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On the mean nitrogen phosphorus ratio in the mixed winter surface layer of the Baltic

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Abstract: According to investigations between 1969 and 1978 the mean ratio of nitrate to phosphate is about 6 to 7 : 1 (by atoms) in the mixed winter surface layer of the central parts of the Baltic, whereas the ratio of nitrate, nitrite, and ammonia to phosphate is roughly 7 to 8 : 1. In the Belt Sea, the Gdansk Deep, and the Gulf of Finland these ratios are higher but do not reach the oceanic ratio.

In contrast to the oceans, in the Baltic the nitrogen to phosphorus ratio varies strongly in space and time (FONSELIUS, 1973, 1978, 1979, NEHRING, 1974, 1979, NEHRING et al., 1969, NIEMI,1979). Nutrients are transported into the euphotic layer by vertical mixing in the ratio present in the deep water. For the spring bloom of the phytoplankton the inorganic nitrogen and phosphorus compounds enriched in the surface layer in winter as well as their ratio are very important. According to FLEMING (1940) this ratio should be about 16 : 1 (by atoms). Investigations on nutrient ratios in the productive season are only of limited significance because the inorganic nitrogen and phosphorus compounds are assimilated and remineralised at different rates. In addition, the exact determination of the very small amounts of nutrients in the depleted summer surface layer is limited by the analytical methods.

Since the International Baltic Year 1969/70 the Institute of Marine Research of the Academy of Sciences in Rostock-Warnemünde carries out regular investigations on nutrient distribution in the Belt Sea, the central Baltic and the Gulf of Finland (fig. 1). The mean ratios of inorganic nitrogen to phosphorus compounds were calculated from measurements between 1969 and 1978 in the season with the lowest biological activity. The depths used in the investigated areas varied according to the depth of the mixed layer (tab. 2). Normally measurements were carried out in February.

Data from the March/April cruises were taken only in the eastern Gotland Basin where the spring outburst starts in May (KAISER, SCHULZ, 1976). As shown in table 1, the number of data from the different subregions varies. Table 2 gives the mean nitrogen to phosphorus ratios in these areas.

In the mixed winter surface layer of the central parts of the Baltic the mean nitrate to phosphate ratio is about 6 to 7 : 1 (by atoms). In the Belt Sea it is significantly higher than in the Gotland Sea. In the Gdansk Deep it seems to be higher as well. But the highest ratio was found in the Gulf of Finland. In this case we have to consider that the Gulf of Finland was visited by GDR research vessels during the winter only in 1975. RINNE et al. (1980) also report a high nitrogen phosphorus ratio in this area. Nutrient ratios higher than the oceanic ratio were observed in the Bothnian Bay (FONSELIUS, 1978, 1979, NIEMI, 1979).

The nutrient ratio in the mixed winter surface layer of the Baltic is mainly influenced by the nitrate concentration. The nitrite and ammonia contributions are much smaller (tab. 2). The ratio of the total inorganic nitrogen compounds to phosphate is roughly 7 to 8 : 1 in the central Baltic.

In the productive season the euphotic layer of the Baltic is depleted not only of nitrogen containing nutrients but also of phosphate. The deficit of inorganic nitrogen compounds observed relative to the oceanic ratio in winter is obviously regulated by nitrogen fixing blue-green algae (HÜBEL, H., HÜBEL, M., 1976, RINNE et al., 1980) and by the atmospheric input of nitrate and ammonia (NEHRING, WILDE, 1979). As in the Bothnian Bay (NIEMI, 1979), the relatively low nitrogen fixation in the Belt Sea observed in August 1975 (HÜBEL, H., HÜBEL, M., 1976) may be caused by the higher nitrogen to phosphorus ratio in this area.

In February and March 1980 extremely high nitrate concentrations (up to 10 - 13 µg-at./l) were measured over large areas in the surface layer of the Belt and Arkona Seas (stat. 10, 11, 12, 22, 102). In our experience such high concentrations have never been observed before in Baltic surface waters. The resulting nitrate to phosphate ratios are between 17 and 22 : 1, and thus exceed the oceanic ratio.

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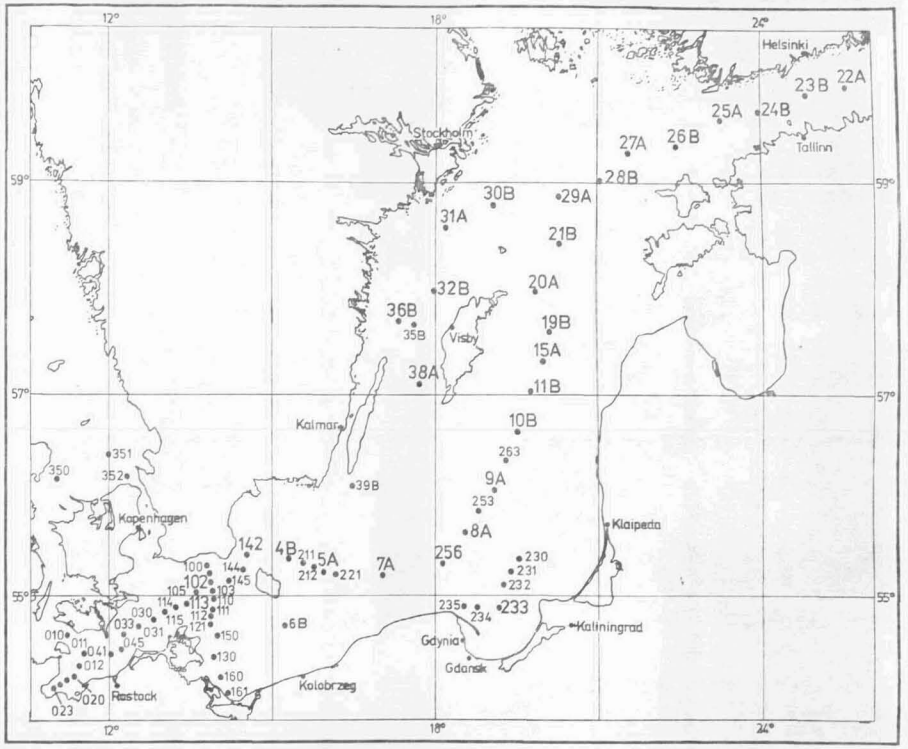

