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WAVES RECORDED AT SCARWEATHER BANK IN THE BRISTOL CHANNEL

by

B C H FORTNUM and P J HARDCASTLE

Data for December 1976 to November 1977 at position 51 27'N, 03 55'W

Summary Analysis and Interpretation Report

Report No 79
1979

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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The preparation of this report and the collection of the data contained in it have been financed by the Departments of Energy, of Industry and of the Environment

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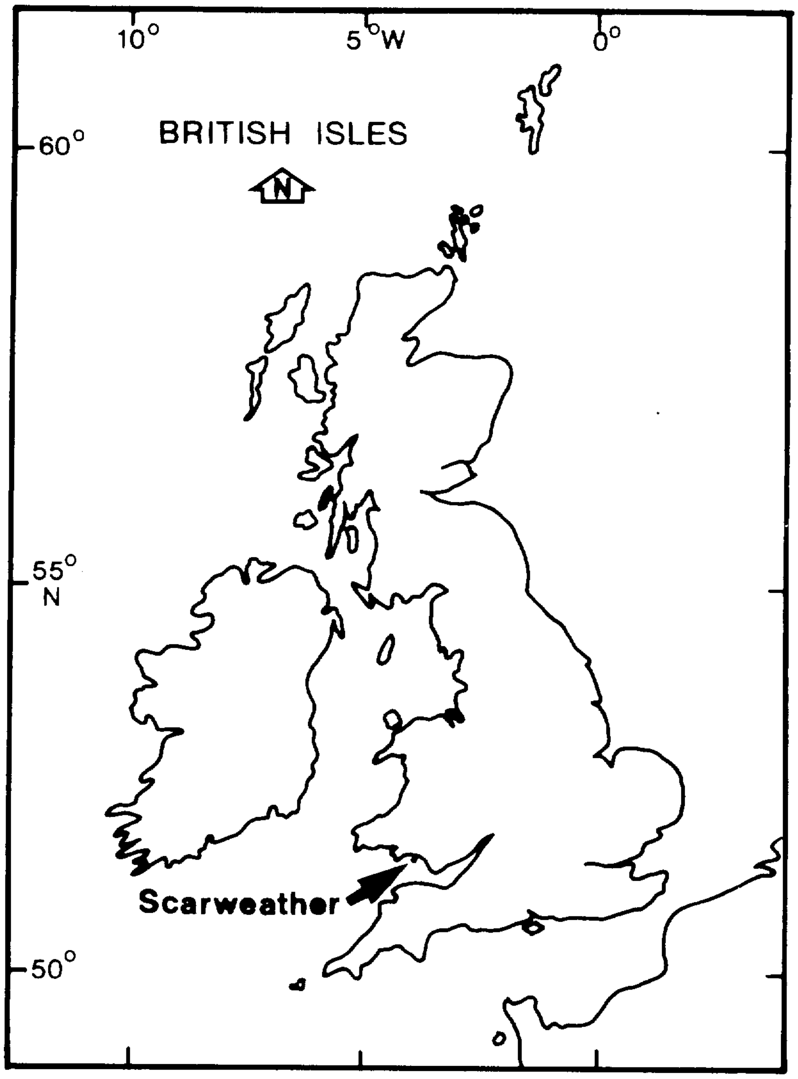
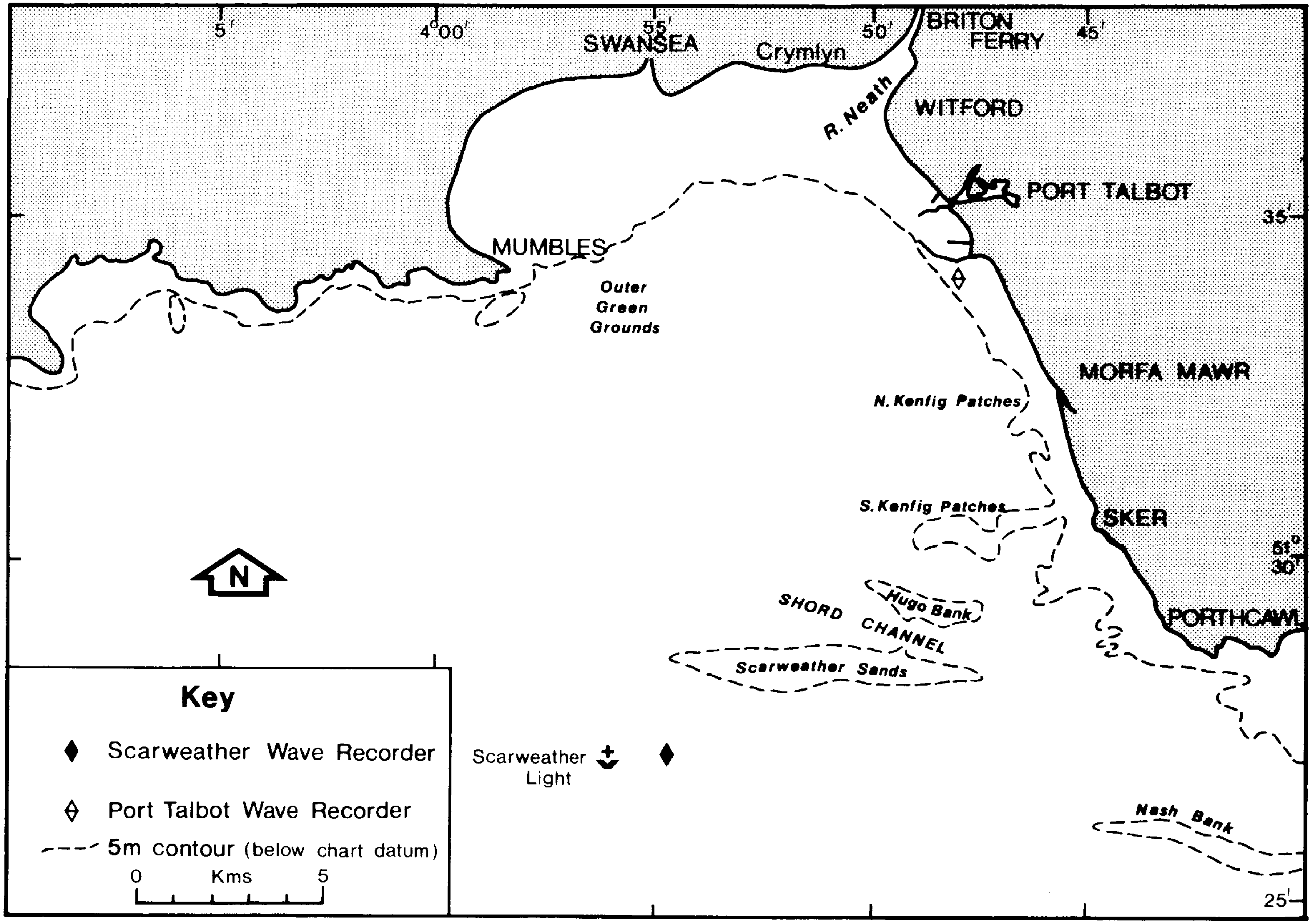


Map showing positions of Wave Recorders in relation to local topography



INTRODUCTION

The wave data presented in this report have been collected using a Waverider buoy. The buoy was moored in water of mean depth of approximately 27 metres at the western, outer end of the Scarweather Bank in the Bristol Channel. Information about water surface elevation is transmitted by radio link and is received at the Mumbles Coastguard Station where it is recorded for twenty minutes every three hours on fm analogue magnetic tape cassettes. A ten-minute section of each record was analysed to give the mean rectified wave height, the number of zero up-crossings and the number of crests. From these figures the significant wave height, the zero up-crossing period and crest period were derived. A more detailed description of the methods of recording and of replay, and of the techniques used to derive the statistical wave parameters may be found in Hardcastle (1978).

The data were gathered for the Swansea Bay (Sker) project (several IOS internal reports on this project are listed in the References) which was supported financially by the Department of the Environment.

The period for which data have been analysed in this report, together with the percentage of valid data, is as follows:

Period	Valid data (per cent)
December 1976 to November 1977	92.9

The cumulative probability distributions of Hmax(3 hr) are computed and plotted on graphs whose axes are scaled so that if the distributions obey a chosen formula, they will appear as straight lines. Four such formulae are used in this report, as follows:

1. Weibull

$$\mathrm{Prob}(X \leq x) = \begin{cases} 1-\exp\left[-\left(\frac{x-A}{B}\right)^C\right], & \text{for } x > A \\ 0, & \text{for } x \leq A \end{cases}$$

where B and C are positive, and A represents a lower bound on Hmax(3hr).

2. Log-Normal

$$\mathrm{Prob}\,(X \leq x) = H\left(\frac{\ln x/\beta}{\delta}\right)$$

where H is the normal distribution function

$$H(\Theta) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\Theta} \exp\left(\frac{-t^2}{2}\right) dt.$$

3. Gumbel's Third Asymptote

$$\text{Prob}(X \leq x) = \begin{cases} \exp\left[-\left(\frac{A-x}{B}\right)^C\right], & \text{for } x \leq A \\ 1 & \text{, for } x > A \end{cases}$$

where B and C are positive. This is the extreme value distribution first considered by Fisher and Tippett (1928) for a variable bounded above by A (see Gumbel (1958)).

4. Gumbel's First Asymptote

$$\text{Prob}(X \leq x) = \exp[-\exp(-ax+b)]$$

The formula used to calculate the standard deviation in the sections on the month-to-month variability of significant wave height and of wind speed is

$$\text{s.d.} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

where $\bar{x}$ is the mean of the observations,

and n is the number of observations.

METHOD OF ANALYSIS AND DEFINITIONS

For each three-hour interval the corresponding ten-minute record gives values of the following parameters:

1. The number of zero up-crossings, Nz. A zero up-crossing is considered to occur when the pressure signal crosses the mean line in an upward direction.
2. The number of crests, Nc.
3. The mean rectified wave height, H_R.

