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CHANGES IN PHYSICAL, CHEMICAL AND PHYTOPLANKTON PARAMETERS IN THE NORTHERN NORTH SEA 1961-70

by

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Introduction

This paper describes some results obtained from the evaluation and integration of physical, chemical and biological data obtained by the Marine Laboratory at Aberdeen on routine surveys during the period 1961-70. The prime objectives of the exercise were to (i) study the inter-relationships between the data, (ii) examine the data for trends, (iii) assess the usefulness of such survey data and (iv) aid the planning of future programmes. A detailed report will be published at a later date (Adams, Martin and Hall, in preparation); this paper outlines some of the methods used but, in particular, deals with changes during the period in the spring bloom of phytoplankton.

The data and their processing

The main data considered were temperature and salinity at surface, 75 m and bottom; surface and bottom oxygen, nitrate, phosphate and silicate; chlorophyll *a* at 3 metres and zooplankton dry weight. All were identified by year, day, hour, ship, latitude and longitude.

During the basic preparation and screening of the data most errors were eliminated. However, adjustment of data products was necessary because of modification of sampling techniques, differing methods of measurement etc. Special problems associated with the analytical methods used for phosphate, nitrate and chlorophyll *a* are outlined below.

Phosphate

Phosphate analysis was changed in 1967 from the method advocated by Strickland (1958) to that advocated by Murphy and Riley (1962); both used spectroanalysis on a Unicam SP600 spectrometer. Cross calibration was satisfactory and the order of accuracy throughout lies within ± 0.055 /ug-at/l of the observed value.

Nitrate

Hydrazine reduction method (Mullin and Riley, 1955) was used to analyse nitrate samples but this was changed in 1969 by the introduction of a Technicon Auto Analyser using a cadmium reduction column (Armstrong and La Fond, 1966). A modification was introduced the following year when the EDTA buffer was replaced by an Ammonium Chloride one. These changes increased the order of accuracy from ± 0.5 to ± 0.1 /ug-at/l.

The vast majority of nitrate samples were frozen at sea before analysis in the Laboratory. Recent comparative studies show that freezing a sample increases its nitrate value by 0.4 µg-at/l (J.M. Pirie - personal communication). Unfortunately, it is not known which samples were and which samples were not frozen. However, since the vast majority were, it is considered that the data should be reasonably consistent.

Chlorophyll a

Changes in chlorophyll a are also complex. Up to 1967 analysis by spectrophotometer did not distinguish between chlorophyll a and phaeopigments. From 1967 the fluorometric method of Yentsch and Menzel (1963) with the modifications of Yentsch (1965) and Lorenzen (1966) was introduced with the consequence that the chlorophyll a results from 1967 excluded phaeopigment a. The change in chlorophyll a is unfortunately not constant as the amount of phaeopigment a will vary with locality and season and for the North Sea in spring should decrease chlorophyll a values by between 5 and 10%. Mechanical grinding was introduced at the same time as a further complication. This can result in a high increase in values (Yentsch and Menzel, 1963) but laboratory tests have consistently enhanced values between 3 and 10%. The net result would therefore indicate no overall change in chlorophyll a values in this particular instance.

The means and variances of data products, both for individual years and for the decade, were analysed and were initially grouped into 16 time periods and into a geographical net of 30 miles square. A preliminary assessment using these geographical blocks showed that comparatively large areas would be needed for the data to have any statistical meaning. The areas chosen (Fig. 1) were a subjective compromise between seeking the minimum areas of maximum uniformity and the largest compatible areas for statistical significance. They were chosen on consideration of the mean values of bottom temperature and salinity and on their annual range in the basic geographical units (for example, Fig. 2); on the distribution of surface salinity and on their conformity to an assessment of the northern North Sea current system (Dooley, 1974).

