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Preliminary Chemical and Hydrological Observations in the Ionian Sea

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ABSTRACT

The paper contains the results of the investigation on nutrients and hydrological parameters at 11 stations at standard depths covering all the water column in the Ionian Sea in March 1983.

The following characteristics can be observed from the vertical distribution of dissolved oxygen during the Spring: from 0 to 75 m the waters are always saturated; a maximum gradient depletion occurs between 75-150 m, where easily oxidizable material is decomposed and respiration processes prevail; the concentration gradient is very small from 150 m to the bottom.

The distrubution of nutrients can be considered as a normal pattern for Mediterranean waters. In the euphotic zone, nutrients are practically depleted by the phytoplankton uptake. The oxidation of organic material induces a progressive enrichment of reactive phosphate, nitrate and silica from 100 m to the bottom. A nitrate maximum is observed at the compensation depth for photosynthesis.

The N:P and Si:P atomic ratios are characterized by a wide variability with depth at the euphotic zone. On the contrary, from 75 m to abour 80 m, the ratios increase and afterwards they tend to constant value of 21 for N:P and 35 for Si:P.

Some conclusions are also drawn about the levantine and deep waters filling the Ionian basin.

Introduction

Literature on the distribution of nutrients and physical features in the Ionian Sea is limited to a few series of observations made by Mc Gill (1965) and Ovchinnikov (1966).

In this paper the hydrological parameters, the nutrient content and the nutrient ratios over a wide area of the Ionian Sea will be examined.

Methods

The samples were collected by metallic Nansen bottles provided with reversing thermometers from a cruise of the Greek Navy at 11 stations (Fig. 1) at standard depths covering all the water column in the Ionian Sea in March 1983. Determination of salinity and dissolved oxygen were carried out immediately on board.

