QUANTITAIVE ECOLOGY OF PHYTOPLANKTON IN THE COCHIN BACKWATER

C. P. GOPINATHAN, P. V. RAMACHANDRAN NAIR AND
A. K. KESAVAN NAIR*

Central Marine Fisheries Research Institute, Cochin.

ABSTRACT

A one-year study on the standing crop in terms of chlorophylls, primary production and total-cell counts of four station grids has shown that there were regional and seasonal variations in the magnitude of phytoplankton production in the Cochin backwater. Statistically treated using a microcomputor, a multiple regression relationship has been established between parameters within stations. But the Correlation coefficient and Standard Regression coefficient have revealed that the plankton production and the related parameters at all the stations were independent of each other and the parameters varied from station to station. Probable reasons are briefly discussed.

INTRODUCTION

The account on the organic production of the Cochin backwaters by Qasim et al (1969) had shown that the estuarine system was one of the most productive in the tropical environment, with an estimated annual gross production of 295 gC/m^2. Subsequent studies on the variation and distribution of the phytoplankton and the factors affecting its production had revealed that the standing crop in terms of chlorophylls (Qasim and Reddy 1967), biomass (Gopinathan 1972), total cell counts (Gopinathan et al 1974, Joseph and Pillai 1975) and primary production (Nair et al 1975) varied from place to place and from time to time as a result of the water masses being constantly renewed by an inflow of freshwater from the rivers and seawater from the inshore areas of the Arabian sea.

In an earlier investigation, Gopinathan et al (1974) had stated the usefulness of chlorophyll *a* as a measure of the phytoplankton abundance and that a common relationship existed between phytoplankton and chlorophyll *a* for the estuary. Studies on the phytoplankton of different environments have shown that none of the productivity indices, such as chlorophylls, biomass and total counts, can independently give a true picture of the standing

* *Present address*: Central Institute of Fisheries Technology, Cochin.

crop because of the inherent drawbacks in each method. Moreover, the hydrological and productivity parameters also differ according to the change of environment and place of sampling. Hence, in this account, an attempt was made to determine the relationship of different variables responsible for the phytoplankton production by means of multiple regression analysis.

Area of study and Methods

In the central part of the estuarine system of Cochin, four surface stations were sampled fortnightly for one year, 1974, for collecting hydrological and productivity data (Fig. 1). The phytoplankton crop was estimated by total-cell counts and chlorophylls and by primary-productivity measurements using radioactive isotope of carbon (^{14}C). For calculating the concentrations of chlorophylls revised equations of Parsons and Strickland (1963) were employed. Duplicate samples were analysed for hydrological properties such as salinity, oxygen and nutrients as followed by Strickland and Parsons (1968).

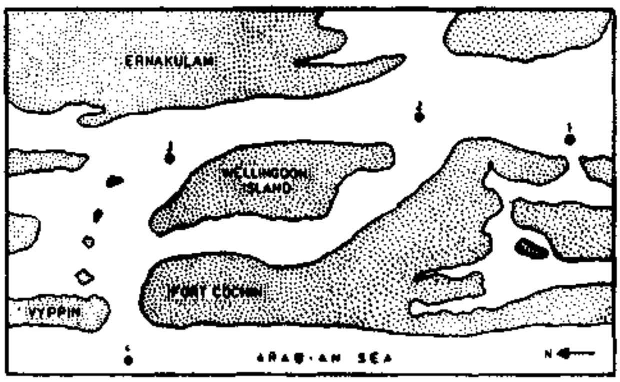

FIG. 1. Map of Cochin Backwater showing the sampling stations.

Observations

Primary Production

Two seasonal peaks of primary production were noticed in all the four stations, a primary peak during premonsoon season and a secondary peak during the postmonsoon. The range of production for the first station was 432-3900 mgC|m^3|day; for the second, 360-3400 mgC|m^3|day; for the third, 261-1750 mgC|m^3|day; and for the fourth, 438-2035 mgC|m^3|day (Fig. 2A). Though the monsoon months are said to be the most productive season for the phytoplankton in the coastal waters, it was not so in the estuarine system. Generally there was a higher rate of production noticed in the backwater area than in the inshore. The observations of Qasim et al (1969) had indicated three small peaks, in April, July and October. But it appeared from the present study that the fluctuations might not be consistent year to year, probably due to prevailing environmental conditions.

