A REPORT ON THE O:N:P RATIOS OF PHILIPPINE AND ADJACENT WATERS

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THREE TEXT FIGURES

The composition of sea water in the marine environment with respect to nitrogen and phosphorus is known to be regulated in a large measure by the growth and activity of organisms. The cycle of synthesis and decomposition involves the absorption of these nutrients by growing plants and the release upon decay of their tissues. The first phase takes place within the photosynthetic zone, and the second phase largely in the "zone of decay" below this productive zone. Oxidative processes during the decomposition phase entail the utilization of oxygen which, as a by-product of the synthesis phase, is conditioned by the oxygen exchange between the atmosphere and the surface layer of water with which it is in contact. In the underlying zone of decay the amounts of dissolved oxygen and the nutrient salts can be accounted for by the mineralization of organic matter and the addition of new supplies of these materials due to water circulation.

Thus, as Ketchum (1947) has pointed out, three processes are readily recognized as motivating the cycle, namely, the assimilation by plants, regeneration of the nutrient salts following the organic breakdown of dead tissues and animal excretions, and enrichment of the water due to circulation. The first is a process that tends to exhaustion of the available nutrient salts in solution, which in temperate waters may likely occur during summer, and in tropical waters practically the whole year round. The other two are, on the other hand, processes of replenishment in which these essential materials are either returned to solution or are augmented by addition from outside sources. The net result of these processes is to maintain a nearly constant ratio of nitrogen to phosphorus in the sea (Ketchum, 1947).

Investigating the N:P ratios of the waters of the Atlantic, Indian and Pacific Oceans, Redfield (1934) reported results showing a ratio which varied from around 15 atoms of nitrogen to one of phosphorus, after applying a salt error correction

on the phosphate values. If these constituents were utilized in the same proportion as they occur in the waters, which in the light of recent investigations appears to be so, the constancy of the ratios implies that organic matter synthesized and decomposed in the sea will have a composition of about 6.8 grams of nitrogen to one gram of phosphorus. Analysis of diatoms by Cooper (1932), as cited by Harvey (1945), yielded values ranging between 6.8 and 9.2 times more nitrogen than phosphorus.

Discovery data in the Atlantic as compiled by Harvey (1945) showed very low ratios in waters below the productive layer in the low altitudes. In that ocean, at about the same latitude as the Philippines, an average of 8.9:1 was noted. This low atomic ratio was implied to be due to the difference in the rates at which the regeneration of phosphate and nitrate proceed at those levels. While the first is known to be directly regenerated, the second undergoes a cycle before it becomes in an available form.

Of the Philippine waters no known attempt has been made to examine their N:P ratios. In this report the *Baird*[1] data had been examined for their O:N:P ratios in which the first factor represents "utilized oxygen." By this is meant the difference between the amount of oxygen which theoretically a liter of water of a certain temperature and salinity can hold and the amount of dissolved oxygen as determined by the modified Winkler method. Nitrate-nitrogen includes nitrite-nitrogen which is found only within a narrow strip of the water column and in a comparatively much lower concentration, while phosphate-phosphorus includes arsenates which are known to occur in exceedingly small quantities in sea water. It was deemed unnecessary to apply a salt error correction on the phosphate values, as synthetic sea water was used in diluting the phosphate standards used in the determination.

The number of analyses considered in this report, which comprised all the *Baird* data from the deep offshore stations, was distributed as follows: 6,018 for dissolved oxygen, 5,616 for nitrates and 6,104 for phosphates, making a total of 17,738 analyses. The number of samples collected from each level de-

[1] "Spencer F. Baird" is a converted diesel electric tug of 800 tons gross, with two 950 H.P. engines. This was used as a research vessel equipped with complete oceanographic gears by the former U.S. Fish and Wildlife Service in the oceanographic survey of Philippine and adjacent waters during its Philippine Fishery Program in 1947–50.

creased with depth; at the surface about 5 times more samples were collected than at 2,000 meters. A summary of these data is tabulated in Table 1.