From these the following parameters are computed:

4. The mean zero up-crossing period of the pressure signal, Tz. This is defined as the duration of the record divided by Nz.
5. The significant wave height, Hs. This is defined as four times the standard deviation, or, as has been shown in Hardcastle (1978), $2\sqrt{2\pi}$ times H_R. For a narrow band random process Hs approximates closely to the mean height of the highest one-third zero up-cross waves (Longuet-Higgins (1952)). Comparison between the two definitions is made by Goda (1970, 1974). (A zero up-cross wave is defined as the portion of the wave record between two zero up-crossings, and its height is the vertical distance between the highest and lowest points on the wave).

6. The most probable height of the highest zero up-cross wave in the three-hour interval, Hmax(3hr), calculated from the variance of the record assuming a Rayleigh distribution of zero up-cross wave heights. The parameter Hmax(3hr) which is the mode of the distribution, should not be confused with the expected height of the highest wave in three hours, which is the mean of the distribution. The mean of the distribution is typically 3% higher than the mode (Tann (1976)).

7. The bandwidth parameter, ε, which is a measure of the range of frequencies present, $\varepsilon = \sqrt{1 - \left(\frac{N_z}{N_c}\right)^2}$.

DISCUSSION OF RESULTS

The division of the year into four three-month seasons was made as follows:

Winter	December, January, February
Spring	March, April, May
Summer	June, July, August
Autumn	September, October, November

This is consistent with the seasons used in the Port Talbot wave data report (IOS Report No 78) and is partly supported by Figure 23.

Figures 1 to 5. Percentage exceedance of Hs and Hmax(3hr).

These graphs may be used to estimate the fraction of the time during which Hs or Hmax(3hr) exceeded a given height. For instance, from Figure 2 we see that during spring the significant wave height exceeded two metres for 22 per cent of the time.

Figures 5 to 10. Frequency histograms for Tz.

It may be seen from these figures that the highest wave periods were up to 15 seconds and occurred in the winter season. The most frequent values of Tz were between 6 seconds and 7 seconds, with the exception of the winter season when values of Tz between 6.5 seconds and 9 seconds occurred with approximately equal frequencies.

Figures 11 to 15. Scatter diagrams.

The numbers of occurrences of particular pairs of values of significant wave height and zero-crossing period, expressed in parts per thousand, are shown in these diagrams. Joining up points with equal occurrences (contouring) has not been carried out for these data, as the correlation between Hs and Tz is not obvious from these figures. Theoretically the limiting value of wave steepness for a progressive wave is 1 : 7, where wave steepness is defined as the ratio of wave height to wave length. A line of maximum steepness may be drawn on a scatter diagram (defining steepness as $\frac{2\pi H_s}{g T_z^2}$), but it will in general have a value less steep than 1 : 7 because Hs and Tz are parameters averaged over a number of waves most of which have steepnesses less than the maximum. For these scatter diagrams maximum steepness lines of 1 : 18 or 1 : 19 have been drawn in.

Figure 16. Frequency histogram for ε.

It is seen from the figures that all values of ε lie between 0.16 and 0.90. In winter, the most frequently occurring values are between 0.60 and 0.72, whereas during summer there is a definite peak centred at 0.55.

Figures 17 to 18. Persistence diagrams

Use of the terms 'storm' and 'calm' is illustrated in the following example: a two-metre calm (storm) is said to occur when the significant wave height is less (greater) than two metres. Given a duration D hours, a diagram of persistence of calms (storms) shows how many calms (storms) with duration greater than or equal to D hours can be expected during the season in question.

For example, suppose an operator requires twenty hours with Hs smaller than three metres to complete a particular job at the site. It may be seen from Figure 17 that there were about 35 occasions during 1976/77 when the job could have been done.

Strictly, persistence diagrams require series of data with no gaps whatsoever, and this should be borne in mind when using these figures, since effectively data were used from only 92.9 per cent of the year. The technique used was to close up all the gaps and to treat the data as a continuous time series with a reduced overall duration.

Figures 19 to 22. Cumulative distribution of Hmax(3hr)

The cumulative distribution of Hmax(3hr) for the period covered by this report is plotted on four scales as shown and a straight line fitted where appropriate. This is equivalent to fitting the corresponding distribution function to the data. Having found the distribution which gives a satisfactory fit, the line is extrapolated to find heights which have a very low probability of being exceeded. (The rationale for this is discussed by Tann (1976)).

None of the four distributions fits the data particularly well, which may be partly the result of using only one year's data. However, the best fit straight line has been drawn on Figure 22, the Gumbel III distribution, since, having an upper bound, it may be expected in principle to be more appropriate for waves in water of this depth; the value of this upper bound, A, is 46 metres.

From Figure 22 the height of the wave with a 50-year return period is found to be about 14.7 metres.

Figure 23. Month-to-month variability of significant wave height.

The mean value of significant wave height for each month is calculated and plotted. The mean wave heights vary between almost 2.2 metres (November) and about 0.7 metres (July). The month of December is noteworthy for its comparatively low value of almost 1.0 metre (it is defined in this report as a winter month), and that of November for its comparatively high value of almost 2.2 metres (defined as an autumn month).

WIND DATA

The wind data station nearest to the site of the wave recorder is Port Talbot (51°34'N, 03°45'W) where wind data are available from 1970 onwards. Only winds which have approached the site from the Bristol Channel are considered, those approaching from South Wales and south-western England being expected to affect wave conditions less due to limitations of fetch. Consequently only winds in the 60°-sector from 210° to 270° have been considered in this report. The data used are mean hourly wind speeds, and no data are available for September, October and November 1977.

Figure 24. Month-to-month variability of wind speeds.

This figure shows the mean and the standard deviation of the average wind speeds for each month: data (where available) both for the year covered by this report and for the seven years from 1970 are shown. As can be seen from the figure, two months (January and May) show a mean wind speed for the seven-year period which is higher than for the period covered by this report: the other seven months for which all data are available show lower average wind speeds. The greatest differences are for December and April, with the seven-year averages being less in both cases: for December the difference is about 2.5 metres per second (about forty per cent of the seven year period), and for April it is about 2 metres per second (about forty per cent).

Figure 25. Year-to-year variability of wind speeds.

For each twelve month period shown, the mean of the highest N values of wind speed is plotted for N = 1, 5, 10, 20, 50, 100. The figure shows that only the period 1970/71 had maximum wind speeds as low or lower than the period 1976/77 covered by this report; but that the mean wind speed for 1976/77 is the second highest during the seven periods examined, although the yearly variation in the mean is almost negligible (except for 1970/71). The conclusion appears to be that during the period covered by this report the wind climate at the wave recording site was comparable with the previous six years, except that the highest wind speeds were lower.

ACKNOWLEDGEMENTS

The authors are grateful to those people whose contributions have made it possible to produce this report, in particular R Gleason, R Hall and K Reeves of the Institute of Oceanographic Sciences for assistance with the data processing, and D J Painting of the Meteorological Office for supplying the wind data.

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APPENDIX - INSTRUMENTAL ASPECTS

The Waverider buoy was replaced at intervals of approximately six months. The buoys were calibrated before installation and after retrieval. The method of calibration was to drive each buoy through a vertical circle, three metres in diameter, at speeds of rotation corresponding to wave periods of between five and twenty seconds. The transmission from the buoys was monitored and the demodulated wave output measured. It is estimated that this calibration was to an accuracy of approximately ± 2 per cent; for two of the three buoys deployed during this period (the last buoy was lost while on station), the pre-deployment and post-deployment calibrations agreed to within this figure.

The receiver/recorder at the Mumbles Coastguard Station was calibrated annually using simulated Waverider transmissions. These checks agreed with the original calibration to within 1 per cent. The accuracy of the recorder-replay system is within ±1per cent.

The overall accuracy of the wave measurement and data analysis system is thus of the order of ± 3 per cent.

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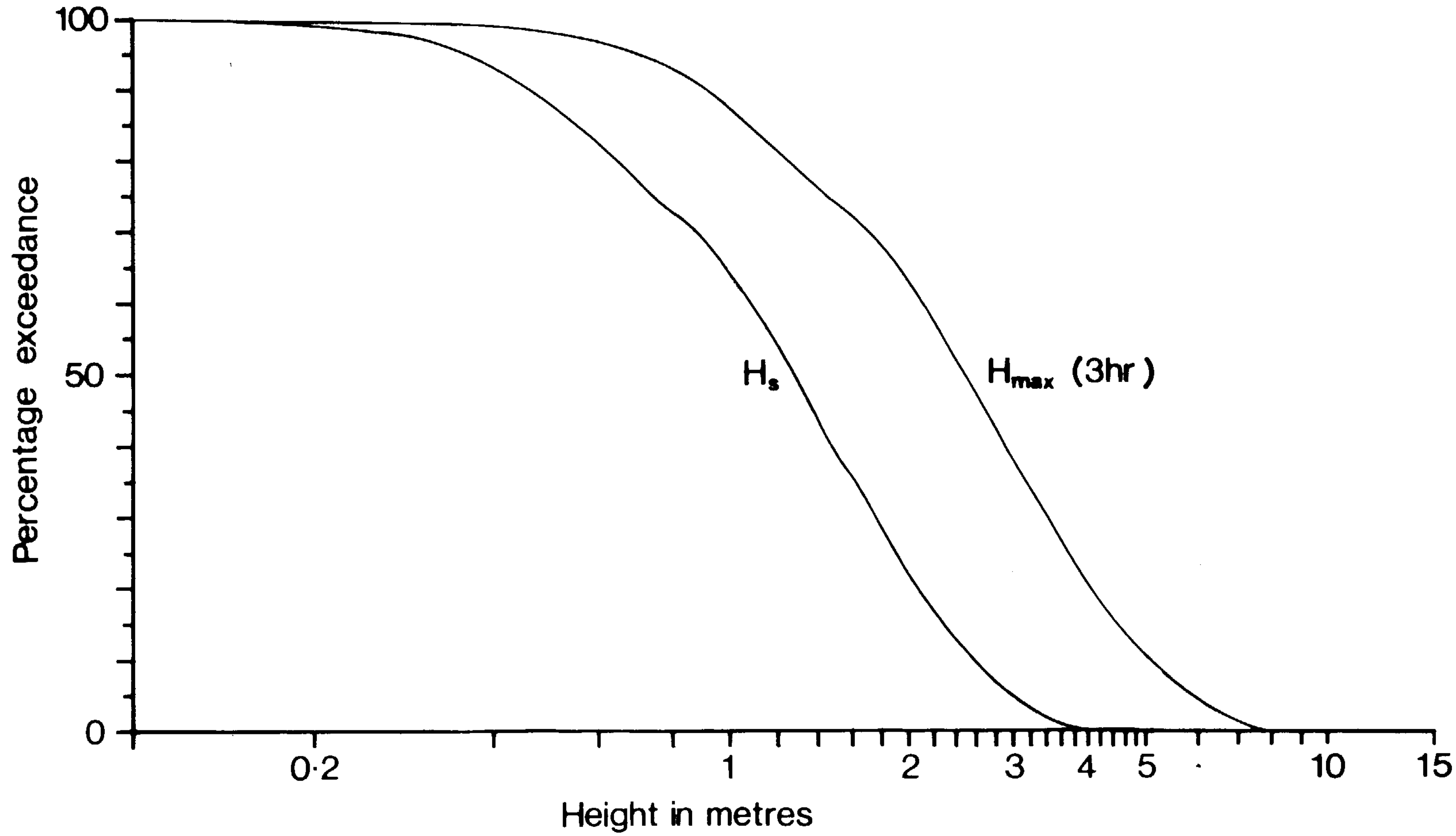

Percentage exceedance of H_s and H_{max} (3hr) – Winter 76-77

Fig. 1.