Some features of the physical environment in the geographical areas chosen

The bottom temperatures are higher in the coastal areas 5, 6 and 9 than in areas 1 and 2 reflecting the weak summer thermocline in the former areas and stratification in the latter (Fig. 3). For the same reasons the bottom temperature range is over 6°C in the coastal areas compared to less than 2°C in area 2. The two different regimes are separated by area 8, an area of high variability in the physical data, probably due to the presence of a spatially variable current (Fair Isle current). The coastal areas along with area 8 show an annual salinity range of 0.3‰ while the more stable areas 1 and 2 have an annual range of less than 0.15‰. However, in temperature area 8 is more akin to area 1 than to either the coastal areas or area 2. The latter is most affected by the spread out of lower salinity water from the Norwegian Deeps which is covered by areas 3 and 4. Area 7 is a south-easterly extension of area 8. Areas 3, 4 and 7 were all poorly sampled.

The Spring Bloom of Phytoplankton

Perceptible changes in climate, the decrease of the westerly circulation, and the cooling of the oceans have all been linked with biological change. In the North Sea, the most intensely sampled area in the world, these links have been tenuous; nevertheless changes in the biomass of zooplankton, number of copepods and the timing of the spring bloom (Glover, Robinson and Colebrook, 1972) have been suggestive.

The chlorophyll a values in the 1961-70 data collection have been evaluated with these changes in mind. Areas 1, 2 and 8 have been considered together because of the lack of data in the later years. This is acceptable since the chlorophyll a peaks at the same time in all three areas and since the same trend is discernible in the separate areas with their lesser number of observations.

The spring bloom reaches a peak during the period 16th-30th of April (days 106-120, Fig. 4). The timing is in agreement with Robinson (1970) and coincides with the spring development of a thermocline. The earlier onset of rising temperatures in area 6 (Fig. 5) also coincides with the earlier Spring bloom to the south (Robinson, 1970).

There is no evidence of any significant blooming in areas 1, 2 and 8 before day 106. Consequently only the two 15 day periods 106-120 and 121-135 days (1-15 May) which coincide with the peak values of chlorophyll a have been considered. Thereafter the biological processes with the recycling of nutrients and variation in timing will increasingly invalidate the interpretation of statistical analysis. What available data there are for the subsequent period 136-150 days (16-30 May) have been included, however, to confirm that there is no evidence to suggest delayed peaking in the later years.

There were marked differences in the level of chlorophyll a between years with a tendency for the level to be lower in the latter years (Table 1). That this is a natural variance in the growth of phytoplankton and not a biproduct of differential grazing is clearly suggested in a study of nutrient levels. A comparison of chlorophyll a and nitrate values in the period 16th-30th April (days 106-120) shows an inverse relationship between the two. Although limited to only six years there is a negative correlation of 0.82, significant at the 5% level.

The establishment of a surface thermocline in spring is the most likely cause for a phytoplankton "bloom". Calm conditions, which reduce vertical mixing, and high solar radiation are the two factors most commonly associated with such a thermocline. In order to quantify this, sunshine data from Dyce (Aberdeen) and Lerwick have been extracted from Meteorological Office monthly reports. As a measure of calmness the percentage of six hourly wind reports from Dyce, Wick and Lerwick when the wind was less than 11 knots was used. The difference in temperature between sea surface and bottom was used as a measure of the intensity of the thermocline (Table 2).

Lack of wind rather than solar heating appears to be the dominant factor in producing a thermocline and the blooming of phytoplankton. The intensity of the thermocline during the period 1st-15th May is significantly related to the percentage of observations when the wind is less than 11 knots in April. Based on eight years the correlation coefficient was 0.91, $p < 0.01$. The mean level of chlorophyll a over the period 16th April-15th May correlates significantly, with the intensity of the thermocline, based on six years ($r = 0.92$, $p < 0.01$), and with the wind, based on seven years, Fig. 6, ($r = 0.89$, $p < 0.01$) for the corresponding periods above. However, no significant relationship could be established from the data for hours of sunshine.

With the exception of 1968 there was a trend towards lower levels of chlorophyll a during the decade, particularly noticeable during the period 16th-30th April with corresponding higher nutrient levels (Table 1). This can be accounted for by the stronger winds in the later years and the slower development of the thermoclines (Table 2).

1968 was particularly interesting; the wind was exceptionally light during April but the strongest of the decade in May. The fact that the thermocline was exceptionally well developed early and only declined slightly in May, when the chlorophyll a level was very high, does suggest that the influence of the wind is most crucial in April when the thermocline is becoming established rather than later when it has become established and is less affected by the wind.

