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On the coherence of the dynamics in zooplankton abundance of the Baltic proper with phosphorus and Kattegat waters advection.

by

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Abstract.

Statistical connections of phosphorus (as the index of mineral food supply of primary producters) and crustacean plankton abundance in spring, summer and autumn periods are considered on the base of long-term (1960-1977) materials analysis. Clear direct connections between these factors in summer-autumn period (r_1= 0.79 and r_2= 0.90) are observed. The influence of Kattegat waters advection on the productivity of some sea areas is shown. It is noted, that to the greatest extent it is observed in the Southern and North-eastern Baltic, where nutrient outflow from depth is accompanied by the increase of zooplankton abundance.

R E S U M E

Sur la base de l'analyse du matériel de plusieurs années (1960-1977) on examine les rélations statistiques du phosphore "en tant qu'indice de ravitaillement en nutrition menérale des reproducteurs primaires" et de la quantité de plancton animal dans les périodes de printemps, d'été et d'automne. On distingue des rélations directes bien nettes entre ces facteurs pour la période d'été-automne (r_1 = 0.79 et r_2 = 0.90). On démontre l'effet de l'advection des eaux de Cattégat sur le rendement de différentes régions de la mer. On a noté que cet effet se manifeste le plus dans les parties sud et nord - est du la Baltique, où l'entraînement des biogènes est accompagnéde l'augmentation de la quantité de zooplancton.

Very intricate means of phosphorus and nitrogen circulation in the Baltic, in particular intensified P sedimentation with the participation of terrigenous substance (Yurkovskis, 1968; Yurkovskis, Luke, 1975) and denitrification in the deep layers together with sharp stratification of sea water thickness condition low efficiency of upwards nutrients current. This is only partially balanced by considerable inflow of P and N with river waters (Sen Gupta, 1973; Fonselius, 1976) and by acceleration of substances, vertical outflow when local upwelling functions for relatively short periods. Nutrients, which limit bioproductivity of seas, are phosphorus and nitrogen. There is contradictory information about this for the Baltic Sea. Tarkiainen, Rinne and Niemisto (1974) show, that nitrogen must be the nutrient of limiting minimum there. Fonselius (1969, 1972, 1976) considers, that salt nitrogen does not limit the

synthesis of organic matter in the Baltic, phosphorus is more deficient there. Our long-term regime investigations allow to suppose that phosphorus as well as nitrogen and even both nutrients together may be limiting in dependence on sea areas and seasons.

Rather detailed and long-term data of the investigations on phosphorus and zooplankton in the Baltic and less long observations on phytoplankton being available, an attempt was made "to step over" autotrophic link of trophic chain and to search for connections between zooplankton abundance and the amount of this deficient nutrient in the lighted sea layer as well as the availability of precondition of deep waters rise - the situation of Kattegat waters advection. Phosphorus - the first of the two comparing components of sea biogeocenosis having direct and reverse connections, is used in this paper as the index of mineral food supply of primary producers.

Phosphates accumulated during autumn-winter period are intensively spent in spring by impetuously developing phytoplankton and cause its bloom. Therefore food supply of zooplankton during this period is in general high and connection between its abundance and phosphorus is not observed (the data for 1961-1977). Only after warm winters, which were in 1960/1961, 1970/1971, 1972/1973, 1973/1974, 1974/1975, a direct connection between these factors ($r = 0.94$; $\alpha = 0.01$; Fig. 1) is underlined. In the years mentioned the spring bloom of phytoplankton seemed to begin early, and the decrease of spring outburst in May was more considerable than in cool and cold springs, zooplankton food availability was worse.

The most considerable connection between zooplankton abundance and phosphates is observed in summer, when P amount in trophogenic layer is at the level of annual minimum and cause vegetation decrease of food phytoplankton (all algae groups except blue-green), as the result of this food supply of zooplankton decreases, and food requirement because of intensive reproduction and populations growth of main species increases. Clear direct connections between zooplankton abundance and phosphorus amount in the active sea layer is formed ($r=0.79$; $\alpha=0.01$; Fig. 2). The analysis of connections between zooplankton abundance and other environmental factors (temperature, fish stocks, parent stock and other) did not reveal clear dependence. The said above allows to consider food supply the main factor, which conditiones abundance dynamics and development level of zooplankton in summer period.

In autumn the influence of phosphates on zooplankton abundance preserves ($r=90$; $\alpha=0.01$; Fig. 3).

