

The Rate of Liberation of Phosphate in Sea Water by the Breakdown of Plankton Organisms.

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With One Figure in the Text.

In the late spring of 1934 four experiments were started to determine how quickly inorganic phosphate may be set free from plankton. Samples of plankton caught in fine and very fine silk tow-nets were analysed for phosphorus (Cooper, 1934) and aliquot parts were filtered on a silk disc having 200 meshes to the linear inch. The plankton was then added to two litre samples of fresh outside sea water in Winchester quart bottles. In all cases the amount of plankton initially present in the sample of sea water was less than 3% of that added.

In each experiment a sample of sea water untreated except for passage through butter muslin was kept as a control. The Winchester bottles, except in Experiment 1, were wrapped in black paper and all were stored in a cupboard away from light and shaken by hand at intervals. The mean temperature of the storage cupboard was about 14° C. in April, 16° C. in May and 19° C. in June. At suitable times 100 ml. portions were removed from the well-shaken bottle and analysed for phosphate in the usual way (Denigès-Atkins method), except that samples enriched with plankton had first to be filtered through Zsigmondy membrane filters (filtration time, 20 seconds). Even so after a few weeks the colour match with standards in the phosphate analyses on these filtrates was not too good and the analyses are less accurate than those on ordinary sea water. The worst samples to compare were those rich in plants. All results are recorded as mg. P. per cubic metre corrected, when necessary, for salt error.

Experiments 1 and 2. Zooplankton.

The sample of plankton used for Expt. 1 was mixed, consisting mostly of animals. That for Expt. 2 contained *Calanus*, some *Acartia* and *Temora*, a few *Ctenophores* and very little plant life.

The control to Expt. 1 after two months reached a maximum phosphate content greater than the preceding winter maximum in the

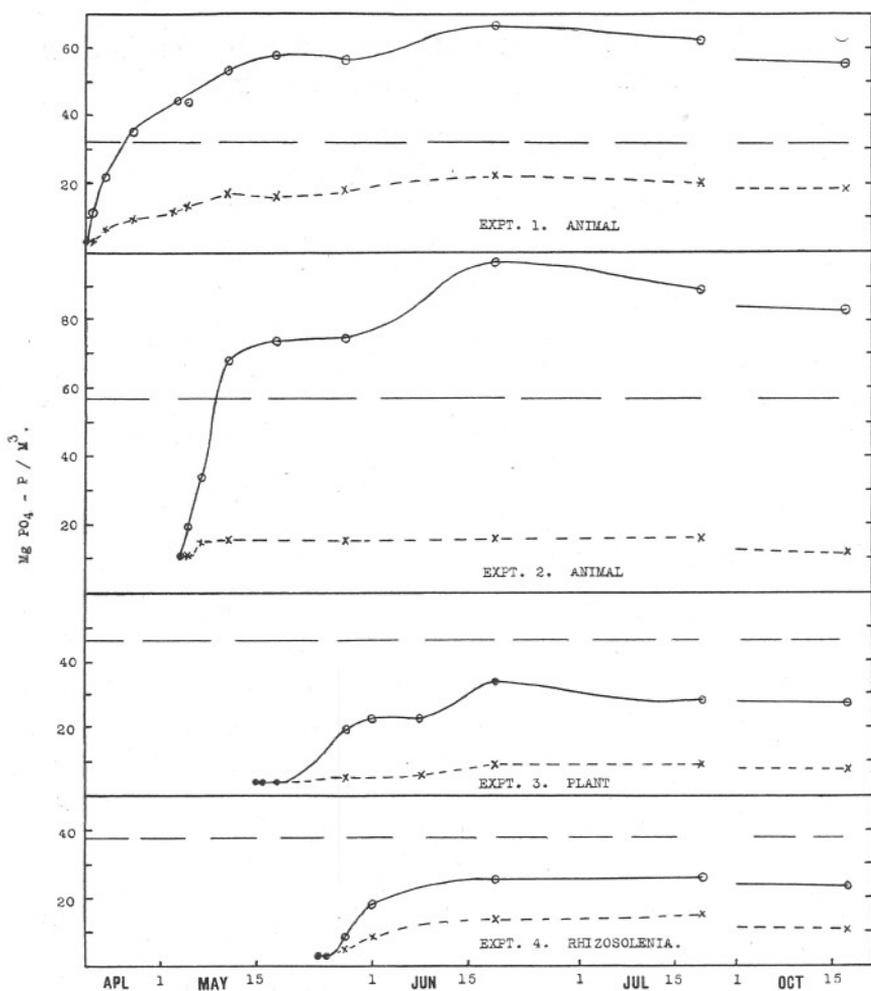


FIG. 1.—Liberation of Phosphate-phosphorus (PO₄-P) by breakdown of plankton.