Abstract

This paper describes the integration of physical, chemical and biological data obtained on routine surveys from 1961-70 in the Northern North Sea with particular reference to the spring bloom of phytoplankton. It draws attention to the differing levels of chlorophyll a during the decade, looks at some of the possible physical causes and suggests that lack of wind is a major factor in the blooming of phytoplankton.

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Table 1

	Chlorophyll a in mg/m³ Days			Nitrate in µg-at/l Days			Phosphate in µg-at/l Days		
	106–120	121–135	136–150	106–120	121–135	136–150	106–120	121–135	136–150
1961	0.71 (28)	X	1.18 (5)	7.13 (8)	X	0.64 (5)	0.60 (28)	X	0.25 (3)
62	6.53 (9)	2.43 (74)	2.24 (47)	3.01 (6)	2.13 (3)	X	0.26 (6)	0.33 (79)	0.28 (51)
63	3.87 (23)	2.66 (91)	2.12 (17)	3.61 (3)	3.35 (4)	2.69 (17)	0.41 (23)	0.52 (99)	0.39 (14)
64	4.55 (27)	1.43 (65)	1.35 (45)	1.54 (7)	2.77 (9)	4.82 (9)	0.30 (27)	0.38 (64)	0.39 (58)
65	X	2.31 (67)	1.89 (46)	X	1.15 (6)	X	X	0.32 (76)	0.40 (42)
66	1.89 (13)	1.69 (18)	X	9.41 (4)	5.34 (12)	X	0.58 (5)	0.48 (12)	X
67	X	1.11 (7)	1.55 (13)	X	5.60 (7)	3.98 (13)	X	0.44 (6)	0.43 (13)
68	0.70 (5)	6.28 (8)	X	X	X	X	X	X	X
69	1.03 (7)	0.86 (26)	X	X	X	X	X	X	X
70	1.54 (4)	0.50 (9)	1.11 (23)	8.29 (4)	5.50 (9)	1.21 (22)	X	0.52 (2)	0.40 (37)
1961–65	3.92	2.24	1.75						
1966–70	1.29	2.08	(1.33)						

Table 2

Year	Wind Obs % <11kts April	Wind Obs % <11kts May	Hours of Sunshine Per Day April	Hours of Sunshine Per Day May	S-B Temp °C Days 106-120	S-B Temp °C Days 121-135
1961	48.6	45.4	4.16	4.92	0.30	X
1962	53.9	54.6	6.29	3.87	0.50	1.58
1963	52.0	51.4	4.37	5.65	0.41	1.16
1964	45.8	48.1	3.88	4.70	0.61	X
1965	51.4	46.0	5.33	3.36	X	1.30
1966	44.7	50.6	5.11	5.99	0.06	1.18
1967	38.1	44.9	4.67	4.99	X	0.88
1968	55.3	44.1	5.22	4.60	1.92	1.42
1969	35.8	62.4	4.54	3.29	0.60	0.59
1970	43.3	49.7	5.82	4.05	0.02	0.82
61-65	50.3	49.1	4.81	4.50		
66-70	43.4	50.3	5.07	4.58		