Kattegat waters advection, provoking nutrient outflow from deep sea layers, is the main factor of forming productive areas in the Baltic Sea. Its influence on zooplankton is the most clearly revealed in summer period. When Kattegat waters enter the Bornholm Deep in winter-spring period (February-May) the maximum of zooplankton abundance in summer is usually observed on its aquatory and in the adjacent areas. Such coincidence was observed in 1969, 1970, 1972, 1974, 1976 and 1977 (the years of observation 1962-1977).

In the Eastern Baltic (the Gotland Basin), when Kattegat waters advection in the active deep layer is observed, the outflow

of deep waters from the Fore Deep occurs (Yurkovskis, Rugaine, 1979). The movement of Kattegat waters along the bottom layer efficiently redistributes (in the northern, north-eastern and eastern directions) nutrients from deep water zone of the Gotland Deep (Yurkovskis, Fomeinykh, 1978). Replenishment of nutrients stock in the eastern part of the sea occurs also owing to the Gulf of Riga waters richer by nutrient salts. When there are no conditions for appearance of maximum zooplankton abundance in the Southern Baltic during the years of Kattegat waters inflow, to the Gotland Basin (1964 and 1973) or high waters outflow from the Gulf of Riga (1966 and 1967) the highest zooplankton abundance was observed in the eastern part of the sea.

To reveal the dependence of changes of zooplankton abundance in the North-eastern Baltic (the area of Fore Deep) on the discussed hydrodynamical processes the comparison with the eastern sea areas was made, since the difference of temperatures between them in the layer of main zooplankton inhabitancy, 0-100 (90) m is considerably lower(0.3-0.4°C) than between north-eastern and southern areas (1.3-1.4°C)*. The highest zooplankton abundance in the north-eastern area (in comparison with the eastern area) was observed in 1961, 1962, 1965, 1974, 1975 and usually coincided with the inflow of waters of high salinity to the Fore Deep.

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* The temperature of water in the north-eastern and northern sea areas limits the development of heat-loving species, which are in summer season the important component of zooplankton community.

When there is intensive outflow of nutrients in the North-eastern Baltic maximum zooplankton development may be also observed in the northern part of the sea (1965, the area of the Northern Deep).

So, the given data testify to the considerable role of abundance fluctuation over halocline of phosphorus and Kattegat waters advection, dispersing and redistributing the deep water nutrient stock between the layers in the dynamics of zooplankton abundance in the Baltic. The peculiarities of phosphorus annual cycle mainly determined by the complex of hydrological and biological processes, have importance at forming annual level of zooplankton abundance and its variability on sea aquatory.

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F I G U R E S

Figure 1. Statistical connections between phosphates amount in the active* (0-60 m) layer in February-May and crustacean plankton abundance in the layer 0-100 m in May.

Figure 2. Statistical connections between phosphates amount in the active layer (0-60 m) in May-August and crustacean plankton abundance in the layer 0-100 m in August.

Note: 1971 was distinguished by extremely high zooplankton abundance and reverse connections between phosphates amount and zooplankton abundance appeared in some sea areas; this year was not taken into account when correlation factor was calculated.

Figure 3. Statistical connections between phosphates amount in the active (0-60 m) layer in October and crustacean plankton abundance in the layer 0-100 m in October.

Numerals on figures represent years.

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*Under "active" we mean layer of water in which seasonal changes of phosphorus abundance are clearly expressed. It was decided , that its mean thickness for Baltic is 60 m.

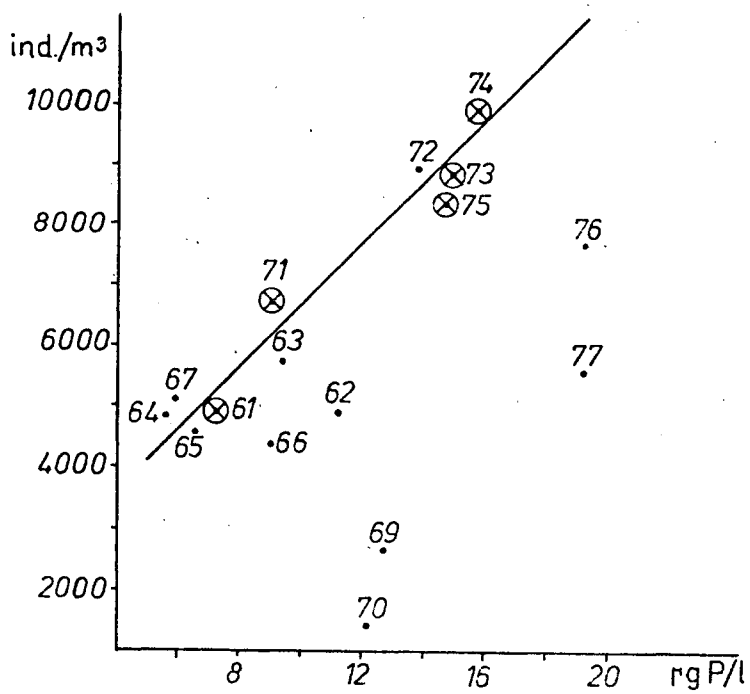
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Fig. 1