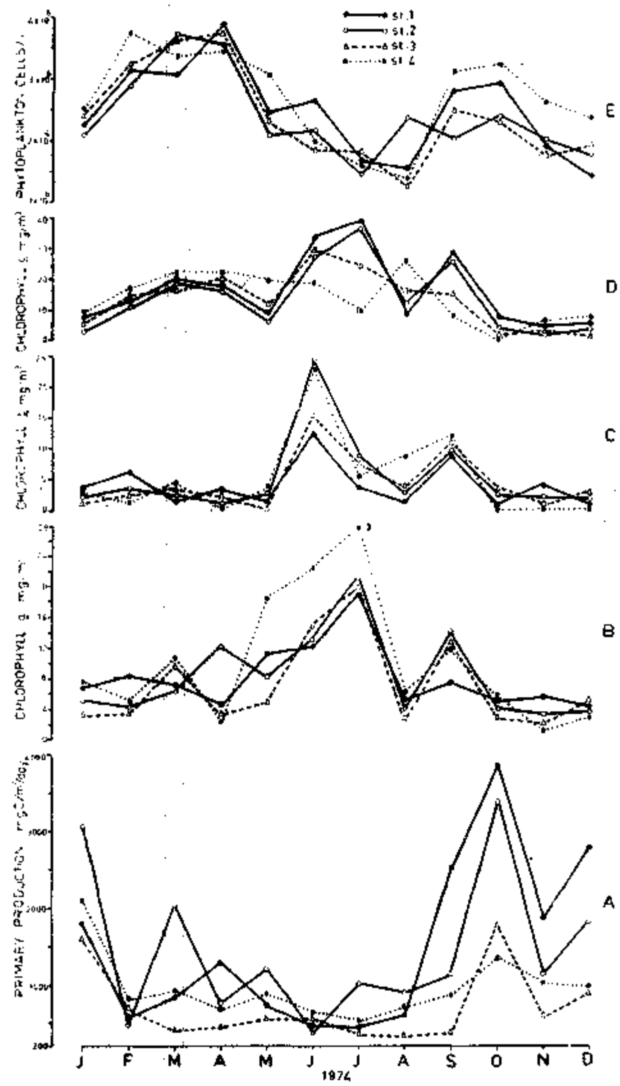

FIG. 2. Different productivity parameters measured from 4 stations.

Chlorophylls

Since chlorophyll *a* is one of the major indices of the standing crop of phytoplankton, the estimation of this pigment along with that of the primary production is expected to give a general idea of the variation in the magnitude of producton. Fig. 2 (B, C and D) gives the average values of these pigments on the surface of the backwaters, from which it can be seen that the most dominant pigment was chlorophyll *c*, followed by *a* and *b*.

Like the primary production, the chlorophyll *a* values aso showed distinct seasonal and spatial variation but, in contrast to the former, chlorophyll *a* values showed only a single peak, during monsoon, in all the stations, indicating an inverse relationship with production. Chlorophyll *b* showed a primary peak during monsoon and a secondary one, of less magnitude, during September. Chlorophyll *c* gave exceptionally high values during premonsoon and monsoon. A comparison of chlorophyll *a*, *b* and *c* (Fig. 2B, C and D) was of interest in view of the generally accepted status of chlorophyll *a* as the most predominant pigment of the phytoplankton and chlorophyll *b* as an accessory pigment (Strickland 1960). With regard to the status of chlorophyll *c*, it has been doubtful whether it could be accepted as an accessory pigment at all (Spencer 1964), though Parsons (1961) had stated that in some algal cells chlorophyll *c* could markedly increase under certain environmental conditions. But Currie (1958), Humphrey (1960, 1963) and McAllister et al (1960) had pointed out errors that would possibly involve in its determination. Krey (1958) and Vallentyne (1965) too had indicated that dead chlorophyll would interfere in the estimation the phytoplankton pigments of coastal waters.

The interrelationships of chlorophylls of Cochin backwater, expressed in terms of ratios *c*|*a* and *b*|*a* are given in Table 1, from which it can be seen that the ratio *c*|*a* was consistently higher, especially during pre- and postmonsoon, in all the stations, indicating a predominance of chlorophyll *c* in the water column. This dominance of chlorophyll *c* could evidently be due to the presence of plenty of degrading chlorophyll.