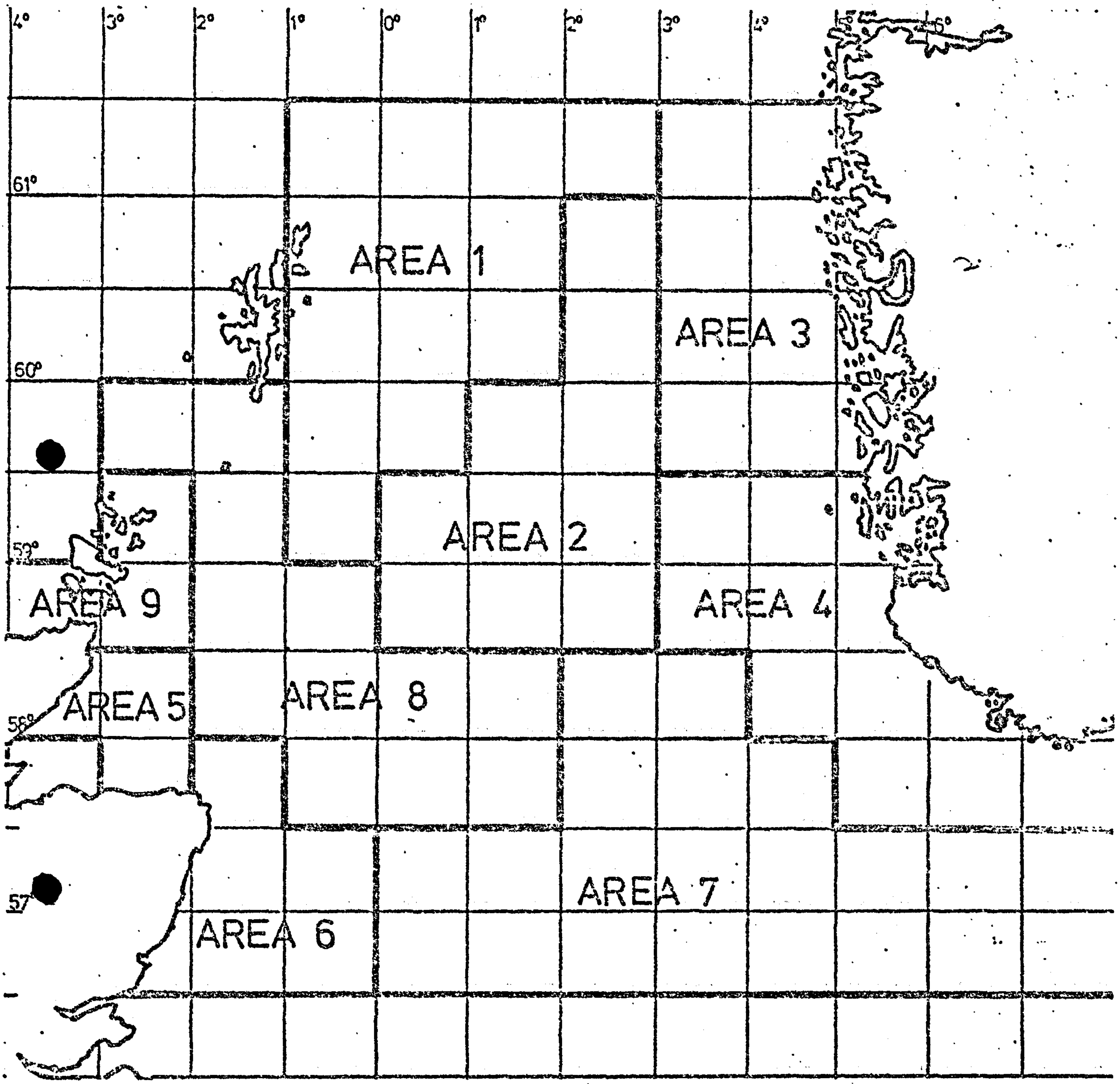

Fig.1 Sub areas for envirionmental data

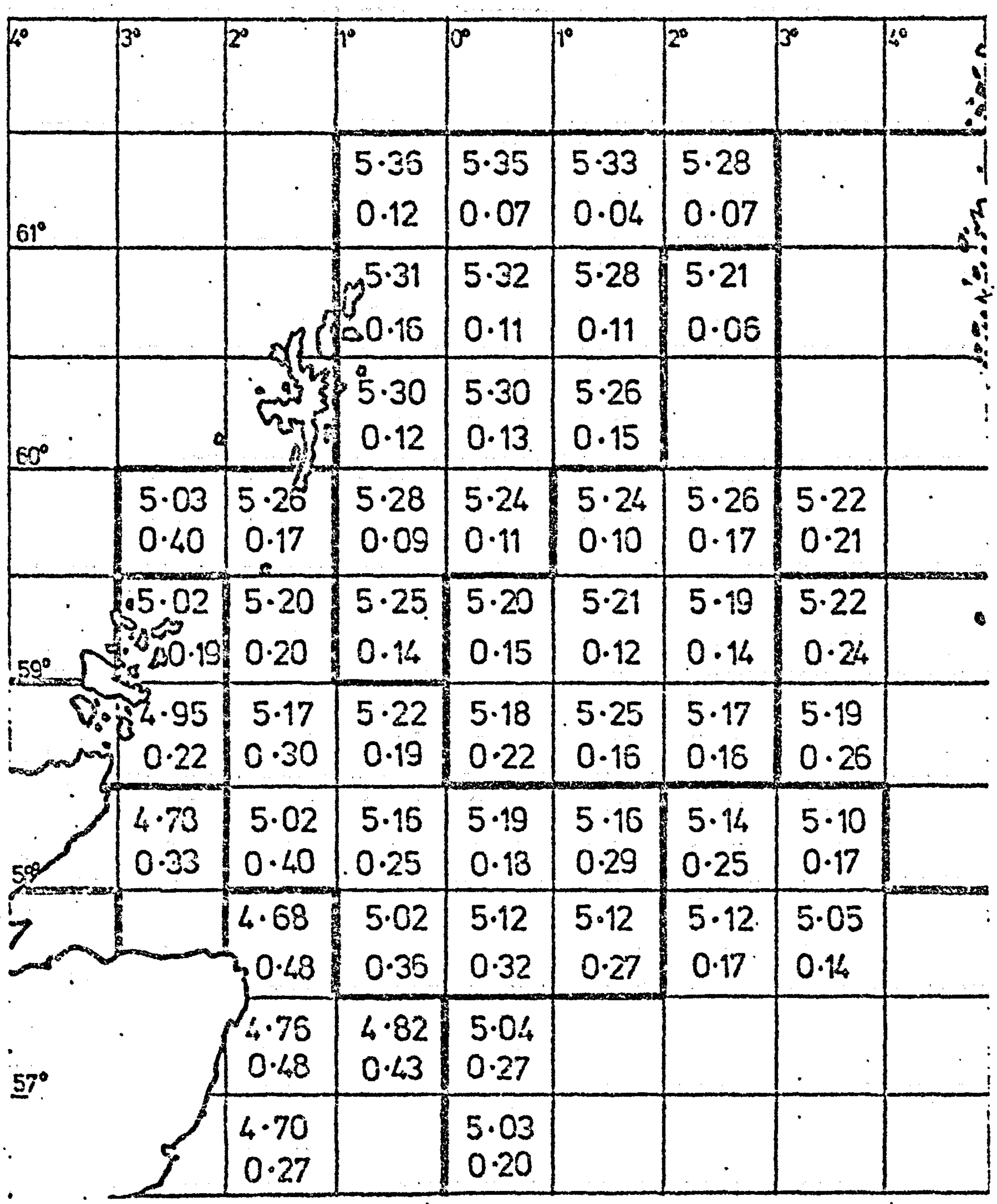