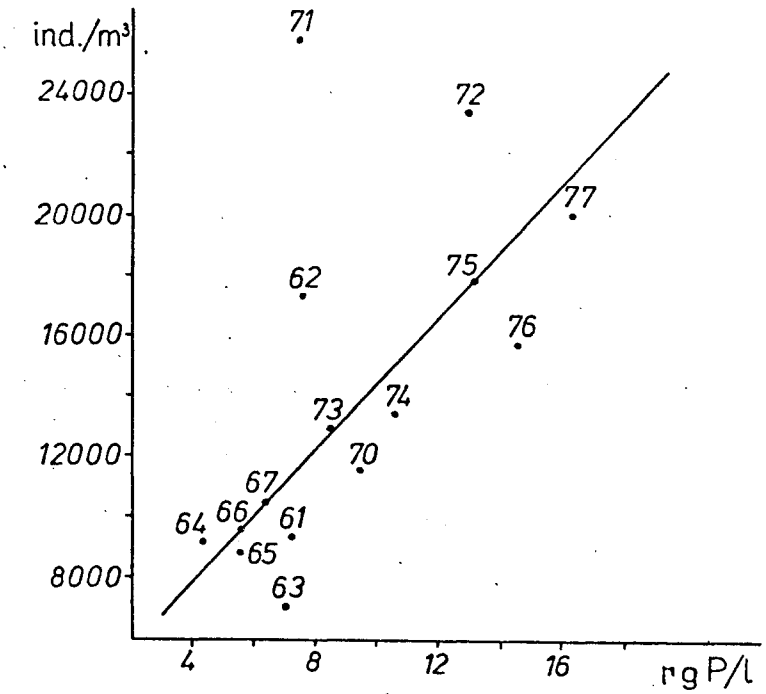
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Fig. 2

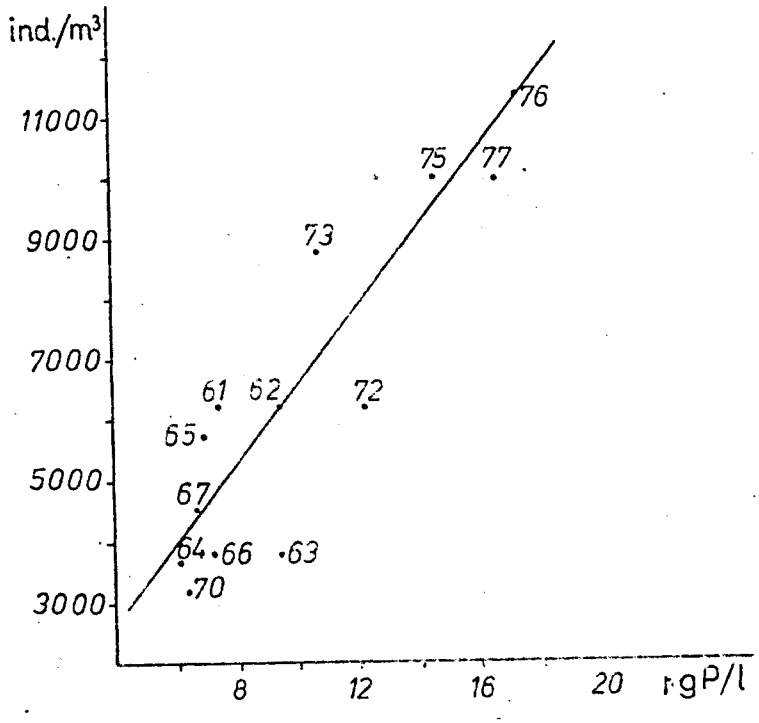
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Fig. 3