TABLE 1. *Chlorophyll* c|a *and* b|a *ratios.*

	Chlorophyll *c/a* ratio				Chlorophyll *b/a* ratio			
	St. 1	St. 2	St. 3	St. 4	St. 1	St. 2	St. 3	St. 4
Jan	1.15	0.48	2.46	0.83	0.05	0.26	0.27	0.25
Feb	1.52	2.53	3.68	2.42	0.07	0.17	0.40	0.27
Mar	3.08	2.43	1.50	2.0	0.15	0.32	0.18	0.37
Apr	4.34	1.38	6.38	6.46	0.82	0.12	0.42	0.65
May	0.69	0.45	2.0	1.05	0.16	0.36	0.19	0.08
Jun	2.88	1.97	1.92	0.85	1.07	1.93	0.99	1.15
Jul	3.66	1.68	1.21	0.34	0.16	0.33	0.33	0.18
Aug	1.44	2.62	6.25	5.92	0.27	0.55	1.25	1.96
Sep	3.86	1.76	1.12	0.58	1.12	0.45	0.84	0.90
Oct	1.51	1.13	0.69	0.88	0.10	0.16	0.38	0.41
Nov	1.08	0.77	0.86	2.75	0.67	0.18	0.75	0.70
Dec	1.08	0.92	0.43	1.15	0.21	0.34	0.26	0.48

Thus the results of plant pigment analysis clearly indicated that the backwater was characterized by a large quantity of organic and inorganic particulate matter. It was however not possible to estimate how much pigment came from the living organisms of the backwater, since the water mass was alternately being renewed by inflow of seawater from one side and river discharge from the other. The pigment stocks were also found to vary considerably from place to place and from time to time according to tidal rhythms.

Total cells

The total-cell count showed seasonal and spatial variations corresponding to the primary production and the chlorophylls, and, similar to primary production, it had a primary peak during the premonsoon months and a secondary peak of less magnitude during the postmonsoon months. Low values were observed in the months of July-August and November-December (Fig. 2E). Generally, the trend in cell numbers was more or less similar, unlike the trends in primary production and chlorophylls, in all the stations.

Thus the different indices of standing crop of phytoplankton showed different trends in their fluctuations with no obvious relationship with one another. The observations of Qasim et al (1969), based on the primary production values, and those of Gopinathan et al (1974) and Joseph and Pillai (1975), based on the total cell counts, indicated that the fluctuations of the standing crop of phytoplankton in the Cochin backwater varied from year to year, depending on the shifting of climatic conditions, chiefly the monsoon, and the resulting environmental parameters.

Qualitative studies

Since the sampling stations had been fixed so as to represent the grading environmental features between backwater and marine, i.e., to cover the different grades of tidal influence, it was natural to expect variation in the species composition from station to station. The backwater station (St. 1) showed a mixture of both freshwater and brackishwater forms almost in equal magnitude, while the second and third stations showed preponderence of brackishwater species. At the marine station (St. 4), there were only marine species, with the freshwater forms completely absent.

During the peak periods the phytoplankton was mainly constituted by diatoms, with nannoplankters forming the next important component. During the premonsoon months the diatoms and dinoflagellates were present in equal numbers, and in the postmonsoon dinoflagellates dominated. The primary peak during the premonsoon months was formed by diatoms such as *Skeletonema costatum, Thalassiosira subtilis* and *Chaetoceros affinis.* During the second peak, the dinoflagellates such as *Ceratium furca* and *Peridinium micans* formed the major components along with diatoms *Skeletonema costatum* and *Fragilaria* *oceanica*. Silicoflagellates such as *Distephanus* and *Dictyocha* were present in lesser numbers during the premonsoon months. The coccolithophore, *Coccolithus huxley*, and a few members of blue-green algae, such as species of *Oscillatoria, Trichodesmium, Meresmopedia* and *Synechocystis*, were found in lesser numbers during the postmonsoon season. Freshwater desmids, *Euastrum, Cosmarium, Micrasterias* and *Desmidium*, and filamentous green algae *Spirogyra, Oedogonium* and *Cladophora* species also were seen during the monsoon season at the first station.

Environmental factors

Temperature, salinity, dissolved oxygen and silicate as was estimated at the surface waters of all the stations are given n Fig. 3.