Fig. 2 Mean of max. and min. bottom salinity 30+‰ and annual range

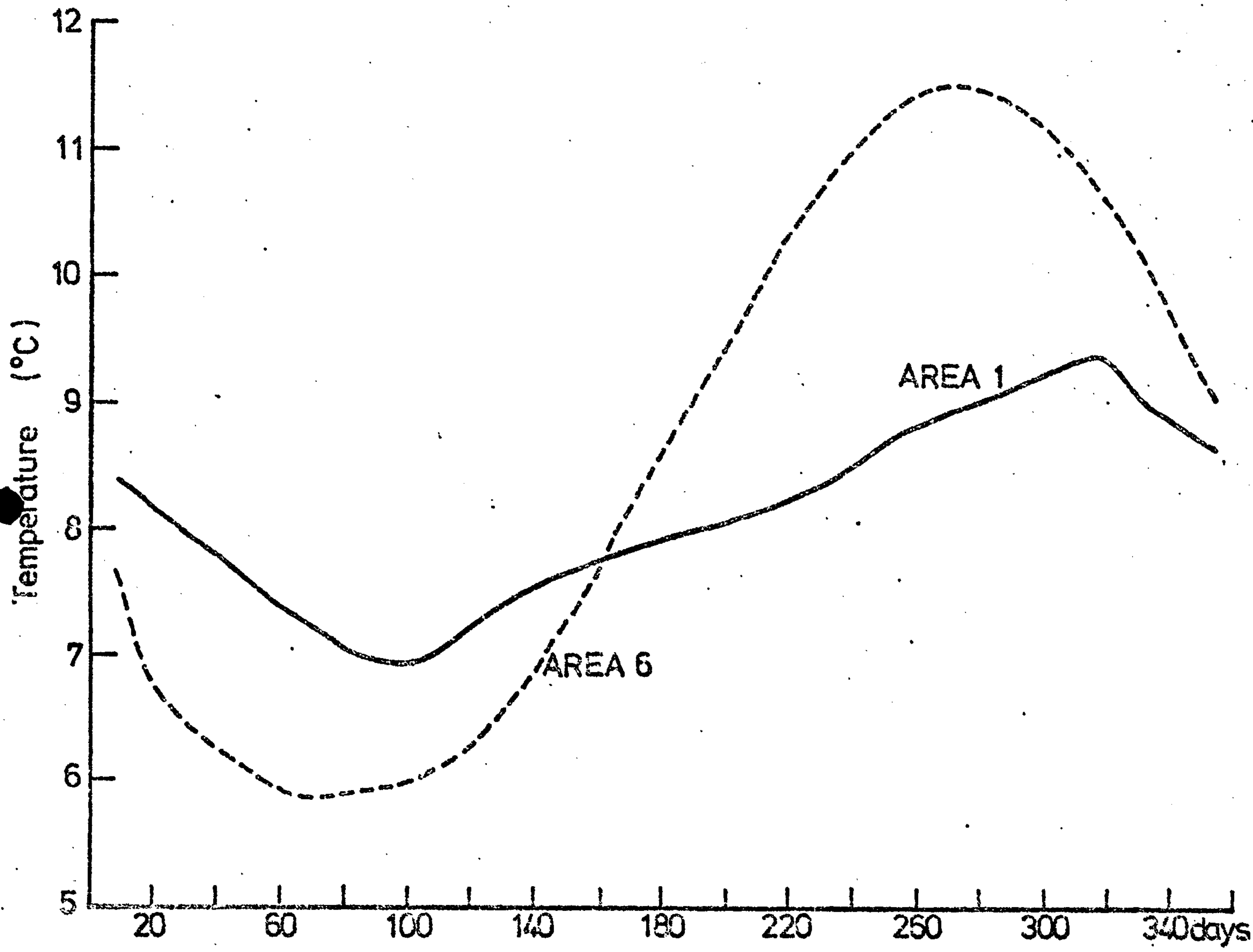