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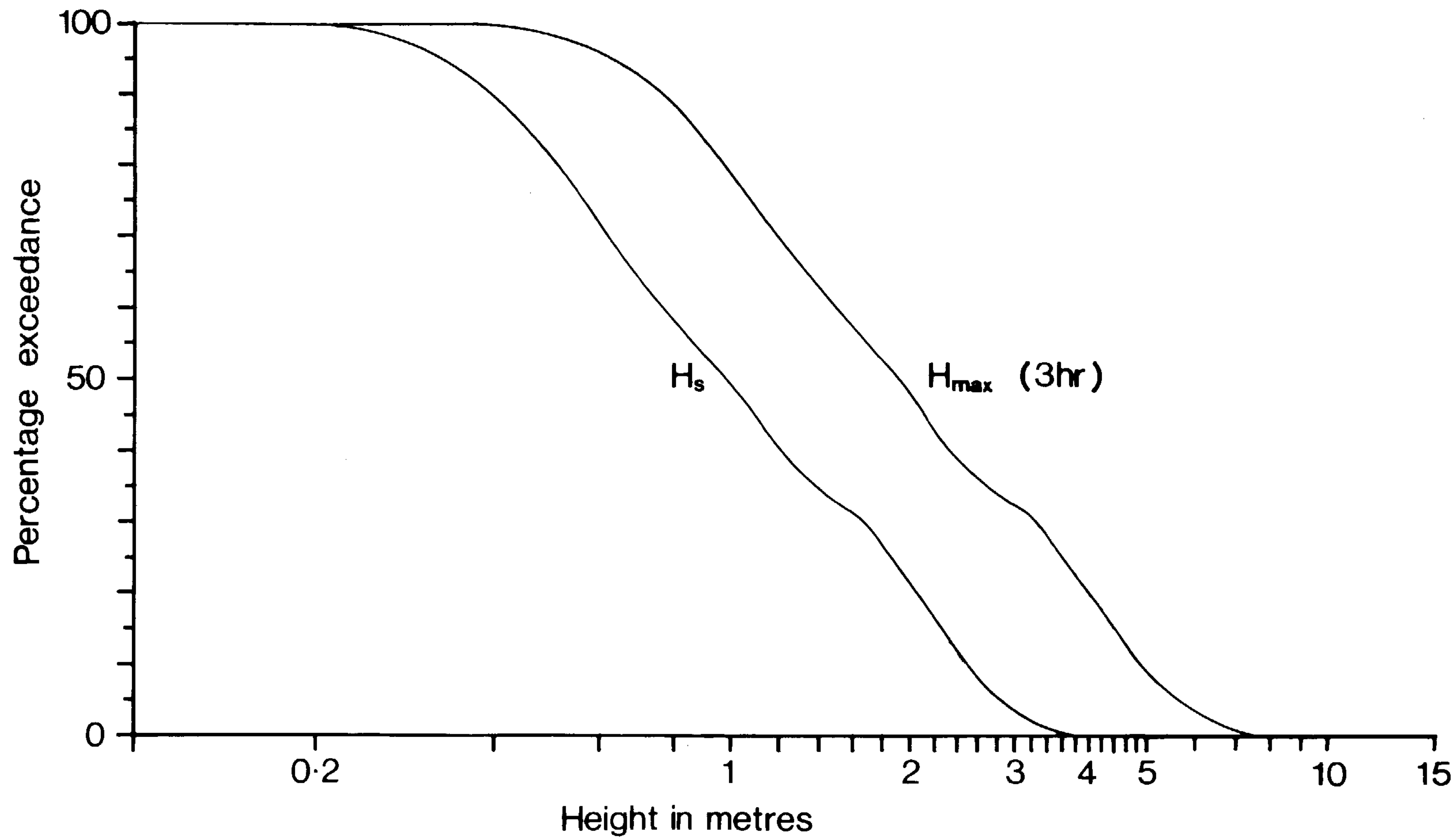

Percentage exceedance of H_s and H_{max}(3hr) – Spring 77

Fig. 2.

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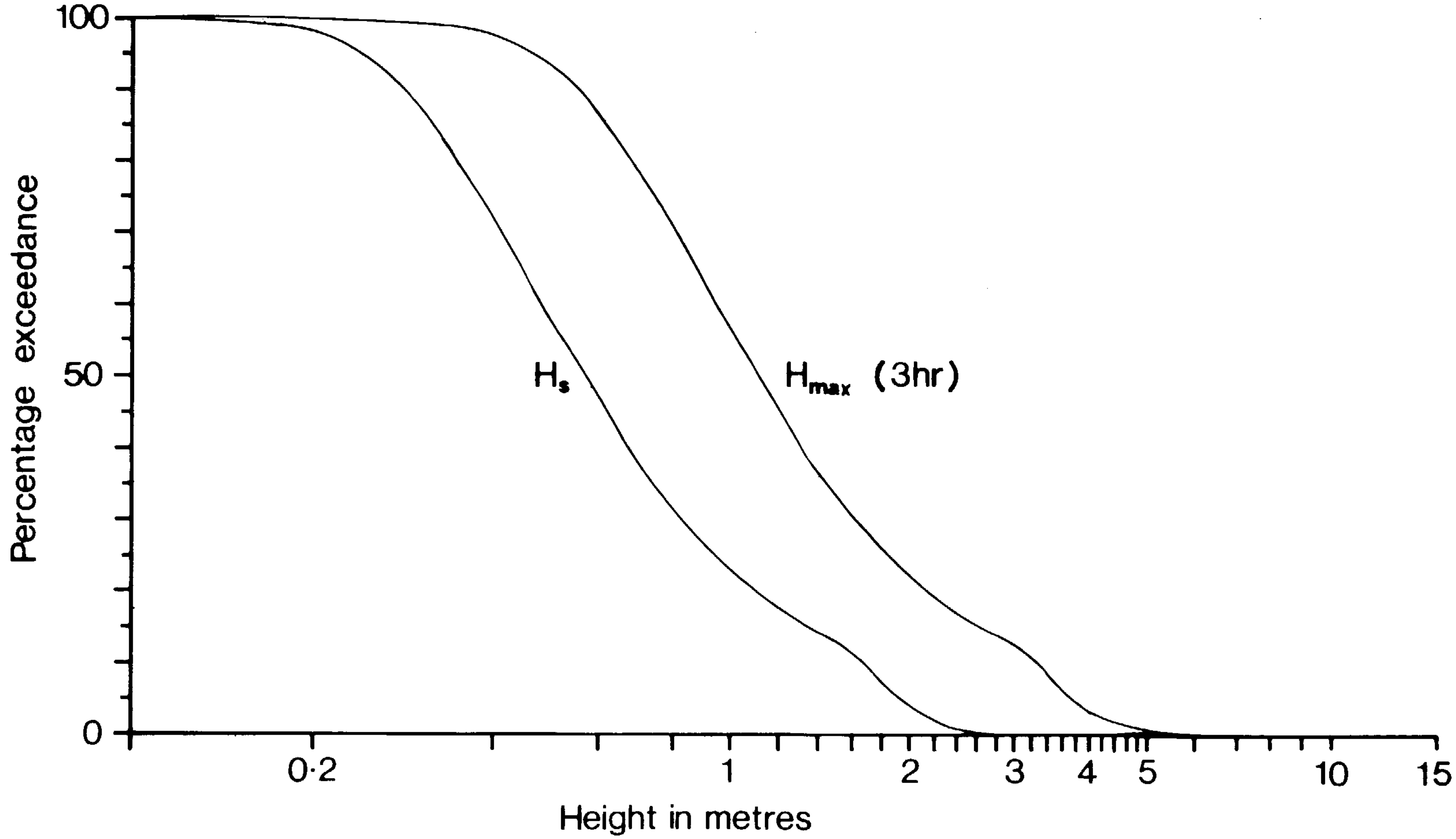
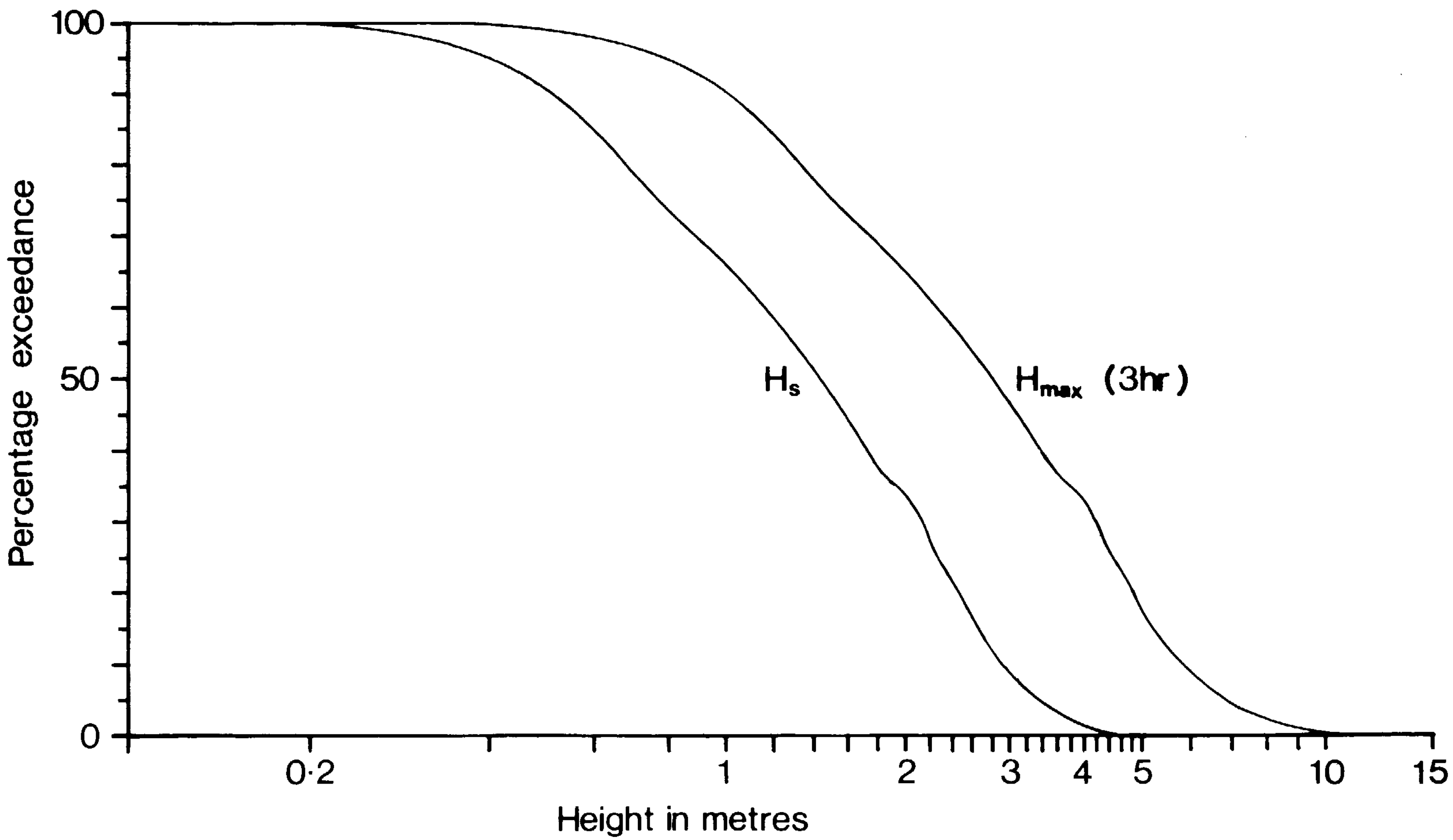