- - - - - Controls.
 _____ With added plankton.
 _____ Sum of PO₄-P initially present in the water and plankton-P added.

English Channel. In the control to Expt. 2, however, the liberation of phosphate was much less. In the waters with added zooplankton (Expt. 1, 29 mg. and Expt. 2, 46.5 mg. per cubic metre of added phosphorus) the liberation of phosphate was very rapid, about 10 mg. P being set free in the first twelve hours and an amount equivalent to that added as plankton in about six days. Quite unexpectedly phosphate continued to be set free until the maximum was reached after about six weeks or two months. It was clear that about 40 mg. P per cubic metre was being rapidly set free from dissolved organic compounds present in the sea water. The results of Matthews (1917), Ibañez (unpublished), Kalle (1933) and Kreps (1934) show that sea water may contain 30-50 mg. of organic phosphorus per cubic metre which, however, may include some arsenic (Atkins and Wilson, 1927, and Rakestraw and Lutz, 1933).

Experiments 3 and 4. Diatoms.

The sample used for Expt. 3 was rich in diatoms, particularly *Rhizosolenia* spp. That for Expt. 4 was practically entirely diatoms; each litre of the experimental water contained 453,000 *Rhizosolenia shrubsolei*, 90,000 *R. fäeroensis*, 28,000 *Skeletonema costatum*, and 6,200 *Guinardia flaccida*, equivalent to, say, 570,000 *R. shrubsolei*. Little else was present. I am indebted to Dr. Lebour for these counts made with the hemacytometer.

The control to Expt. 3 showed little change, but that to Expt. 4 in a month showed a rise of 12 mg. P per cubic metre. In the experiments with diatoms added, little happened for two or three days, in marked contrast to the behaviour of animal plankton, and then rapid liberation of phosphate took place, the maximum being reached in a month. Even at the maximum only part of the phosphorus added as phytoplankton had been set free to the water.

Two phenomena are common to most of the curves in Fig. 1. Firstly, an inflection is to be noted after 15-20 days' storage. The rate of liberation slowed down and then picked up again before reaching the maximum. Secondly, a slow fall in phosphate occurred in the four months after the maximum had been reached. No explanation is apparent for this, although moulds may play a part. The experimental waters were much richer in plankton than the sea ever is, so that presumably compared with natural conditions all processes of decay were much accelerated. A number of other experiments made under somewhat different conditions with the same catches of plankton served but to confirm the results here set forth.

The author is indebted to Mr. H. W. Harvey for suggesting this research and for his interest in its progress.

TABLE I.
ALL PHOSPHATE DATA AS MG. P PER CUBIC METRE CORRECTED FOR
SALT ERROR.

Expt.	Date started 1934.	Initial $\text{PO}_4\text{-P}$ in water.	P in plankton added.	Increase in $\text{PO}_4\text{-P}$ due to breakdown.		Minimum amount of $\text{PO}_4\text{-P}$ set free from original sea water.
				Control.	With added plankton.	
Zooplankton :						
1	20/4	3	29	19.5	64	35
2	4/5	10.5	46.5	5	87	40
Phytoplankton :						
3	15/5	5	46	5	30.5	—
4	24/5	2.5	35	12.5	24	—

SUMMARY.

Samples of animal and plant plankton were added to sea water in glass vessels and the subsequent changes in the phosphate content of the water were followed.

The breakdown of the zooplankton was very rapid and more phosphate was set free than had originally been added as plankton. The balance was produced from dissolved organic phosphorus compounds in the water. The breakdown of phytoplankton showed a short time lag and only a part of the phosphorus added was set free as phosphate.

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