TABLE 1.—*Total number of 'BAIRD' samples analyzed and their corresponding standard depths.*

Depth (m)	Oxygen	Nitrate	Phosphate
0	516	482	525
25	509	476	518
50	497	465	505
75	478	446	485
100	473	442	480
150	458	429	465
200	452	420	459
300	422	393	429
400	393	364	399
500	370	342	372
600	328	305	331
800	316	296	320
1,000	260	244	264
1,200	235	221	238
1,500	203	192	205
2,000	108	99	109
	6,018	5,616	6,104

On account of the difficulty of handling statistically such a tremendous number of samples, the values were averaged for each standard depth irrespective of time and space distributions. A preliminary examination of the coefficients of correlation of the nitrogen and phosphorus yielded positive values of the same magnitude. Geographic classification of the data was negated by the fact that the water column was composed of different water masses whose thickness and depth of occurrence varied regionally. These average values are reported in Table 2.

TABLE 2.—*Average values of nutrient salt content and utilized oxygen in concentrations of microgram atoms per liter and their corresponding depths and nutrient salts and utilized oxygen ratios.*

Depth (m)	NO_3–N μg-at L	PO_4-N μg-at L	O_2 μg-at L	N:P	O:P	O:N
0	0.44	0.05	24	8.8	480	55
25	0.60	0.07	23	8.6	329	38
50	1.60	0.14	40	11.4	286	25
75	4.00	0.30	83	13.3	277	21
100	7.50	0.50	138	15.0	276	18
150	13.00	0.89	225	14.6	253	17
200	16.00	1.15	268	13.9	233	17
300	20.00	1.59	332	12.6	209	17
400	26.00	1.93	380	13.5	197	15
500	29.00	2.15	409	13.5	190	14
600	31.00	2.31	424	13.4	184	14
800	33.00	2.50	444	13.2	178	13
1,000	34.00	2.57	459	13.2	179	13
1,200	36.00	2.65	464	13.6	175	13
1,500	36.00	2.69	458	13.4	170	13
2,000	37.00	2.65	464	14.0	175	13