Percentage exceedance of H_s and H_{max}(3hr) - Summer 77

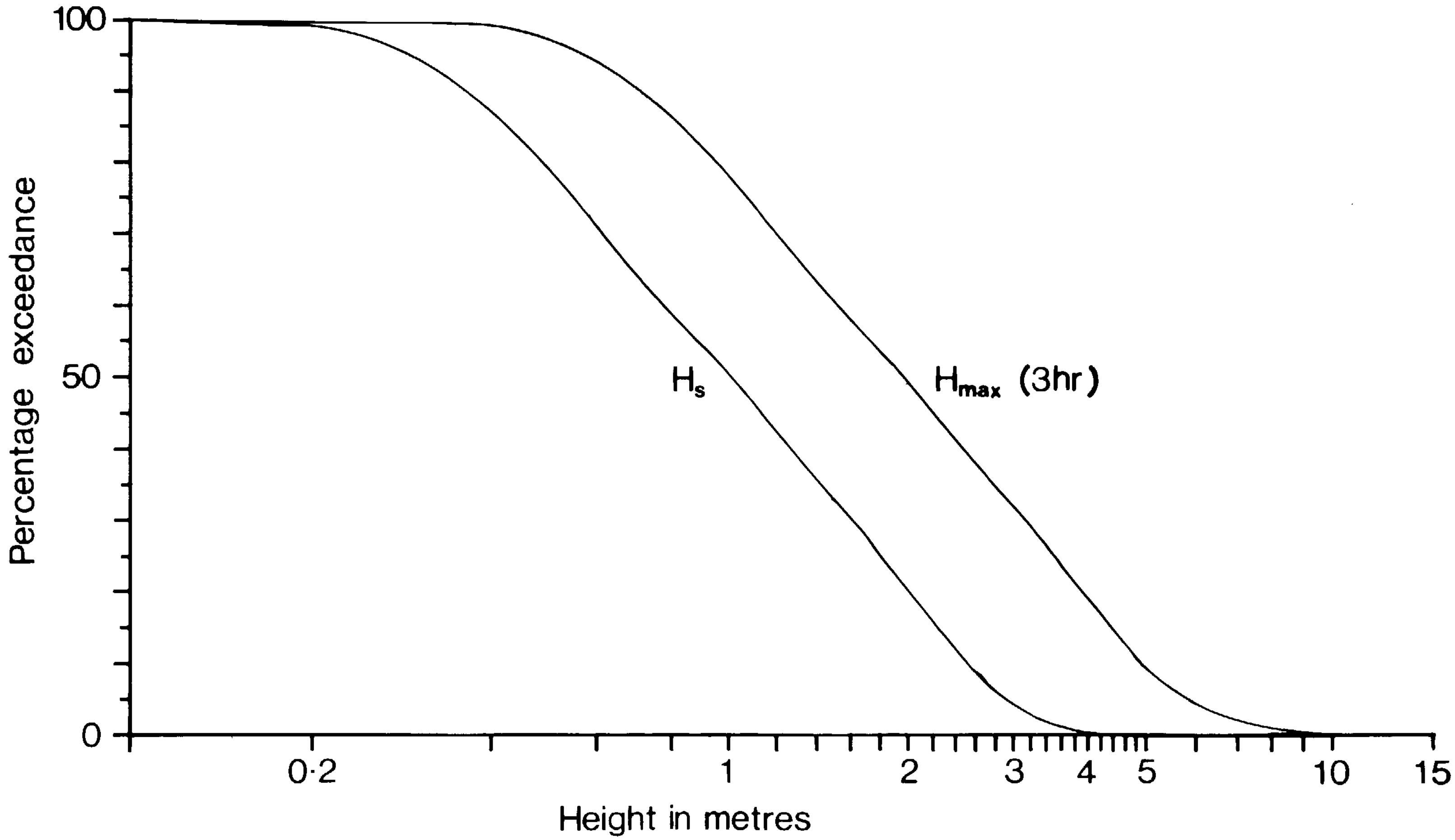
Fig. 3.

SC



Percentage exceedance of H_s and H_{max} (3hr) – Autumn 77

Fig. 4 .



Percentage exceedance of H_s and H_{max}(3hr) – Whole Year

Fig. 5.

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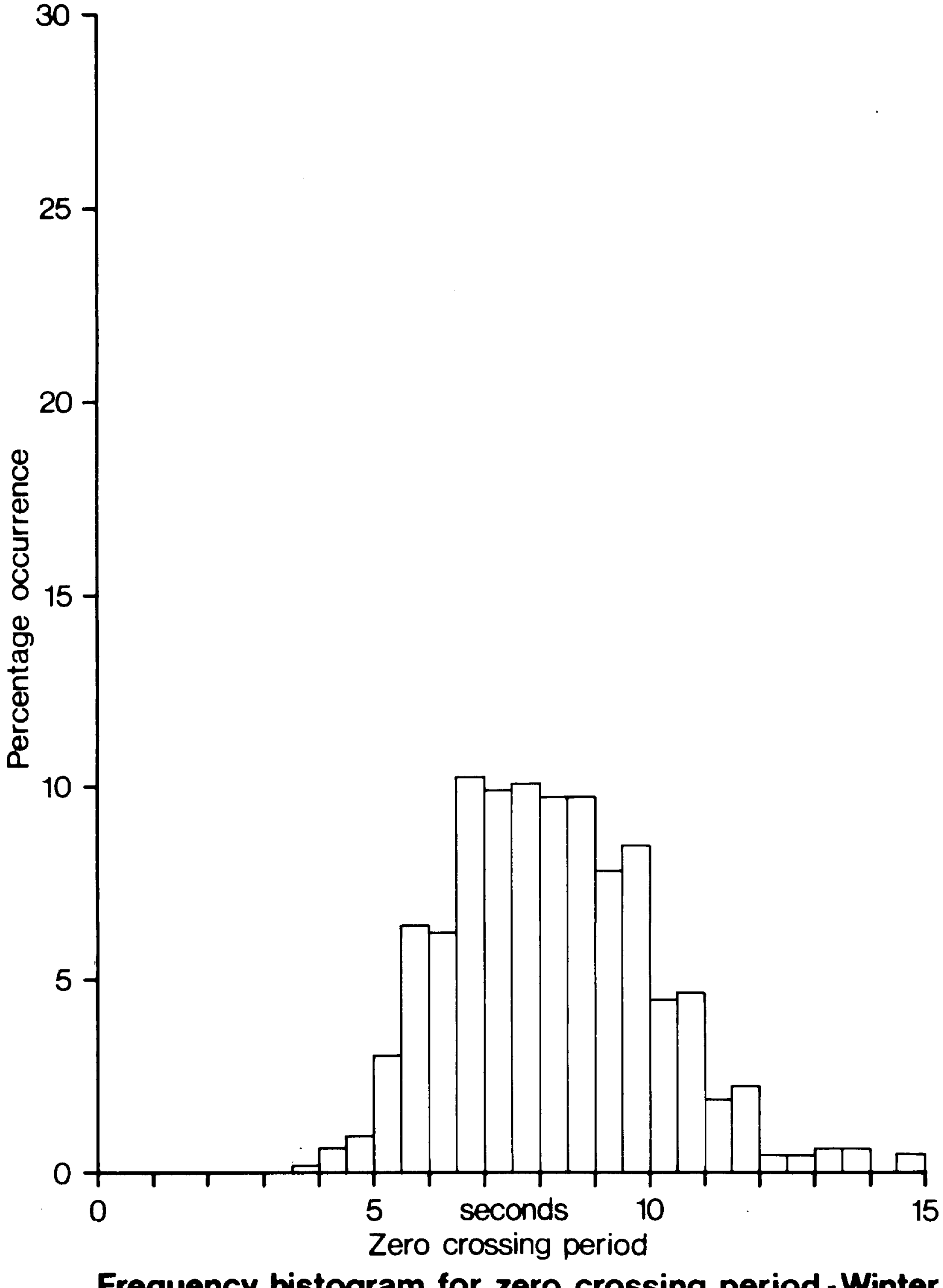

Frequency histogram for zero crossing period - Winter 76-77

Fig. 6.