Fig. 3 Annual temperature cycle at bottom in areas 1 and 6

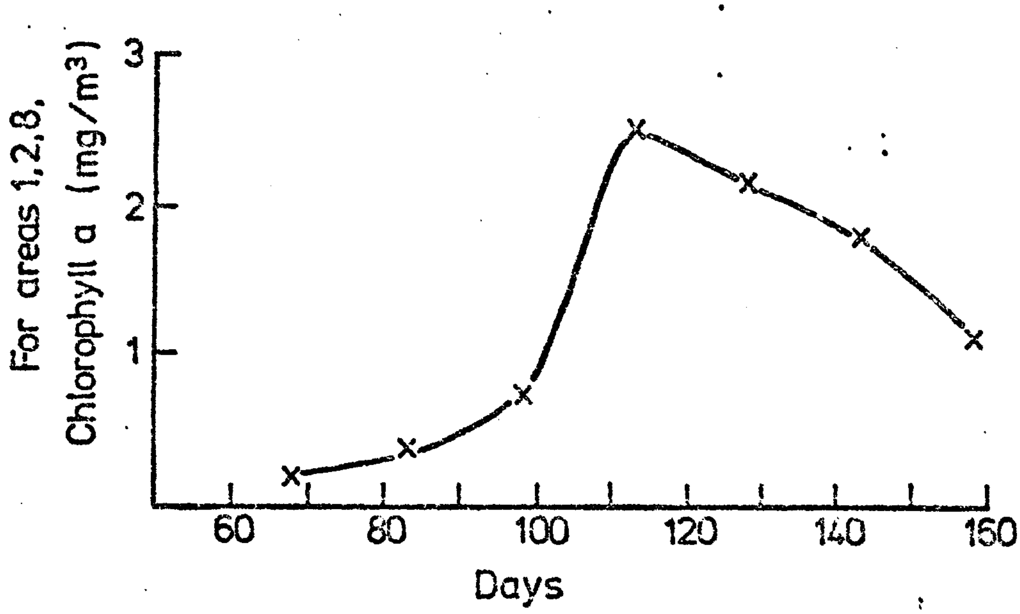