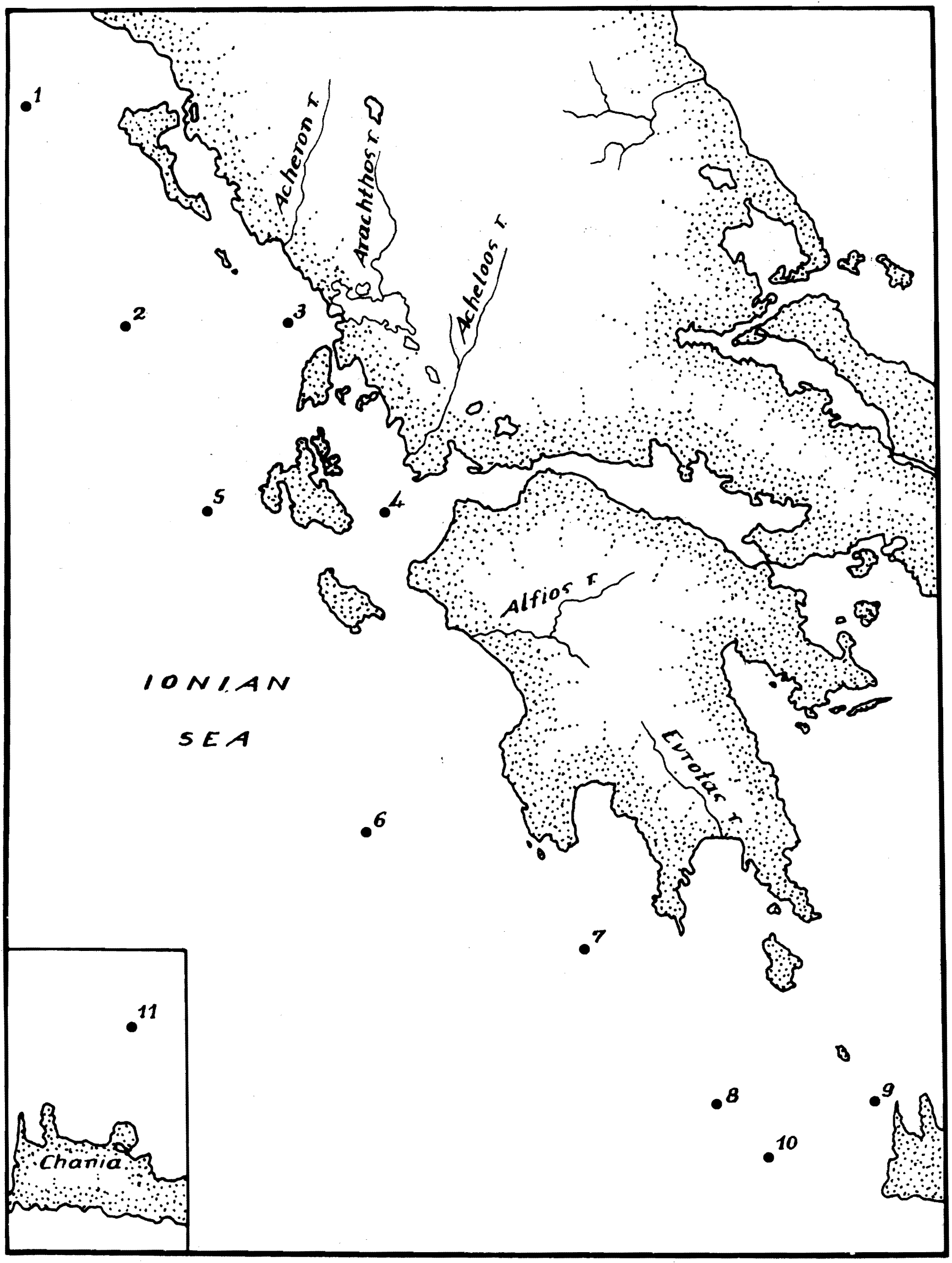


Fig. 1. Map of the investigated area.

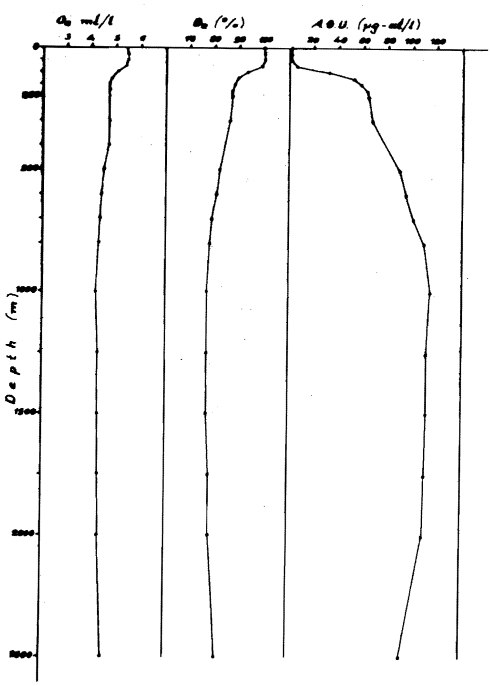
Samples for nutrients were taken and frozen for later analysis with a Technicon Autoanalyser. Measurements of salinity, dissolved oxygen and inorganic nutrsients were made by methods described by Friligos (1982).

Results and Discussion

Vertical distribution of temperature, salinity and density

The mean vertical distributions of temperature, salinity and density are presented in Fig. 2 Variations are essentially restricted to the upper layer, but a significant modification was found to happen in the deeper ones too. At present we consider the surface layer extending from the surface down to the density interface, where the mean salinity is 38.4‰ . A maximum of salinity (– 38.8‰) occurs from 150 m to 400 m (Fig. 2), tagging the levantine waters spreading all over the Eastern Mediterranean at intermediate depths. To prove this statement we must have in mind that, as the levantine water spreads from the eastern basin, its properties progressively modify from T = 15.70° and S = 39.10‰ at the origin (Lacombe-Tchiernia, 1960), to T = 14.20°C and S = 38.75‰ as it leaves the strait of Sicily (Morel, 1970).

Deeper waters have the characteristics of the Eastern Mediterranean (Fig. 2). The deep water of the Eastern Mediterranean fills the Ionian and Levantine basins to depths of 700 m. It is remarkably uniform at 13.6°C and 38.7‰ . Some variation exists between 700-1600 m, a layer that may be considered as transitional between the levantine intermediate waters and deep waters (Pollack, 1951). The water below 700 m represents 66‰ of the total Eastern Mediterranean volume (excluding the Aegean and Adriatic). Also, the analysis carried out by Pollack (1951) indicated that the deep waters in the two basins had the same temperature of 13.7°C and a salinity sporadically