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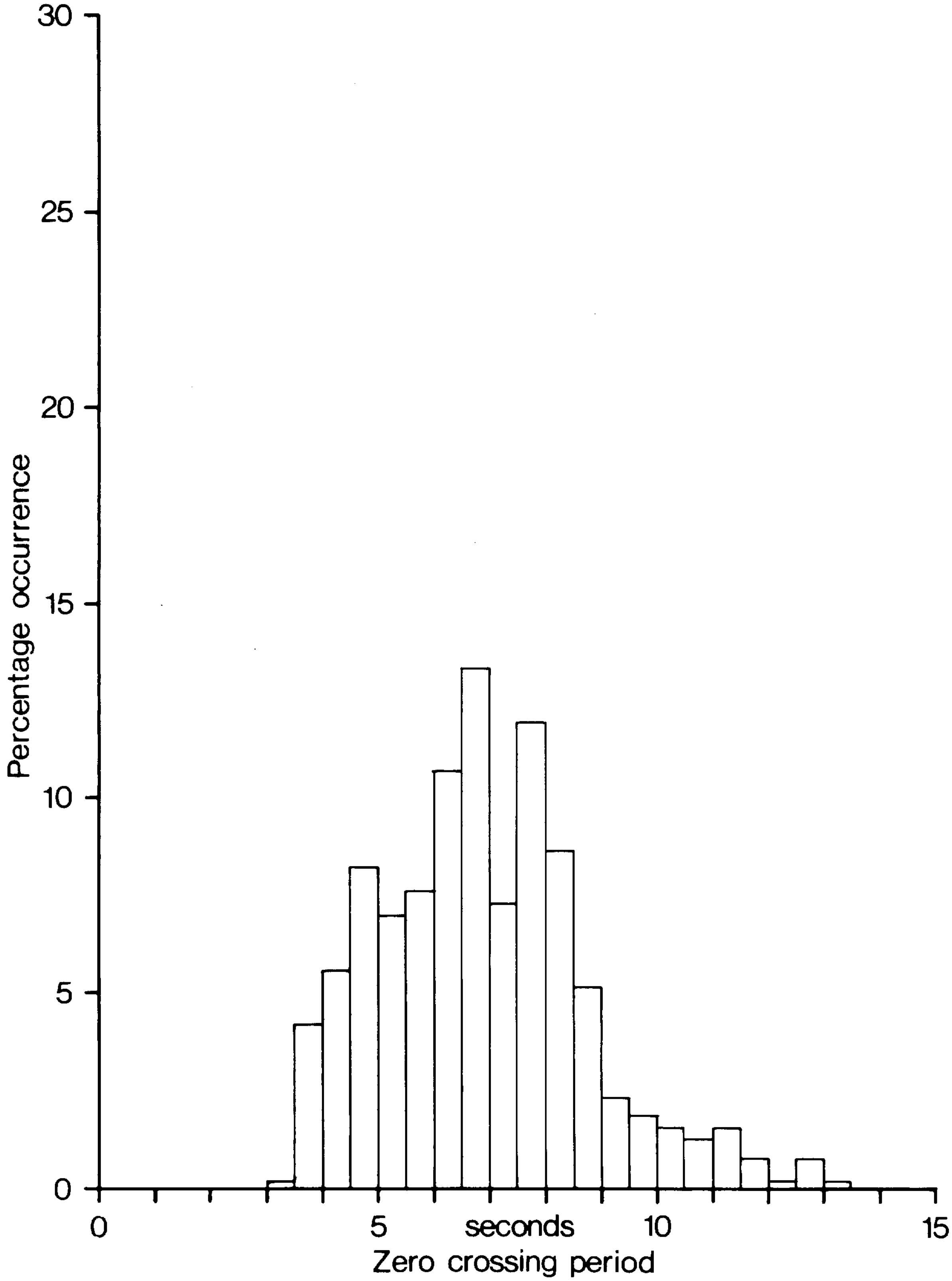

Frequency histogram for zero crossing period - Spring 77

Fig. 7.

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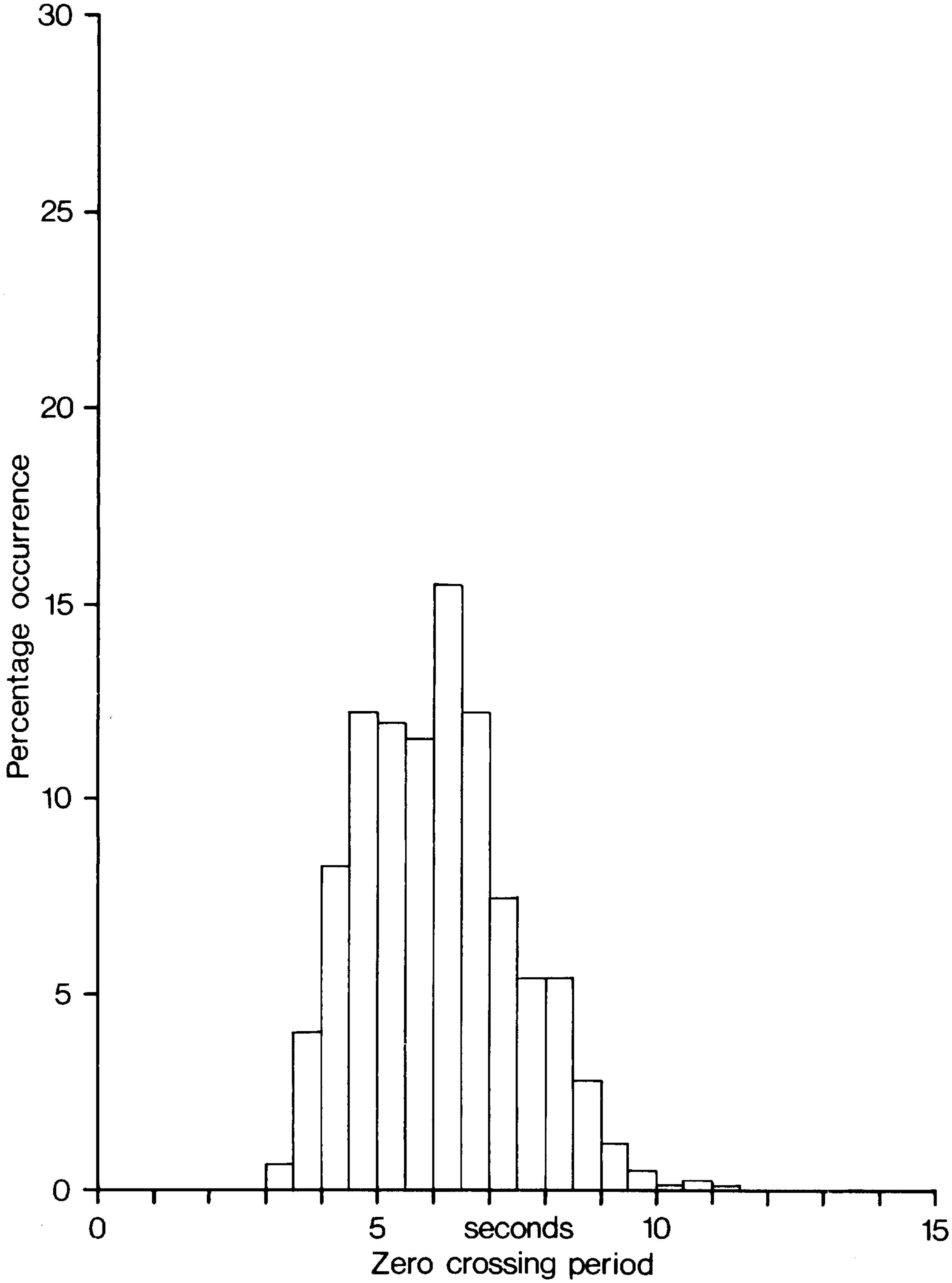

Frequency histogram for zero crossing period - Summer 77

Fig. 8 .