Fig.4 Timing of spring bloom

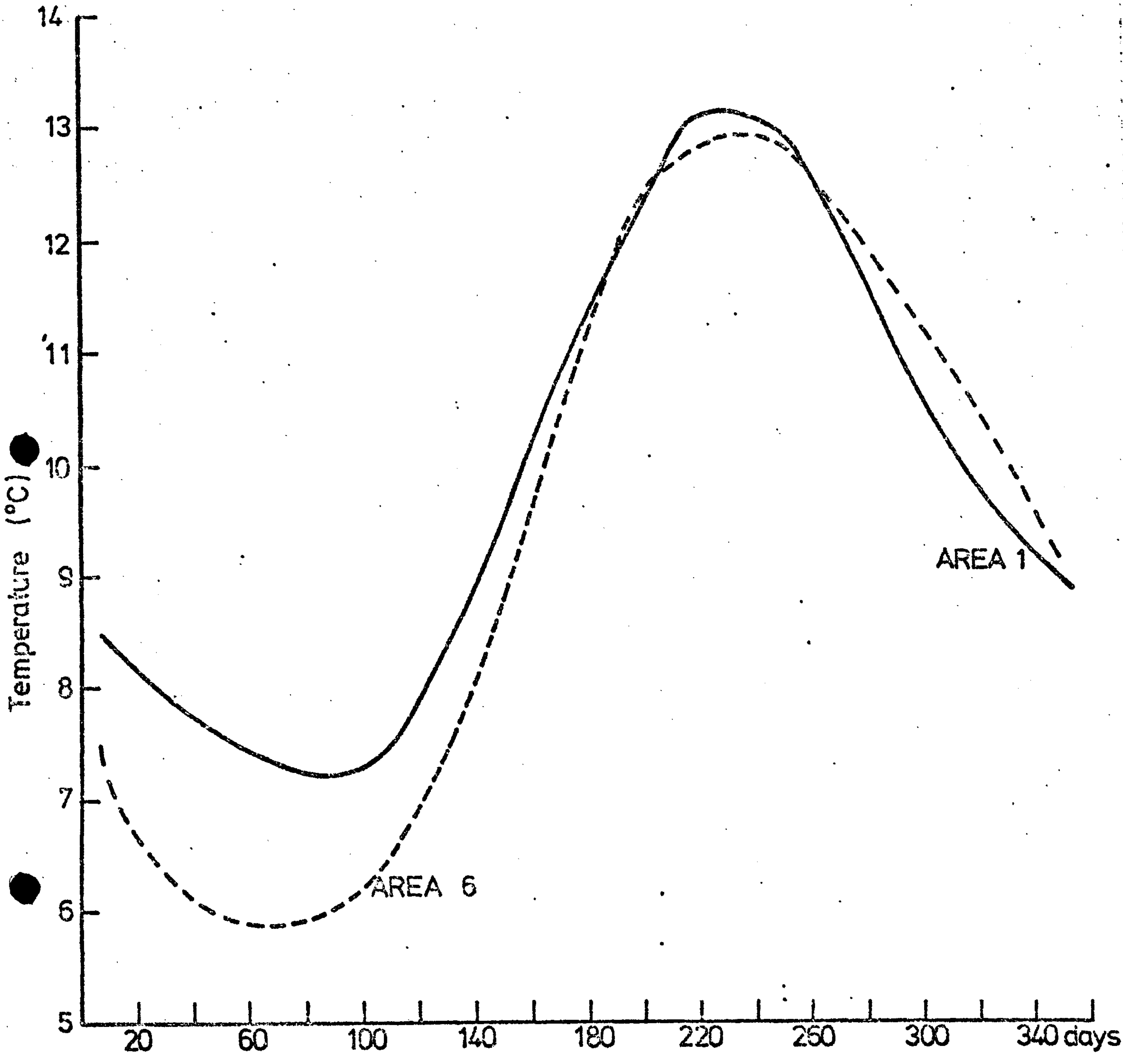

Fig.5 Annual temperature cycle of surface in areas 1 and 6

