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SPECTRAL ANALYSIS OF SPATIAL SERIES OF OCEANOGRAPHIC PARAMETERS

by

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INTRODUCTION

The ecological importance of spatial heterogeneity in phytoplankton populations has been pointed out by several authors (HUTCHINSON, 1961; MARGALEF, 1963, 1967, 1976; PLATT, 1975; PLATT & DENMAN, 1975) However, the statistical study of the heterogeneity raises many still unsolved difficulties. Localized concentrations of plankton are frequently designated as "patches", although in general it is very difficult or impossible to etablish some criterion that allow their exact delimitation; in this context, the conception of a patch as an isolated appearance has to be abandoned and replaced by more general approaches to the study of plankton distribution in nature. The methods of spectral analysis, recently applied to the study of phytoplankton heterogeneity (PLATT, 1972; DENMAN & PLATT, 1975; RICHERSON el al.,1975; CRUZADO & KELLY, 1973; KELLEY & CRUZADO , 1974, among others) have made a positive contribution, although, for the moment, it is difficult to find regularities in the existing results, based usually in very different sampling procedures.

This work is concerned with the application of spectral analysis tecniques to the study of data sequences of fluorescence, temperature nitrite and nitrate + nitrite concentration, obtained along some of the transects between stations in the cruise Atlor II, of the "Cornide de Saavedra", carried out in March 1973 in the upwelling zone of NW Africa.

METHODS

Water was taken from a depth of 3 m through a seawater opening into the engine room of the ship, and brought into the laboratoiries by means of a centrifuge pump with an approximate output of 30 l m^{-1}, connected to 2.5 cm diameter plastic tubing. Part of the flow was derived trough a Turner III fluorometer; by a syringe needle fitted into the tubing, water was driven to an ensemble of Technicon autoanalyzers recording nitrate+nitrite and nitrite. The temperature sensor is described in BALLESTER et al. 1972. The value of the variables were recorded each minute on paper tape by means of a data Logger system and processed lollowing essentially the procedures described in BALLESTER et al. 1972.

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Six data series of 200 minutes of duration were considered (table 1) The computational methods for spectral analysis used in this work were based in the subroutines given in JENKIN & WATTS 1968; we chose the Tukey window with a truncation point of 20. To correct for non-stationarity in the data, a first difference filter was applied; in this method, used frequently in the study of time series (see, for exemle, MARGALEF & ESTRADA , 1972; LAUREC & BLANC, 1974), the series:

$x(t)$, $t=0,1,2,\ldots,N$; in subsituted by
$x'(t)= x(t+1)-x(t)$, $t=0,1,2,\ldots,N$.

After this transformation, a test for stationarity was carried out (WAGENSBERG & ESTRADA, in press)

RESULTS AND DISCUSSION

In most of the series, the spectral desities were higher at the lower wavelengths, in spite of the drastic effect of the first difference filter in reducing them.

Observation of the coherence showed that significative non zero values corresponded in general to the lower frequencies studied. Fluorescence-Temperature coherences were significant for runs 1,2 and 3 from respectively 0.115 0.130 and 0.040 cpm to the lowest frequency considered (0.005 cpm); assuming a constant speed of the ship relative to the water close to 4.1 m sec^{-1}, the associate spatial scales would range from approximately 1.9 to 50Km.; on the other hand, in runs 1', 4 and 5, significant coherences between fluorescence and temperature were reduced to narrow frequency intervals at intermediate or high frequency zones. Significant coherences between nitrate+nitrite and temperature were found in wider frequency ranges than for fluorescence-temperature. In this context, it is logical to think of phytoplankton growth as a perturbation that tends to lessen the significant coherence that coult be expected between nutrients and temperature if only mixing physical processes were acting. The two analyzed nitrite series behaved very similarly to the corresponding ones of nitrate+nitrite but showed higher coherences with fluorescence and lower with temperature (Figs. 12 and 15), as could be expected from the intervention of phytoplankton in the production of nitrite at sea (BLASCO, 1971, ESTRADA, 1976).

It has to be pointed out that the variability found in the series can be attributed, not only to the existence of horizontal heterogeneity ("patchiness") in a restricted sense, but olso to other phenomena, like internal waves. FASHAM & PUGH (1976) and DENMAN (1976) discuss this question; in our examples, it is not possible with the available data to attempt a separation of the contribution to the total variance of each of these possible components.

Although it is necessary to be careful when comparing conclusion drawn by different authors, due to the wide variations in the sampling scales and methods involved, some comments may be made. DENMAN & PLATT studied the coherence between series of fluorescence and temperature and found that it was significative for spatial scales between 100 m and 5 Km. Below 100 m, the proportion of the total variability was very small, fluctuations of both parameters would be buffered by turbulent mixing. The decrease of coherence for spatial scales greather than a certain length could be caused by a predominance of phytoplankton growth effects over physical transport mechanisms in the production of heterogeneities, as suggested by DENMAN & PLATT (1975) and POWELL et al.(1975)

Our findings agree basically with these explanations, but the diversity of results obtained indicates that in a habitat as complex as the ocean, many factors affecting the history of the water bodies involved must be important in determining the degree of coherence between actual series of biological and fisico-chemical variables.