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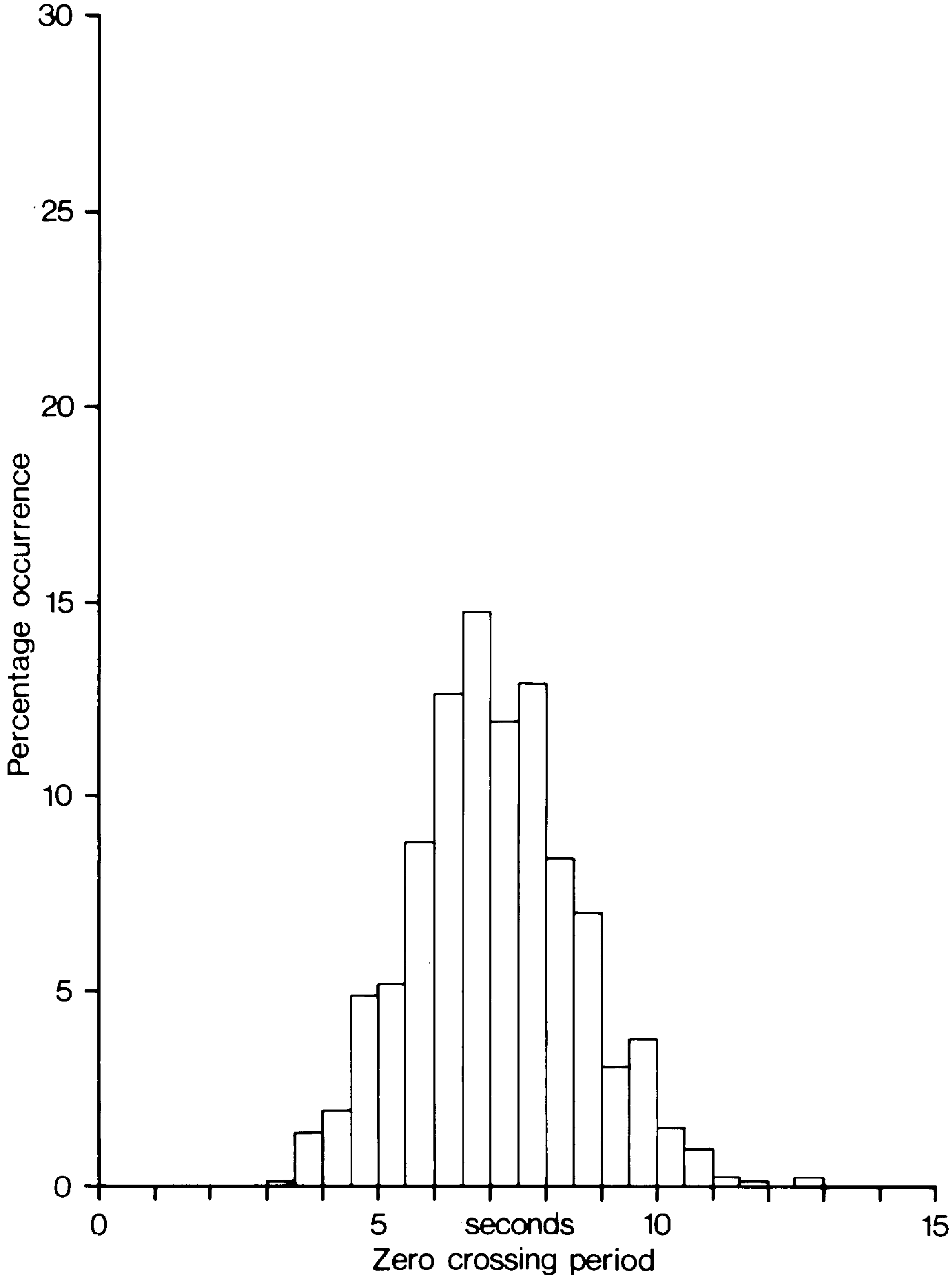

Frequency histogram for zero crossing period - Autumn 77

Fig. 9.

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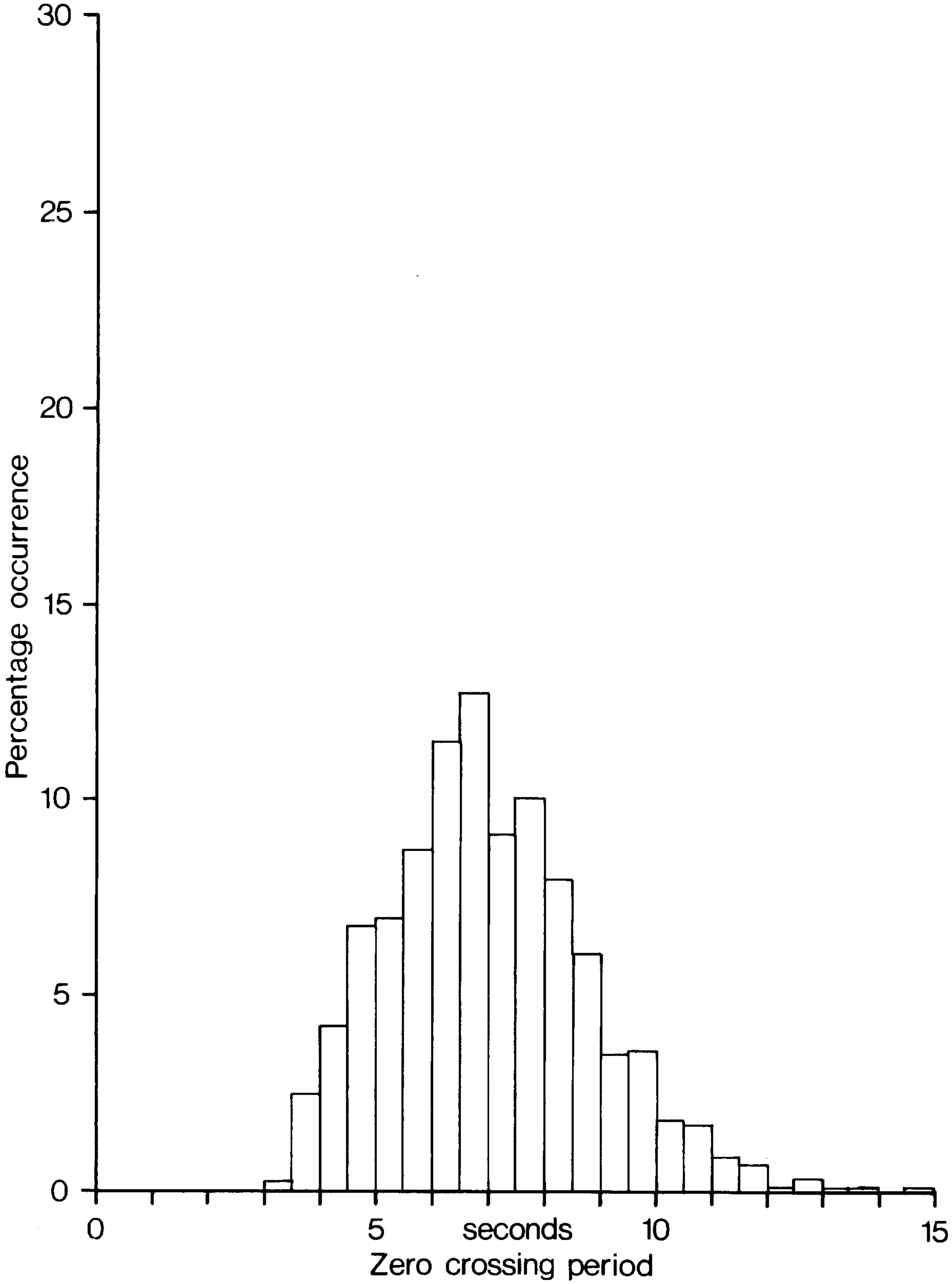

Frequency histogram for zero crossing period - Whole Year

Fig. 10.

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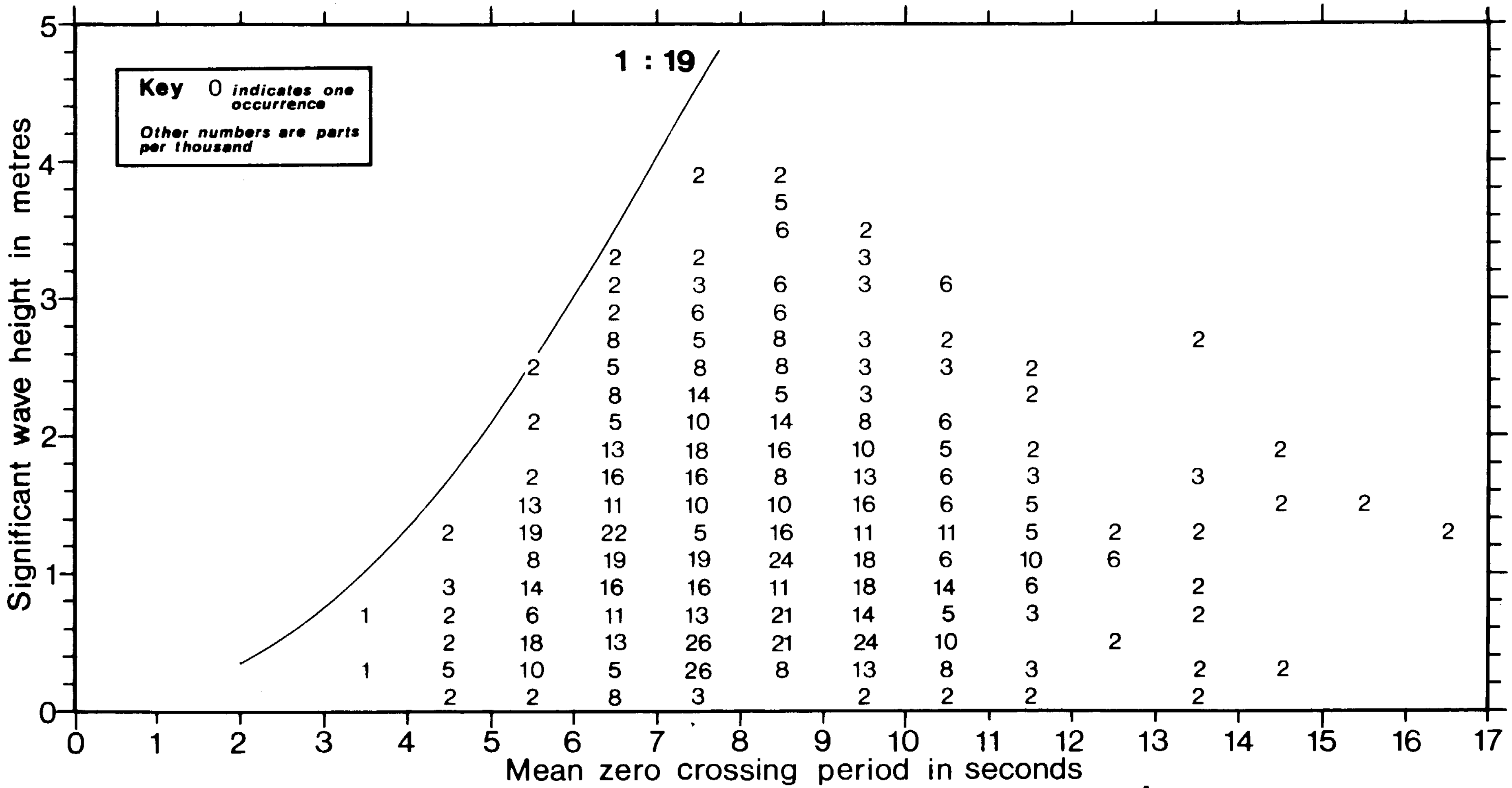

