Marine Biology 40, 337-339 (1977)

MARINE BIOLOGY


# Continuous Plankton Records: Changes in the Composition and Abundance of the Phytoplankton of the North-Eastern Atlantic Ocean and North Sea, 1958-1974

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## Abstract

In most areas of the north-eastern Atlantic Ocean, diatoms have declined drastically in abundance in the last decade. Additionally, in areas to the north of 59°N *Ceratium* species and an index of total phytoplankton have also declined. South of 59°N the phytoplankton index has increased, diatoms have declined and *Ceratium* species have remained at a constant level of abundance. A possible explanation of the increase in the phytoplankton index at a time when the diatoms were declining south of 59°N is the development of unidentified phytoplankton organisms such as microflagellates. As many of the variables influencing phytoplankton standing crop are governed in turn by the prevailing weather, the phytoplankton changes may well be a consequence of the general deterioration, since 1940, of North Atlantic weather. Changes in phytoplankton which may be attributed to an amelioration of climate since 1971 are evident as yet only in the southern North Sea.


## Introduction

Continuous plankton recorders (CPR's) have been towed by merchant ships and weather ships in a survey of the plankton of the north-east Atlantic Ocean and North Sea in each month since 1948 (Hardy, 1939; Glover, 1967). The CPR samples continuously at a depth of 10 m, collecting the plankton on a moving band of silk (mesh size 0.3 mm). It is primarily a zooplankton sampler and most of the phytoplankton passes through the silk meshes, but a representative proportion of larger diatoms and dinoflagellates is retained (Robinson, 1970). Although towed at normal ship's cruising speeds, retention of plankton is aided by the pressure-reducing nose of the sampler, giving a slow rate of flow through the silk. Continuous sampling integrates the effects of small-scale patchiness and, because of the large area and monthly frequency of sampling, provides material for the detection and analysis of major patterns of variation in the phytoplankton.

## Methods

The examination of phytoplankton samples is carried out in two stages. First, the colour of the filtering silks is assessed and allocated to one of three categories of greenness which have been given numerical values based on acetone extracts (Robinson, 1970). This assessment of greenness, which serves to indicate the relative abundance of total phytoplankton along the filtering silks, is described here as the "phytoplankton index". Second, the silks are cut into samples, each representing 10 nautical miles of tow, and the organisms identified and counted under a microscope. Results are presented here for only the period after 1958, when a new method of counting was introduced (Colebrook, 1960): briefly, 20 microscope fields of 0.3 mm diameter are examined in two diagonals across the filtering silk; the number of fields in which a species occurs is used to calculate the number of that species in the sample.

In the present study, the phytoplankton index and the counts of individual phytoplankton species were averaged for all samples within rectangles of 2° longitude x 1° latitude for each month of the year; these means were then averaged to give in turn monthly and annual means for the larger "standard areas" (Fig. 1). The combined monthly means for the 19 most common diatoms and the 7 most common *Ceratium* species were each subsequently averaged to give monthly and annual

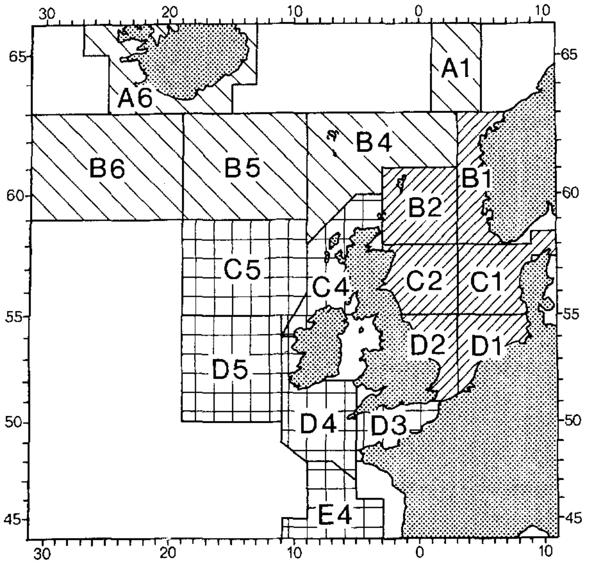


Fig. 1. Set of standard areas used in routine data-processing procedures of the Continuous Plankton Recorder Survey. Hatching distinguishes North Sea areas from northern and southern north-eastern Atlantic areas