Temperature: The fluctuations in the surface temperature during different seasons were very low ranging from 2° to 31°C in all the stations. The temperature was at its maximum during the premonsoon months, extending up to May, after which, with the onset of monsoon, it began to decline. During monsoon and in the early postmonsoon periods the surface temperature was very low. Increase in temperature began again in November-December, reaching the maximum in March-April (Fig. 3A).

In the estuary the temperature by itself seemed to have no direct influence on the phytoplankton production although it was possible that the increase in temperature would enhance the rate of respiration of the planktonic algae and the energy stored during photosynthesis would be used up reducing their multiplication activity. According to Roy (1955), in the Hooghly estuarine system, the low winter temperature never acted as a limiting factor for the phytoplankton production. Shetty et al (1961) had shown that the peak of phytoplankton in the Hooghly area during June-August was due to the relatively high temprature (30°C). Steemann Nielsen and Jensen (1957) have pointed out that in shallow regions where the bottom is in direct contact with the overlying water an indirect influence of temprature would cause an enhancement in the regeneration process to some extent which would reflect in the rate of primary production.

Salinity: The salinity, the most important of all the hydrological parameters in an estuary, since it regulates the entire biological activities of the ecosystem, fluctuated widely in the Cochin estuarine system because of the influence of monsoon and consequent run off from land. During the premonsoon season, especially during March-April, the surface salinity at all the stations exhibited considerable increase. This may be interpreted as the season of highest salinity when the influence of the seawater was at its maximum throughout the estuary. During monsoon large quantities of freshwater entered the estuary from the rivers and through rainfall lowering the surface slainity abruptly even at the marine station (St. 4). By about August an early freshwater condition prevailed in the estuary. After the monsoon abated the salinity values began again to increase gradually through the late postmonsoon months to reach the peak in the premonsoon months (Fig. 3B).

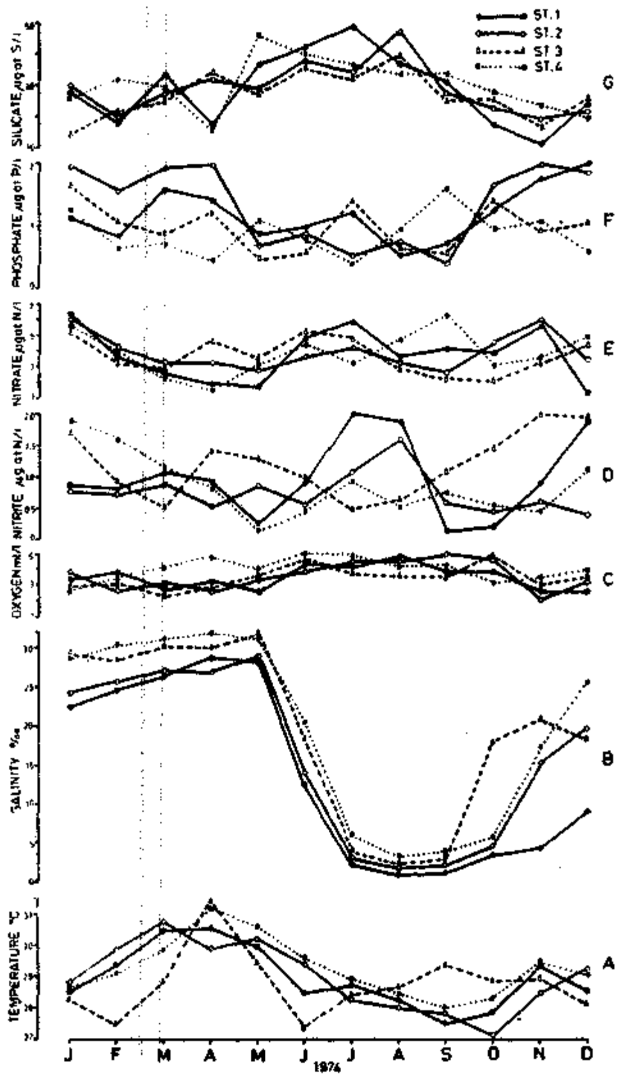

FIG. 3. Seasonal variation of different hydrographic features including nutrients collected from 4 stations.