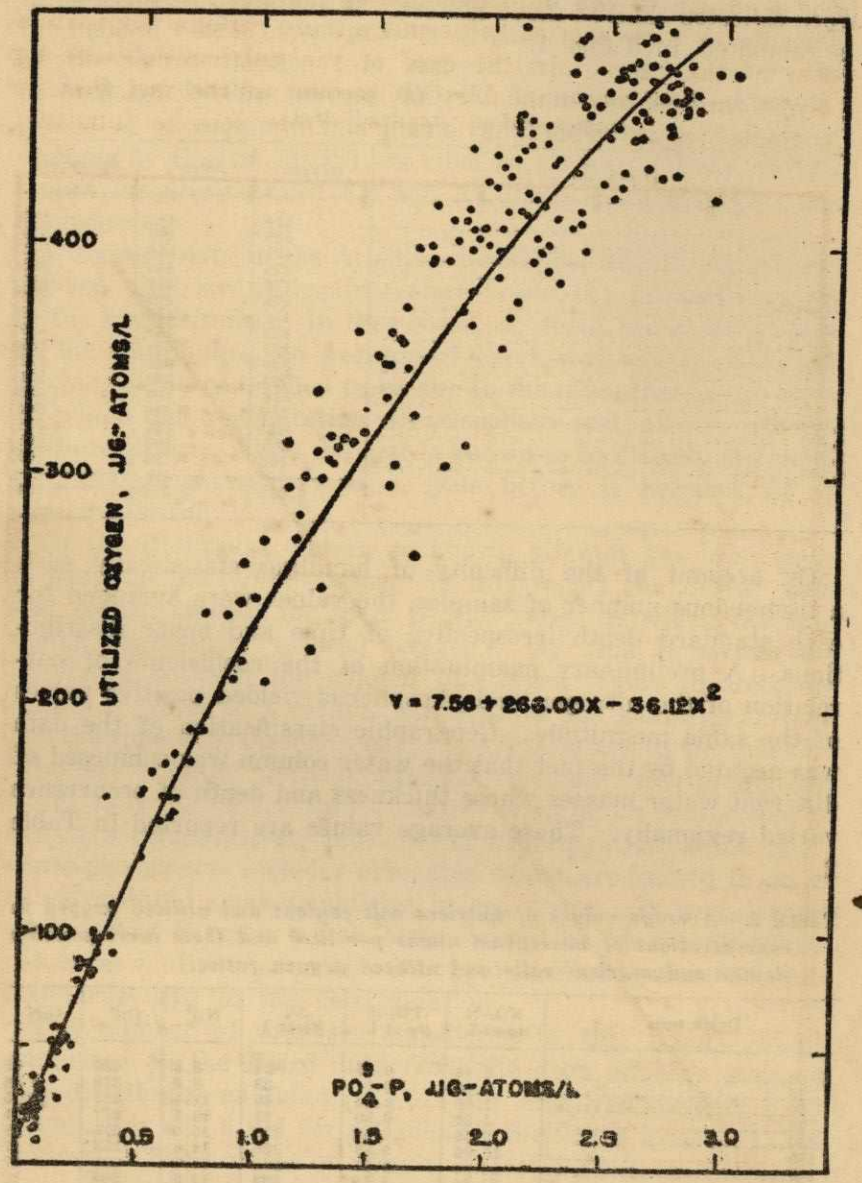

FIG. 1. Regression line for the utilized oxygen and phosphate phosphorus.

In averaging, more significant figures than are allowed by the accuracy of the individual determinations of nitrates and phosphates were carried to permit a more rational approximation of the ratios. In the case of the nutrient-deficient top layers this became mandatory on account of the fact that the computed ratios would have ranged from zero to infinity.

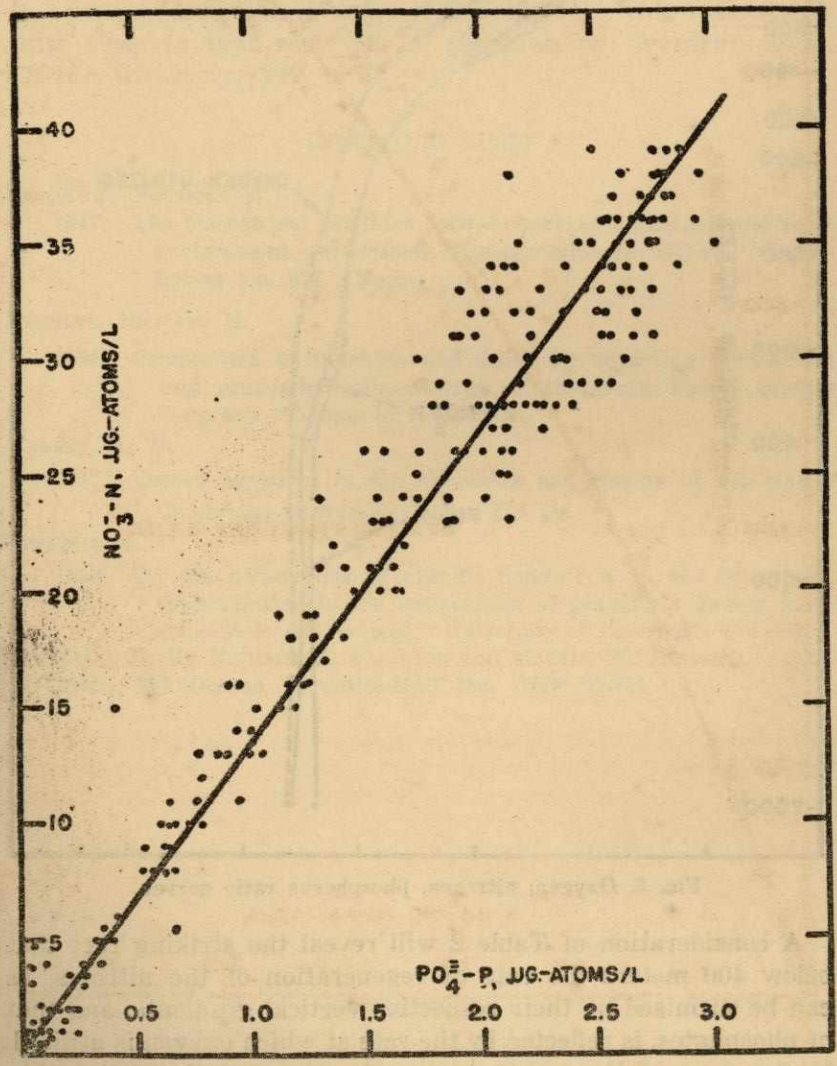

FIG. 2. Regression line for the nitrate-nitrogen and phosphate-phosphorus.