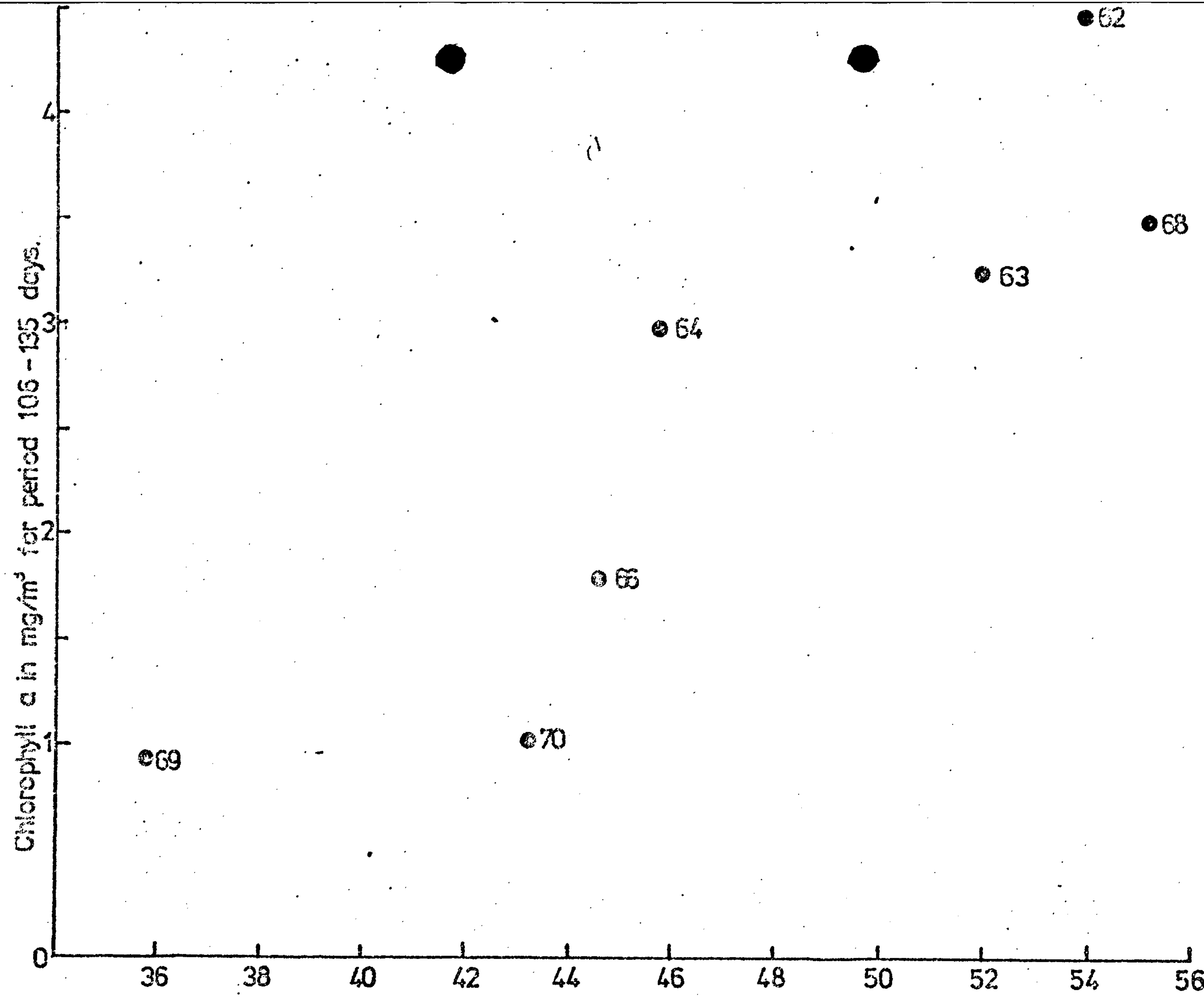

Fig 6. % of observations in April with wind velocity < 11 knots.