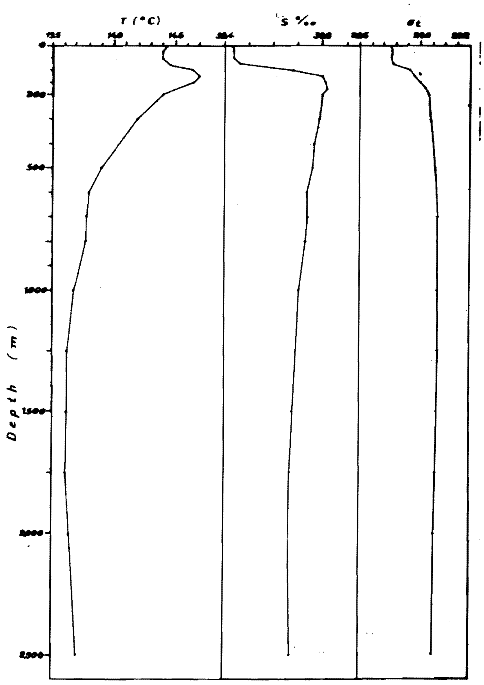


Fig. 2. Vertical distribution of temperature, salinity and density. Points represent mean values.
Fig. 3. Vertical distribution of dissolved oxygen, saturation values and oxygen utilization. Points represent mean values.

varying in the range 38.67 + .04‰ at similar depths. It should be noted that deep waters of the Eastern Mediterranean originate from the mixing of the Southern Adriatic winter water type T = 12.95°C; S = 38.60 (Zore-Armada, 1963) and the Rhodes winter water type T = 15.70°C; S = 39.10‰ (Lacombe-Tohernia, 1960).

Vertical distribution of oxygen

Fig. 3 shows the vertical distribution of dissolved oxygen. The curves have been obtained by graphical interpolation among experimental mean values at the various stations during the March 1983 survey.

Three main layers can be identified in the oxygen curve. The first one, between 0 and 75 m, characterized by saturation conditions in the whole water column, after which the gas concentration starts to diminish; an intermediate layer in the range of 150-500 m. where the concentration gradient is very small; a layer extending from 500 m to the bottom. During Spring the slow rate of oxygen from the surface waters together with the excess of oxygen produced photosynthetically are responsible for a saturation at any depth above 75 m. Since the greater part of organic material has been oxidized in the upper layer (75-150 m), oxygen depletion diminishes with depth and consequently waters from 150 to 500 m are characterized by a smaller negative gradient of oxygen concentration.

Nutrient content

The integrated mean values of nutrients, the surface chlorophyll a and the depth at each station are presented in Table 1. Stations *1* to *6*, located in the northern part of the Ionian Sea, presented higher surface chlorophyll a values, in contrast to stations *7* to *11*.

The range, the mean, the ratio and the correlation coefficient of nutrients for all stations and depths are summarised in Table 2. The variations in nutrient concentration generally agree with the nutrient salts of the Ionian Sea presented by McGill (1965). Levels of nutrients in the Ionian Sea represent a two-fold increase of those in the Aegean (Friligos, 1981). Also, Thomsen (1931) presented data for the southern regions of all basins and showed increasing concentrations westward. However, he noted that "although the quantity of nitrate and phosphate increases considerably as we go from the eastern part of the Mediterranean to the western yet the quantity of phosphate and nitrate even in the westernmost is less than at the same depths in the oceanic regions". This bears out the observation of Redfield (1958) of a sixfold difference between the phosphate level of the eastern Mediterranean and that for the Atlantic.

Vertical distribution of nutrients

The vertical nutrient distributions shown in Fig. 4 can be considered as very normal for Mediterranean waters. In the euphotic zone, nutrients are practically depleted by the phytoplankton uptake. The oxidation of organic matter induces a rapid increase in the nutrient concentration below 100 m, and the enrichment in reactive phosphate, nitrate and silica rises progressively in deeper waters. The nitrate maximum is frequently observed at the compensation depth for photosynthesis. Vaccaro (1965) establised the common boundary of the maximum at 75-125 m, in good agreement with the results presented in Fig. 4. It should be noted that nutrient concentrations increased below 200 m in the Aegean Sea (Friligos, 1981). This is due to more stratification in the Aegean (Miller, 1963). Bumpus (1948) found that the rate of vertical transfer for phosphorus was unusually low in the Aegean Sea and, from this, he concluded that the enrichment of the surface from the deep water was not taking place.