The available information suggests in conclusion, that at some spatial scales distribution of the phytoplankton biomass is driven by the fluctuations in the physical environment. However, the activity of organisms depends on complex interactions of factors and introduces non linear sources of variability which may become apparent at certain scales and distroy the coherence with physical parameters.

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Resumé

Analyse spectrale de séries de paramètres océanographiques

par

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On a appliqué des techniques de l'analyse spectrale à des séries spatiotemporelles de fluorescence, temperature concentration de nitrite et de nitrate + nitrite, obtenues dans la région d'upwelling du N.W. D'Afrique. L'étude de la tendance n'étant pas notre but, on a transformé les données au moyen du filtre des différences finies. Trois des séries ont présenté une cohérence significative entre fluorescence et temperature pour toutes les fréquences inférieures à 0.04-0.13 cycles par minute, mais les autres trois séries ont montré un affaiblissement des cohérences dans les basses fréquences. Les cohérences entre les autres paires de variables ont été significatives dans les plus basses fréquences étudiées à la plupart des cas. La concentration de nitrite présentait des cohérences plus hautes avec la fluorescence et plus basses avec la temperature que celles de la somme nitrate+ nitrite, comme on pourrait attendre de l'intervention du phytoplankton dans la production de nitrite. On discute quelques problèmes concernant les relations entre la distribution du phytoplankton et les variables physiques (temperature).

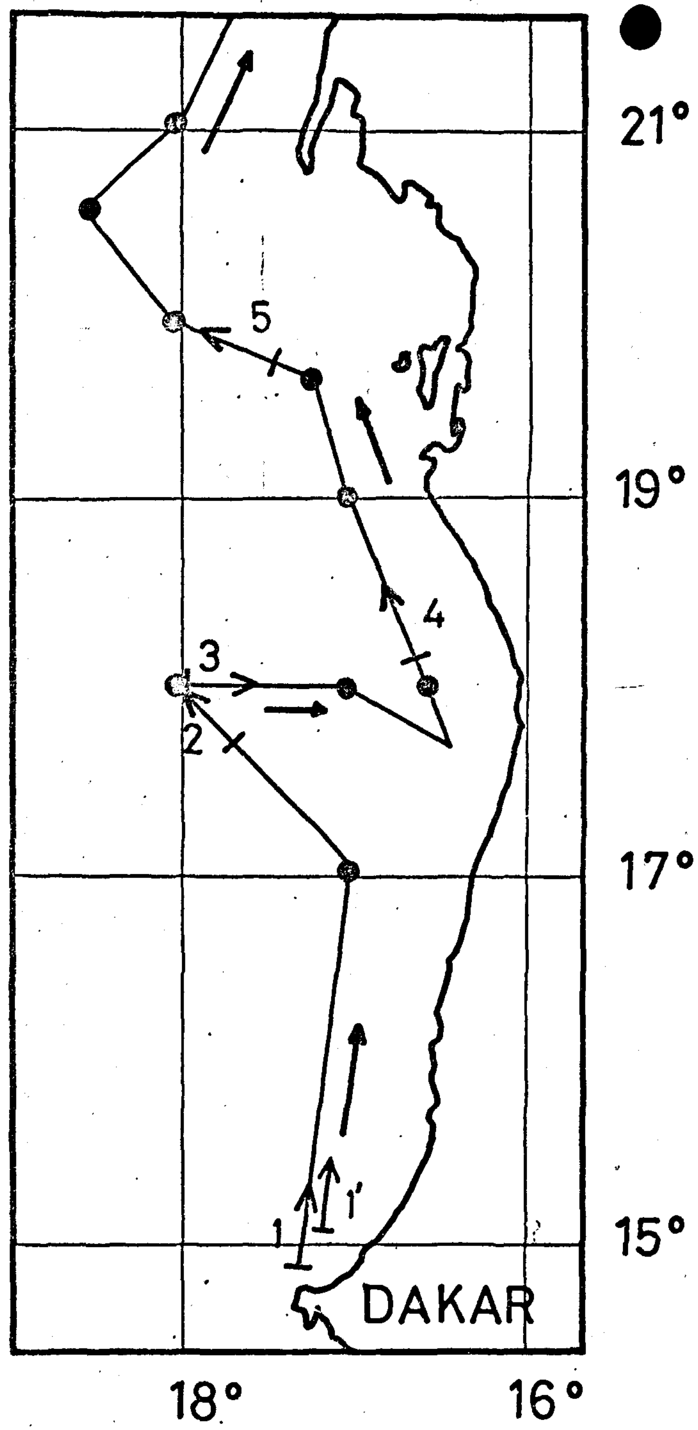

TABLE 1.

Data runs. Length of the series was 200 minutes in all cases.

Run	Date	Time (GMT)	Variables
1	16 March 1973	14:43-18:02	Fluorescence, temperature
1'	16 March 1973	16:04-19:23	Fluorescence, temperature
2	18 March 1973	00:01-03:20	Fluorescence, temperature, nitrate+nitrite, nitrite
3	18 March 1973	11:14-14:33	Fluorescence, temperature, nitrate+nitrite
4	19 March 1973	19:00-22:19	Fluorescence, temperature, nitrate+nitrite
5	21 March 1973	00:04-03:23	Fluorescence, temperature, nitrate+nitrite, nitrite

Geographic position of the transects