Scatter diagram in parts per thousand – Winter '76-77

Fig. 11

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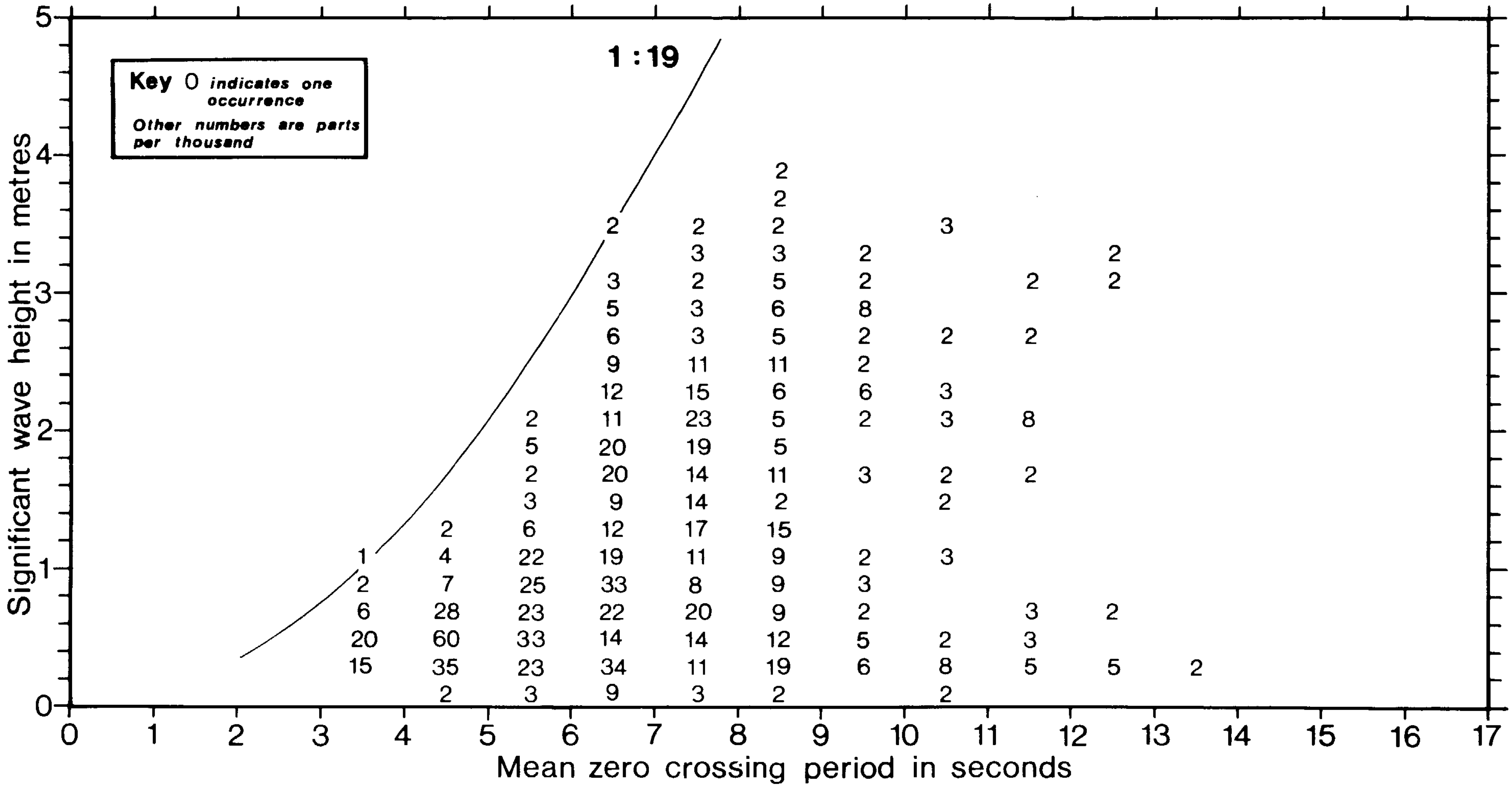

Scatter diagram in parts per thousand – Spring '77

Fig.12

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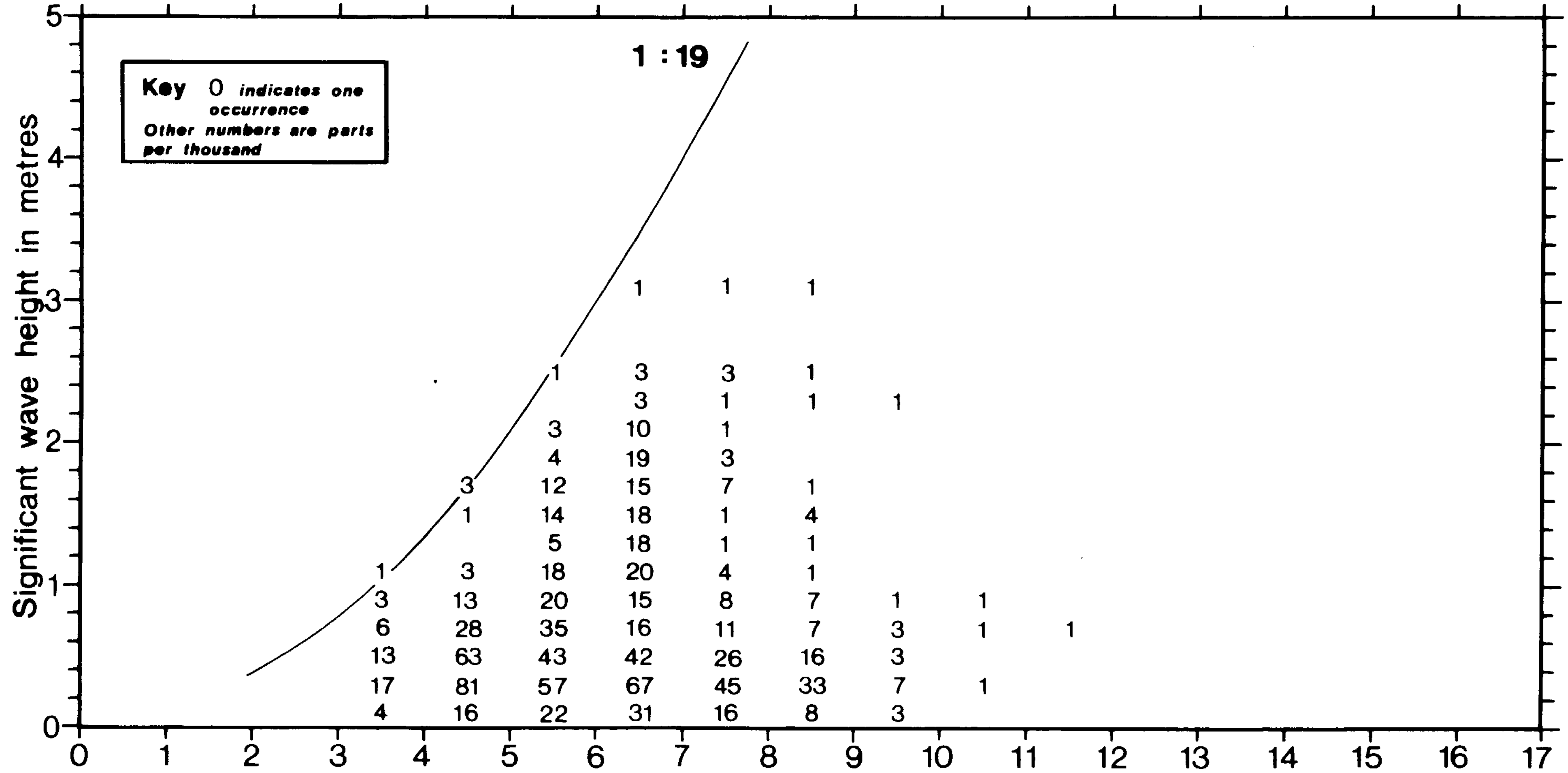
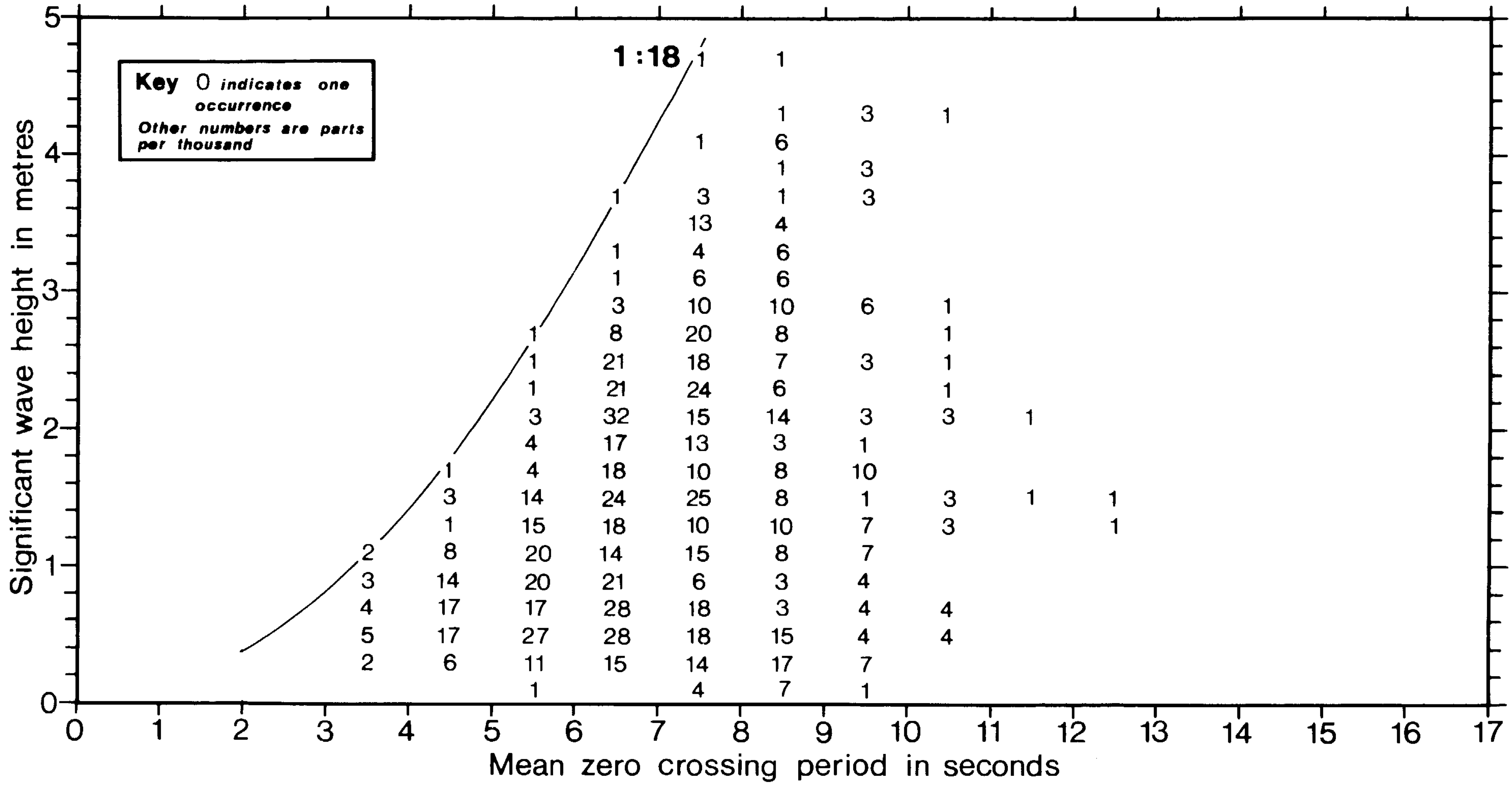