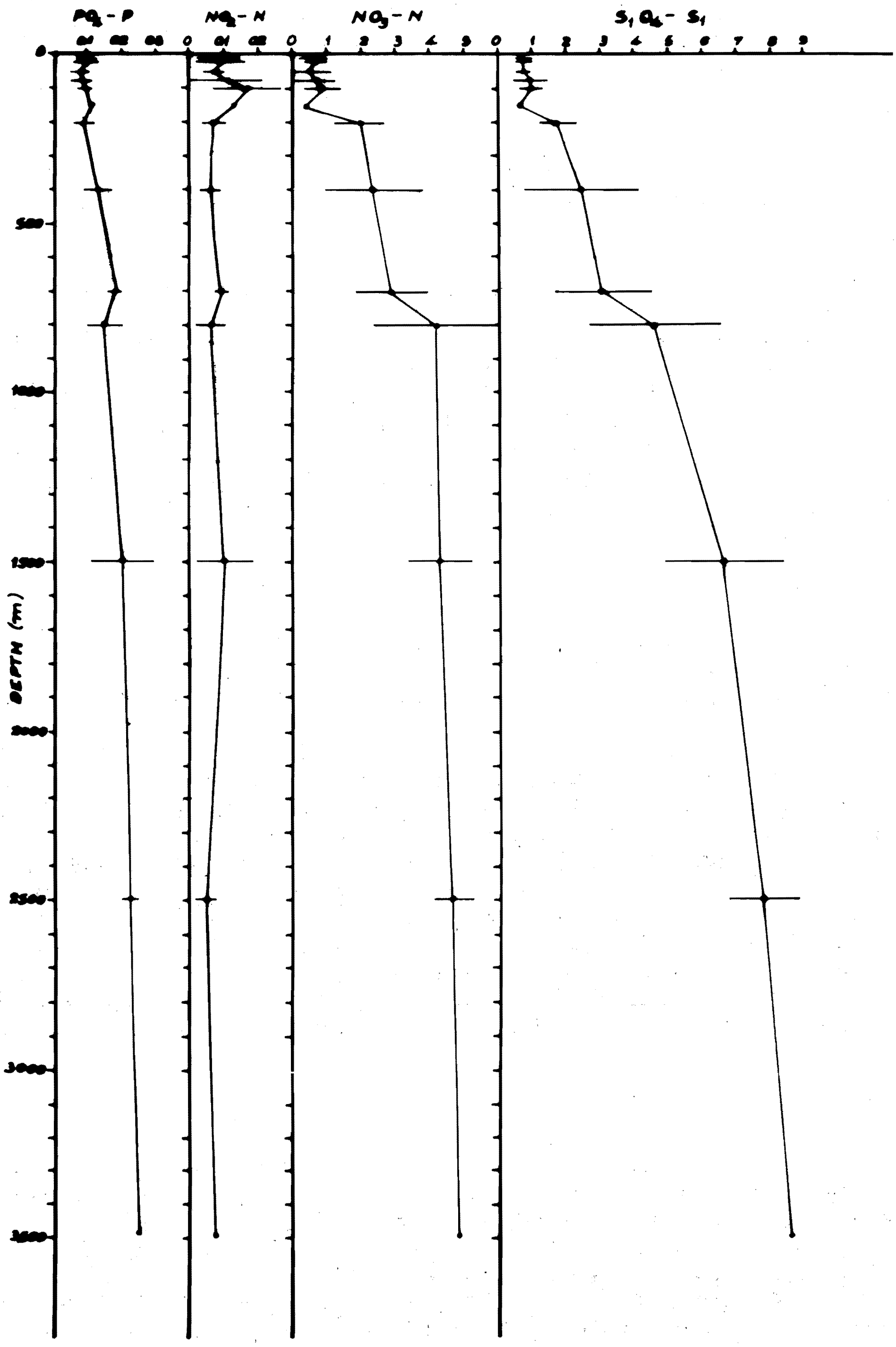


Fig. 4. Vertical distribution of nutrients, Segments indicate mean deviation of measurements (ug-at/1).

However, in the Ionian Sea and the Western Mediterranean, Bumpus obtained a good correlation between turbulence and the change in nutrient concentration. Nevertheless, Redfield *et al.* (1963) pointed out that the exchange over the sill at Gibraltar withdraws nutrients at intermediate depths and, thus, reduces the accumulation in deeper layers. This limits the effectiveness of vertical turbulence as a mechanism of enrichment in the Western Mediterranean.

Nutrient ratios

Many authors, including Cooper (1938), are of opinion, that it is useful to look upon the N:Si:P ratios in various parts of the ocean, and that only certain values of the ratios are favourable for bioproductivity. The best ratio for healthy diatoms is about 15:15:1. From the fifth column in Table 2, we see that the N:Si:P ratios are higher than normal and agree with those found by McGill (1965). We notice that the nutrient ratios found recently in the Adriatic Sea (Buljian *et al.*, 1975) are different from the old ones (McGill, 1965). An evaluation of the ratio of change was also made (Table 2). The ΔN:ΔP ratios were close to the N:P ratio, while the ΔSi:ΔP ratios approached a rather high value of 27.7.