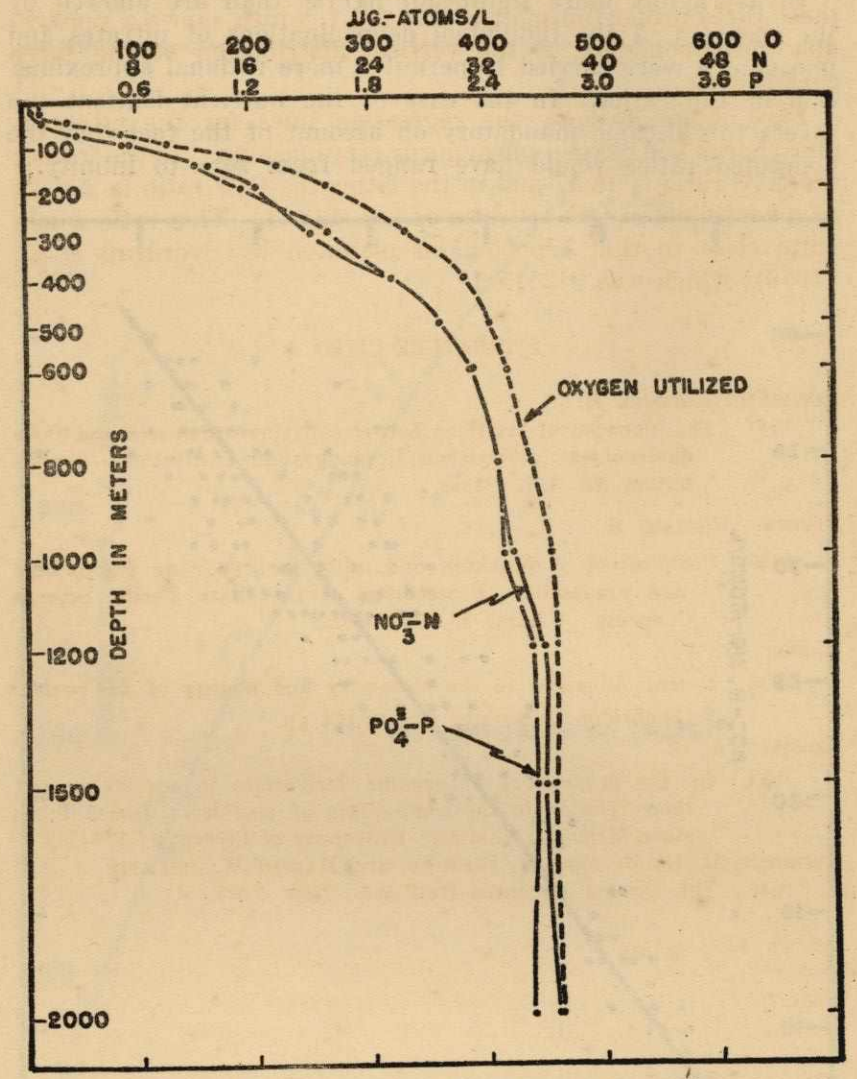

FIG. 3. Oxygen, nitrogen, phosphorus ratio curves.

A consideration of Table 2 will reveal the striking fact that below 400 meters the rate of regeneration of the nitrates, as can be surmised by their respective vertical gradients, and that of phosphates, is reflected by the rate at which oxygen is utilized. In this part of the water column the atomic ratios fall within a much narrower range than those of the top layers whose

the water column. A vertical section of the distributions of these three properties is drawn in fig. 1, which shows a remarkable correspondence in the vertical distribution of the three constituents.

Figs. 2 and 3 show the regression lines for the nitrogen-phosphorus and oxygen-phosphorus relationships. In the former the N:P ratio is 13.47 and in the latter the O:P ratio is 205.28, or a consolidated O:N:P ratio of 205:13.5:1. This ratio comes quite close to that reported on plankton by Sverdrup et al. (1946), which was 212:15:1.

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ILLUSTRATIONS

TEXT FIGURES