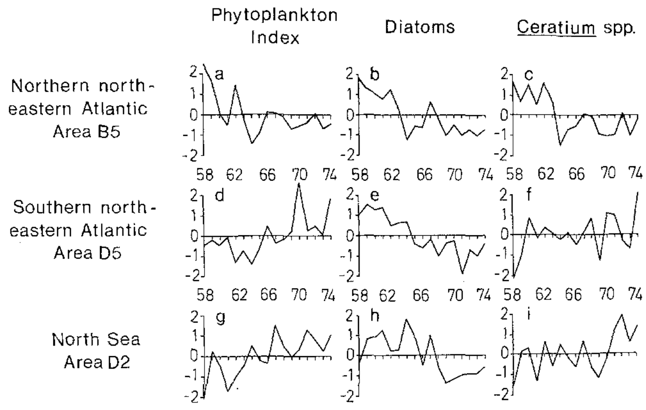


Fig. 2. Standardised annual mean abundance of phytoplankton in areas B5, D5 and D2 from 1958 to 1974. Data have been standardised to facilitate comparison; scale gives standard deviation units above and below 17-year mean for each entity

means for two entities: diatoms and *Ceratium* spp.

## Results

In the period 1958 to 1974, all three entities (phytoplankton index, diatoms and *Ceratium* spp.) declined in the north-eastern Atlantic north of Latitude 59°N. In Atlantic areas south of 59°N, and in the North Sea, the phytoplankton index has increased but "diatoms" have declined, whilst "*Ceratium* spp." have shown little change. To illustrate these differences, results from three standard areas (Fig. 1) are plotted in Fig. 2.

In the most northern part of the north-east Atlantic (Area B5), a decline in the phytoplankton index, diatoms and *Ceratium* spp. occurred between 1958 and 1964 (Fig. 2a, b, c) and all three components tended to remain below average from 1964 onwards.

In Area D5, typifying the north-eastern Atlantic south of 59°N, the phytoplankton index was generally low until 1966 (Fig. 2d). In contrast, diatoms (Fig. 2e) were least abundant from 1965 onwards. The abundance of *Ceratium* spp. (Fig. 2f) varied from year to year, with no long-term trend.

In the North Sea, represented here by Area D2, the phytoplankton index increased to a maximum in 1966 and remained at a high level thereafter (Fig. 2g) while numbers of diatoms (Fig. 2h) were below average from 1968 onwards. *Ceratium* spp. in general showed little change in North Sea areas from 1958 to 1973, with the exception of a period from 1971 to 1973 of unusually long and early seasons in D2 (Reid, in press). The recent increase in abundance of *Ceratium* spp. in D2 was continued into 1974 (Fig. 2i).

## Discussion

Major changes in phytoplankton abundance have occurred in the north-eastern Atlantic Ocean and North Sea since 1958. The main factors which are likely to govern phytoplankton standing crop in these waters are water temperature, insolation, stability of the water column, nutrient availability, grazing and their variability. It is possible that other variables such as pollutants may also influence standing crop. Unfortunately, the complex combined pathways from changes in these factors to phytoplankton standing crop and production are still obscure and difficult to evaluate.

Many of these variables are governed in turn, however, by the prevailing weather; the phytoplankton changes described here may well reflect the progressive deterioration of climate in the north-eastern Atlantic since the 1940's described by Dickson and Lamb (1972).

More recently, in 1970-1971, this deteriorating trend was halted and the climate of the north-eastern Atlantic ameliorated (Dickson *et al.*, 1975).

There is no evidence for a change in the phytoplankton of the North Atlantic following the climatic reversal of 1970-1971. However, changes in the southern North Sea may be related to this reversal. Work in progress has shown that from 1971 onwards there was a marked increase in the flow of high salinity water from the English Channel into the southern North Sea; this coincided with changes in the plankton of Areas D2 and D1 (Fig. 1) after 1970 with, in particular, a marked increase in the abundance of *Ceratium* spp. (Fig. 2i).

In the last decade, the phytoplankton index has increased as diatoms have declined in the Atlantic areas to the south of Latitude 59°N and in the North Sea. The organisms which are the source of this observed increase in colour are not preserved on the CPR silks, but their presence is indicated by a residue of chlorophyll. It is possible that they are microflagellates which would disintegrate in the formalin used for preservation, leaving their more resistant chloroplasts to add to the coloration of the silks.

*Acknowledgements*. The work described in this paper forms part of the programme of the Institute for Marine Environmental Research, a component of the Natural Environment Research Council; it was commissioned in part by the Ministry of Agriculture, Fisheries and Food.

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Date of final manuscript acceptance: November 26, 1976. Communicated by J.H.S. Blaxter, Oban