure of 5 cm of water. The filtration area was 200 cm^2 . In the open sea plankton from 20 l. of water could be concentrated to 5 ml in 2–3 hr. Several filtrations were run simultaneously, and by combining the filtrates concentrates up to 100 l. could be prepared in the same time. As the plankton was gently concentrated, the water in which it was contained was renewed constantly, so there was no accumulation of waste products or depletion of oxygen in the concentrate. Most of the plankton remained in suspension. The surface of the filter was washed at the end of filtration with the aid of a wash bottle of membrane-filtered sea water and a fine brush to remove any adhering plankton.

The plankton concentrate was placed immediately in an 11-ml respirometer and incubated at sea temperature in the dark. The respirometer was equipped with Ag-Pt electrodes (CARRITT and KANWISHER, 1959; TEAL and HALCROW, 1962) which provided a continuous record of oxygen tension on a recording potentiometer. The contents of the respirometer were stirred by a paddle-type stirrer at about 120 rev/min. Respiration was linear with time, and a good record could be made in 1 hr. The total time from sample collection to the end of respirometry was ~ 4 hr.

For purposes of comparison, collections were made in a 12-in Clarke-Bumpus sampler with a No. 2 net. Tows were of 2–5 min duration, and all the material collected was put into a 100-ml respirometer of the same type used for the membrane-filtered material.

In Table 1 the respiration of the membrane-filtered samples (MF) is compared with that of the Clarke-Bumpus tows (CB). Statistical parameters are not given with the mean values, because the distributions are highly skewed, reflecting the patchy distribution of plankton in the sea. It would appear that plankton too small to be retained by the net accounts for from 94 to 99% of the total respiration.

Most of the region covered was of low or moderate productivity and subtropical in character. Most samples were from the surface or depths of not more than 100 m, with two samples from 200 m and one from 500 m. It has been suggested on other grounds that respiration decreases rapidly with increasing depth (WYRTKI, 1962; MENZEL and RYTHER, 1960; RILEY *et al.*, 1965), and the present observations tend to support this.

Concentration of net plankton induces some increase in respiration (SATOMI and POMEROY, 1966), but since we do not know the effect of concentration on respiration of the total plankton, we have not

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Table 1. Respiration of plankton concentrated by a membrane filter (MF) and by a plankton net (CB), expressed as mg atoms O₂/m³ day

Location	Date (1965)	MF	n	CB	n	CB as percentage of MF	°C
Slope N of Hatteras	July	0.19	1	0.01	1	5.7	24
Gulf Stream	May	4.95	8	0.04	3	0.8	24-26
Gulf Stream	July	0.50	6	0.01	4	2.4	27
Sargasso Sea	July	0.37	8	0.01	5	3.0	23-25
Shelf S of Hatteras	May	20.27	5	1.01	2	5.7	20
Shelf S of Hatteras	July	1.25	4	0.01	4	0.6	27

corrected any of the data for the effects of crowding. Our Clarke-Bumpus respiration values for the extreme western Sargasso Sea are in good agreement with those of RILEY and GORGY (1948) for the same region, although they concentrated the plankton less, used a No. 10 net, and measured respiration over a much longer time. RILEY and GORGY also measured respiration in bottles of water containing no additional plankton (to serve as controls for change in oxygen in the water). The rate of respiration in those bottles exceeds our estimates of respiration in surface water by nearly an order of magnitude. Probably there was some overgrowth of bacteria during their experiment.

The plankton concentrates were examined by fluorescence microscopy before and after respirometry, using chlorophyll and acridine orange fluorescence. Composition of the filter-concentrated plankton was so variable both with depth and location as to prevent more than the broadest generalizations. On the continental shelf the concentrates often were dominated in terms of biomass by large diatoms, particularly *Chaetoceros*. In the Gulf Stream and Sargasso Sea small flagellates (2-10 μ) usually were predominant. Many of the flagellates lacked photosynthetic pigments. Metazoans were either rare or entirely absent in the samples; that is, protists completely dominated all samples in terms of both numbers and biomass. Bacteria also were seen in the concentrates, but they were not abundant. Probably most bacteria were retained in the concentrate, because they were attached to particles of detritus larger than the pore size of the filter (WOOD, 1953). Since the entire process of collection, concentration, and respirometry lasted only 4 hr, there was no overgrowth of bacteria during our observations.

There is evidence in the literature that very small plankton account for most of the photosynthetic activity in the oceans, with small, autotrophic flagellates being of considerable importance (ATKINS, 1945; ANDERSON, 1965). Our observations suggest that in the Gulf Stream and Western Sargasso Sea the same is true of respiration, and that small, heterotrophic flagellates probably account for a significant part of the total respiration. WOOD (1963) has noted that colorless flagellates are almost always present in plankton and at times far outnumber photosynthetic organisms. Our observations are at this time limited in scope, but they suggest that a better knowledge of the metabolism of the smaller heterotrophic elements of the plankton will add significantly to our understanding of the bioenergetics of the oceans.

Acknowledgements—The writers thank the Duke University Marine Laboratory for the use of the R.V. *Eastward* on cruises E-16-65, E-24-65, and E-34-65 in the cooperative oceanographic program. This program is supported through National Science Foundation Grant G-17669 to Duke University. This work was also supported by National Science Foundation Grants GB-1040, GB-3671, and by funds from the Sapelo Island Research Foundation.

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