Fig. 1: Map with stations

Table 1 Dates of measurements in the mixed winter surface layer of the Baltic

Area	Station	Year 1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Belt Sea	010			22.2.			13.2.	13.2.		31.1.	4.2.
	011						13.2.	13.2.		31.1.	4.2.
	012			22.2.			13.2.	13.2.		1.2.	
	023			23.2.			13.2.	13.2.		1.2.	23.2.
Arkona Sea	113			12.2.			14.2.	15.2.	18.2.	5.2.	5.2.
	102	21.2.		15.2.			15.2.	17.2.	21.2.	4.2.	5.2.
Bornholm Sea	4 B			18.2.			16.2.	18.2.	19.2.	8.2.	
	5 A	1.3.				13.2.	16.2.	19.2.	19.2.	8.2.	7.2.
Gdansk Deep	233			21.2.		21.2.	17.2.	20.2.		12.2.	10.2.
Eastern Gotland Basin	8 A	27.3.	25.3.	30.3.	8.4.	1.4.	27.3.	10.4.	7.4.	3.4.	30.3.
	9 A	27.3.	26.3.	30.3.	9.4.	1.4.	27.3.	10.4.	7.4.	3.4.	30.3.
	15 A	28.3.	27.3.	29.3.	9.4.	30.3.	28.3.	11.4.	8.4.	3.4.	31.3.
Landsort Deep	31 A						19.2.	26.2.			
Gulf of Finland	24 B							24.2.			
	23 B							24.2.			
	22 A							25.2.			

Table 2 Mean nitrogen phosphorus ratios 1969 - 1978 in the mixed winter surface layer of the Baltic

Area	Station	NO_3-N : PO_4-P (µg-at./l) m*)	s**)	max.	min.	$\Sigma(NO_3^- + NO_2^- + NH_4^+)$: PO_4-P(µg-at./l) m*)	s**)	max.	min.
Belt Sea 1 - 10 m	010	11.5	2.9	16.6	7.6	14.8	3.3	18.9	9.4
	011	9.2	2.0	11.6	6.4	11.8	1.9	13.9	8.6
	012	7.8	3.1	13.1	4.8	10.2	3.0	15.5	6.8
	023	11.7	2.7	14.7	7.8	14.9	3.7	21.7	11.0
tot.mean		10.0	3.0	16.6	4.8	12.7	3.5	21.7	6.8
Arkona Sea 1 - 20 m	113	6.2	1.4	8.7	4.2	8.5	3.0	15.2	5.3
	102	7.5	2.5	12.5	4.5	8.5	2.7	13.8	5.4
tot.mean		6.9	2.2	12.5	4.2	8.5	2.8	15.2	5.3
Bornholm Sea 1 - 30 m	4 B	5.6	1.1	7.3	3.2	6.1	1.7	8.9	3.6
	5 A	6.2	2.5	12.6	3.1	7.2	1.7	10.9	4.3
tot.mean		5.9	2.0	12.6	3.1	6.7	1.8	10.9	3.6
Gdansk Deep 1 - 40 m	233	8.7	3.4	14.1	2.9	11.1	3.0	16.4	6.4
Eastern Gotland Basin 1 - 40 m	8 A	5.9	1.1	8.3	3.3	7.2	1.1	9.4	5.1
	9 A	6.6	2.1	11.9	4.1	7.7	2.7	19.6	5.0
	15 A	6.7	1.3	8.6	3.2	7.7	1.3	9.8	5.2
tot.mean		6.4	1.6	11.9	3.2	7.5	1.9	19.6	4.9
Landsort Deep 1 - 40 m	31 A	7.4	0.8	8.2	6.3	7.7	0.6	8.4	7.2
Gulf of Finland 1 - 40 m	24 B	11.8	2.3	15.9	10.5	13.0	2.6	17.6	11.6
	23 B	11.4	0.8	12.5	11.6	12.5	0.8	13.6	11.6
	22 A	11.3	0.7	12.1	10.5	12.1	0.7	13.0	11.4
tot.mean		11.5	1.4	15.9	10.5	12.5	1.5	17.6	11.4

*) mean

**) standard deviation