A horizontal gradient in salinity was also observed from station 1, which was more brackish, to station 4, more akin to marine inshore environment. Studies by Qasim et al (1972) had indicated that many phytoplankters bloomed in exceptionally low salinities in the Cochin backwater. This ability of the phytoplankton to proliferate in low salinities may be in adaptation to utilize the nutrient enrichment brought down by the fresh water to maximum advantage.

Oxygen: The dissolved-oxygen content of the surface waters did not show much fluctuations, though relatively higher oxygen values were found at all stations during the monsoon period (Fig. 3C), showing that, in the backwater, the oxygen content had no direct relationship with phytoplankton production.

Nutrients: Nitrite, nitrate, phosphate and silicate were studied. The nitrite-N values showed a single peak at the 1st and 2nd stations, while the third and fourth stations showed two peaks, a primary one during the monsoon and the secondary one in postmonsoon season (Fig. 3D). But nitrate-N showed wide fluctuations in different seasons in different stations (Fig. 3E). The inorganic phosphate (PO_4) showed distinct primary and secondary peaks during the pre- and postmonsoon periods in the first and second stations, while the third and fourth stations indicated also a third peak during the monsoon with less magnitude (Fig. 3F). The silicate values were found to be high during the monsoon months, coinciding with the chlorophyll peaks and with an inverse relationship with the diatom abundance (Fig. 3G).

According to Sankaranarayanan and Qasim (1969) the instaneous concentration of nutrients in the Cochin backwater as inorganic salts did not seem to have any significant influence on the production of phytoplankton. Recent studies by Gopinathan et al (1974) also had revealed this fact clearly. But, although the nutrient-phytoplankton relationship is an established one, the cause and effect cannot be established in many ecosystems unless through an inverse relationship, as the nutrients are depleted in proportion to the production of phytoplankton. Such a negative relationship could also be seen in the Cochin backwater. As can be seen from figures 2 and 3, Nitrate-N did not indicate any relationship with any of the productivity indices, suggesting that a major part of the nitrogen was supplied in the form of nitrite and other nitrogenous compounds. The N|P ratio at different stations also supported this assumption (Table 2). The highest ratio for all the stations has been found to be only 8.8, instead of the expected 16:1 by atom observed in highly productive ecosystems. The very low values suggest that the inorganic phosphate present in the surface waters was utilized and regenerated much faster than the nitrates. Under the conditions of depleted nitrogen concentration production of phytoplankton could occur with lower assimilation ratio (McAllister et al 1960).

Statistical Analysis

A statistical analysis was conducted to examine the influence of various hydrological and productivity parameters. For this a multiple regression relationship was set up with all the parameters using a Micro Computor (MICRO

TABLE 2. *Nitrate/Phosphate Ratio*

	St. 1	St. 2	St. 3	St. 4
Jan	6.18	2.73	2.94	4.30
Feb	4.38	2.70	3.09	5.38
Mar	1.68	1.69	3.44	3.53
Apr	1.46	1.55	3.87	2.85
May	2.17	4.38	8.13	3.65
Jun	5.27	4.09	8.86	5.56
Jul	4.81	7.96	2.91	8.88
Aug	6.19	4.48	5.18	5.27
Sep	5.20	5.44	3.85	3.69
Oct	3.08	2.56	1.54	2.96
Nov	3.01	2.63	3.82	2.70
Dec	0.43	1.77	4.37	8.66

2200): the hydrological factors such as temprature, salinity, oxygen and nutrients such as nitrite, nitrate, phosphate and silicate were reckoned as the independent variables and primary production as the dependent variable. The correlation coefficient between the independent variable and production and the standard regression coefficients for the 4 stations are represented in Table 3. From the standard regression coefficients it can be seen that the contributing variables were different at the different stations. Taking the first four important

TABLE 3. *Correlation coefficients* (C.c.) *and Standard regression coefficient* (Std. reg.) *for the four stations.*