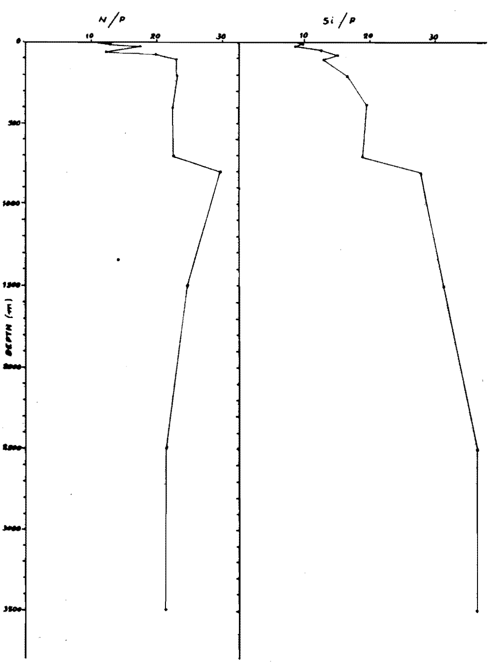


Fig. 5. Vertical distribution of the N:P and Si:P ratios by atoms at different depths. Points represent mean values.

The N:P and Si:P ratios by atoms are characterized by a wide variability with depth. Two different zones can be distinguised (Fig. 5): from 76 to about 800 m the ratios increase rapidly, afterwards, they tend to constant values of 22 for N:P and 34 for Si:P. Strong gradients found in the upper regions are probably due to the progressive regeneration of nitrate and silica following the more rapid regeneration of phosphate. Whereas the N:P ratios found in the deeper regions are in agreement with the results obtained by other authors, there is some discrepancy between the presented Si:P results and those generally accepted for oceanic waters.

Table 1

The integrated mean values of nutrients in uM and the maximum depth at each station

Station	NH_4-N	NO_2-N	NO_3-N	MN	PO_4-P	SiO_4-Si	Chlor. *a*	Depth (m)
1	0.10	0.04	3.66	3.80	0.16	4.21	0.15	800
2	0.23	0.06	3.08	3.37	0.11	2.95	0.22	800
3	0.25	0.06	1.48	1.79	0.06	1.34	0.15	300
4	0.46	0.09	0.57	1.13	0.06	0.92	0.28	75
5	0.41	0.06	3.97	4.45	0.11	5.51	0.15	2500
6	0.96	0.12	3.95	5.03	0.21	5.72	0.17	2500
7	0.23	0.04	4.23	4.52	0.21	6.69	0.11	3500
8	1.29	0.15	1.71	3.16	0.16	1.91	0.03	1500
9	0.86	0.12	1.17	2.15	0.11	1.32	0.15	400
10	1.00	0.11	3.08	4.19	0.17	3.80	0.09	2700
11	1.05	0.11	1.15	2.30	0.11	1.15	0.12	1000

Table 2

Nutrient Relationship

Component	*Number of observations*	*Minimum and maximum values*	*Mean concentration (wM)*	*Mean concentration ratio (by atoms)*	*Ratio of change*	*Correlation coefficient*
PO_4 – P	106	0.07-0.24	0.11 + 0.05			
NR_4 – N	106	0.08-2.83	0.67 + 0.59			
NO_2 – N	106	0.05-0.30	0.10 + 0.07			
PO_3 – N	106	0.20-6.91	1.56 + 1.53			
ΣN	106	0.50-7.37	2.33 + 1.58	$\Sigma N:P = 21.2$	$\Delta Ni:\Delta P = 21.6$	0.71
Si	106	0.48-8.56	1.96 + 2.05	$Si:P = 17.8$	$\Delta Si:\Delta P = 27.7$	0.70

An excess of silica over that expected from biochemical regeneration is rather frequent in the deeper oceanic waters, where it is probably caused, according to Richards (1958), either by an upward diffusion from bottom deposits or by a redissolution of silica taking place after the complete regeneration of phosphate and nitrate. The high observed **Δ** Si:**Δ** P ratios (see Table 2) support this view. In the case of the Mediterranean Sea, this excess is more probably due to a greater contribution of continental waters.

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