St. No.		*Temperature*	*Salinity*	*Oxygen*	*Nitrite*	*Nitrate*	*Phosphate*	*Silicate*
1	C c.	−0.4535	−0.3619	−0 2551	−0 3884	−0.1139	0.4251	−0.5419
	Std. reg.	−0.7148	0.0688	0.0514	−0.5708	−0 0957	0.6114	−0.2597
2	C.c.	−0.3323	−0.0118	0.2198	−0.2722	0.4410	0.4730	−0.2838
	Std. reg.	−0.0979	0.4898	1.2774	0.1623	0.0467	0.9061	−0.4086
3	C.c.	−0.1366	0.2395	0.2047	0.5167	0.0123	0.5934	−0.4911
	Std. reg.	−0.4295	0.1440	0.5598	0.5619	−0.3070	0.7325	0.0205
4	C.c.	−0.2670	0.1400	−0.7649	0.0371	0.1367	0.3594	−0.2842
	Std. reg.	−0.9877	1.0361	−0.4461	−0.6295	−0.0028	0.0305	−0.2702

variables, multiple regression equations were worked out for the four stations. These equations along with the coefficient of determination (R_2) and standard error of estimate (SEE) are given in Table 4.

TABLE 4. *Multiple regression equations, Standard error of estimate* (S.E.E.), *and Coefficient of determination of the values at the four stations.*

St. No.	Regression equation	SEE	R^2	F	
1	$P = 21452.27 - 696.55\,(T) - 685.97\,(NO_2) + 1325.13\,(PO_4) - 24.67\,(Sio_3)$	557.94	0.8447	9.52**	(d.f.) 4, 7
2	$P = -4317.81 + 31.35\,(S‰) + 1231.93\,(O_2) + 1328.67\,(PO_4) - 36.76\,(Sio_3)$	526.52	0.8140	7.62*	„
3	$P = 2773.0 - 170.42(T) + 355.01\,(O^2) + 606.44\,(NO_2) + 801.42\,(PO_4)$	246.20	0.8503	9.94**	„
4	$P = 14677.55 - 434.54\,(T) + 41.46\,(S‰) - 327.98\,(0_2) - 745.58\,(NO_2)$	261.07	0.7988	6.95*	„

* Significant at 5% level
** Significant at 1% level

For station 1, temperature, nitrite, phosphate and silicate gave a significant (1% level) multiple correlation coefficient. According to the order of importance, the variables were: temperature, phosphate, nitrite and silicate. While temperature, nitrite and silicate showed an inverse relationship, phosphate showed a positive relationship. About 84% of the variations in production was explained by all these parameters.

For station 2, the important variables were found to be oxygen, phosphate, salinity and silicate in that order. These variables gave a coefficient of determination of 0.814 which was significant at 5% level. Here salinity, oxygen and phosphate showed a positive relationship and silicate showed an inverse relationship.

For station 3, the important variables in the order of significance were: phosphate, nitrate, oxygen and temperature. Of these, phosphate, nitrate and oxygen showed a positive relationship, while temperature showed a negative relationship. These variables together contributed to 85% of the variation in production. The multiple correlation was found to be significant at 1% level.

For station 4, the important variables in their order of significance were: salinity, temperature, nitrite and oxygen. Of these, salinity showed a direct relationship, as the station was situated in the inshore area. The rest of the variables showed an inverse relationship. The coefficient determination of 0.7988 revealed 5% level of significance.

CONCLUSION

The multiple regression analysis proved that all the four stations were independent of each other and the contributing parameters varied station to station. The probable reason for these variations was the effect of the dynamic nature of the backwater. It may be that the instantaneous concentration of the various environmental factors is reflected in the computor analysis. Another reason for these variations may be the process of mixing of sea water and freshwater brought about by the semi-diurnal rhythm which might not be constant all over the estuary. During the period when the system showed more of marine conditions the nutrient concentrations were low and remained homogeneous throughout the water column, but during the time of freshwater discharge, high concentrations of nutrients occurred with gradient zones within the system. As seen from the regression equation, the first station had all the nutrients, particularly phosphate, highly significant for the production of phytoplankton. This was the station which received the maximum discharge of nutrient-rich freshwater. In the second station, oxygen, salinity, silicate and phosphate played a significant role. This station was in the brackishwater area and had frequent blooming of the diatom *Skeletonema costatum*. The silicate must have been used proportionately for the building up of the diatom cells and hence an inverse relationship was evident between this and production. The third station, being closer to the bar-mouth, where mixing process was relatively high, the nutrients, oxygen and temprature were found to be highly significant for the production of phytoplankton. Similarly in the fourth station, which was in the marine environment, salinity showed a direct relationship with phytoplankton production besides temperature, oxygen and nitrate, in the order of significance.

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