Scatter diagram in parts per thousand – Summer '77

Fig.13



Scatter diagram in parts per thousand – Autumn '77

Fig. 14

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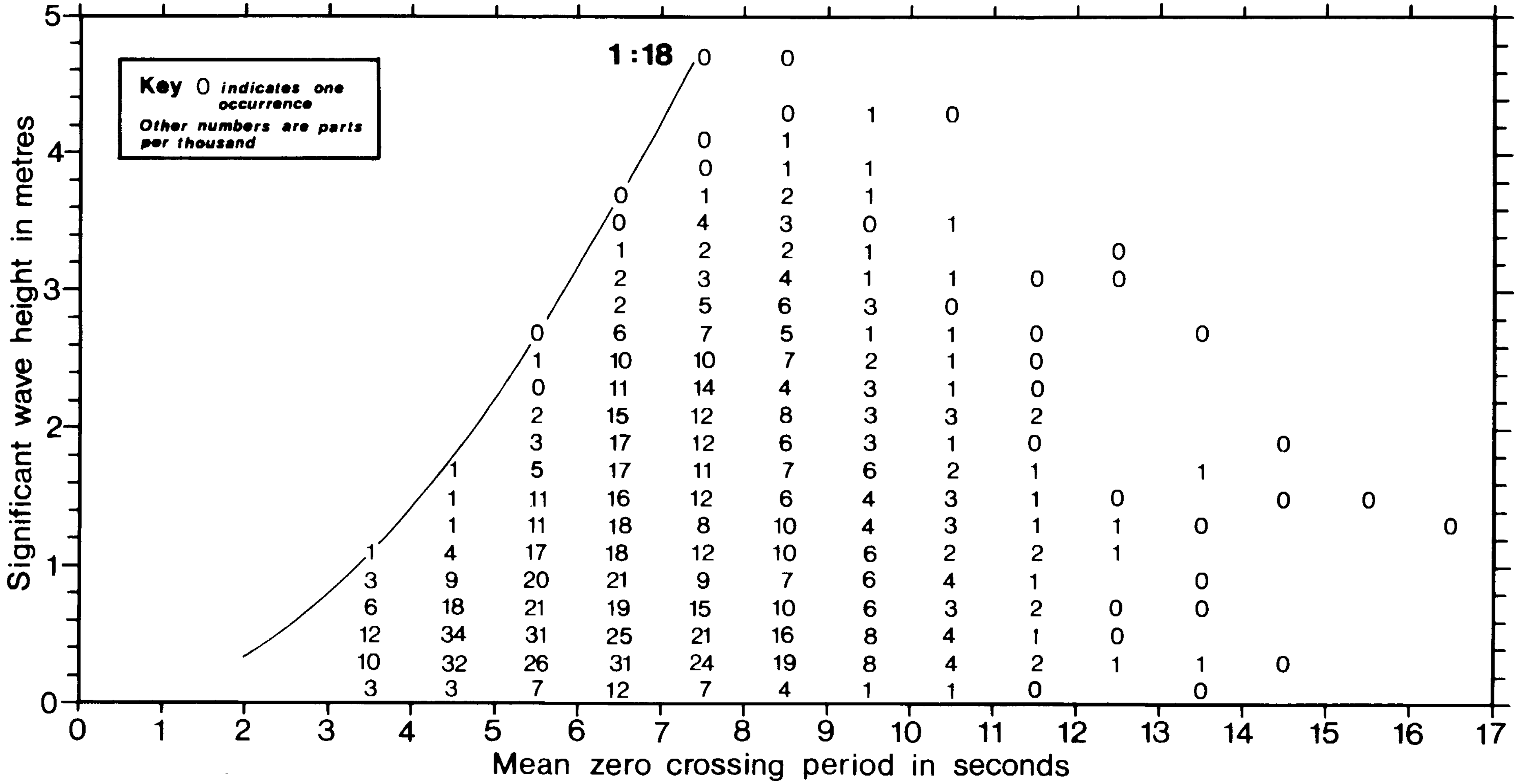
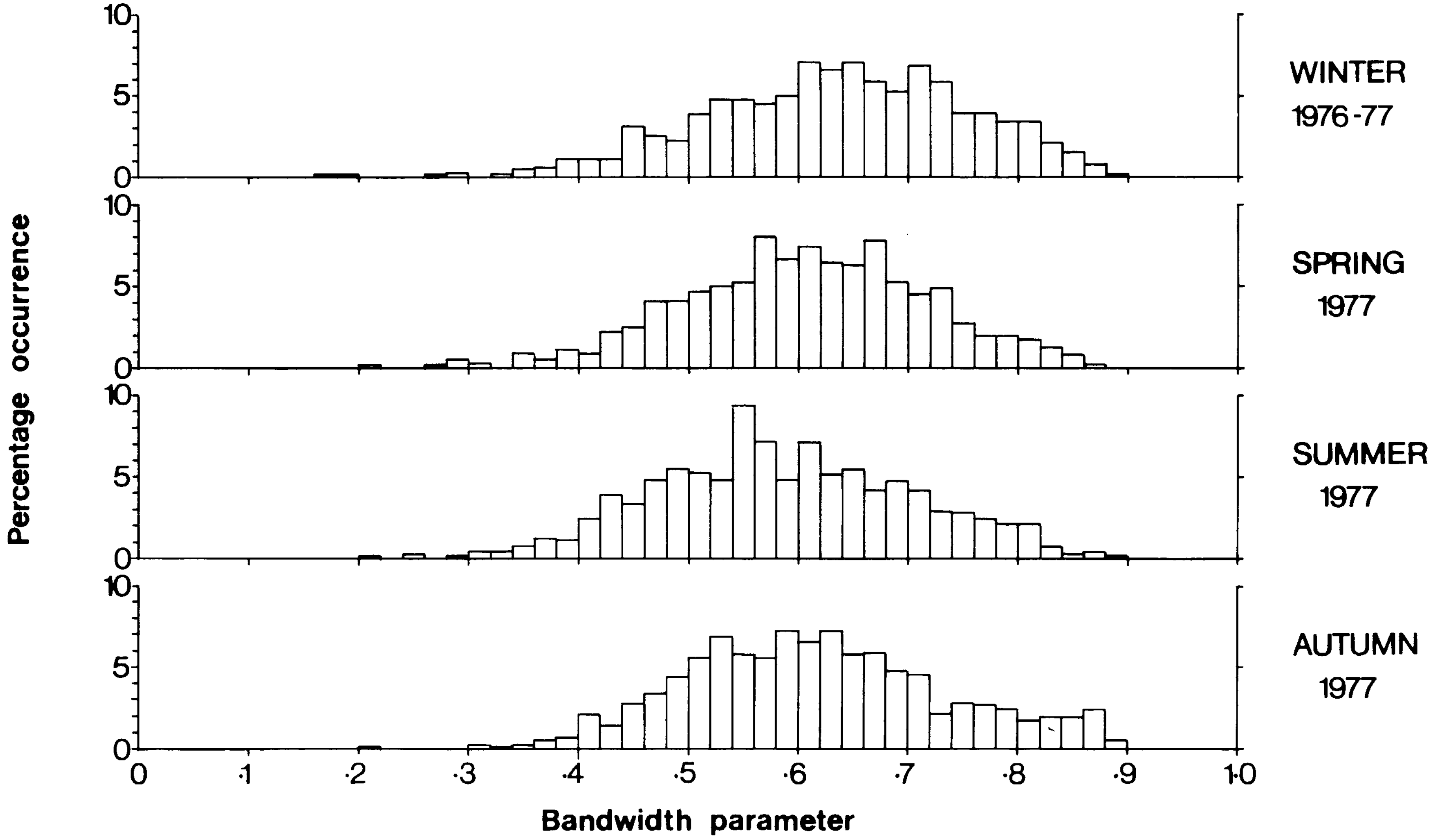


Scatter diagram in parts per thousand - Whole year
Fig.15



Frequency histograms for bandwidth parameter

Fig. 16

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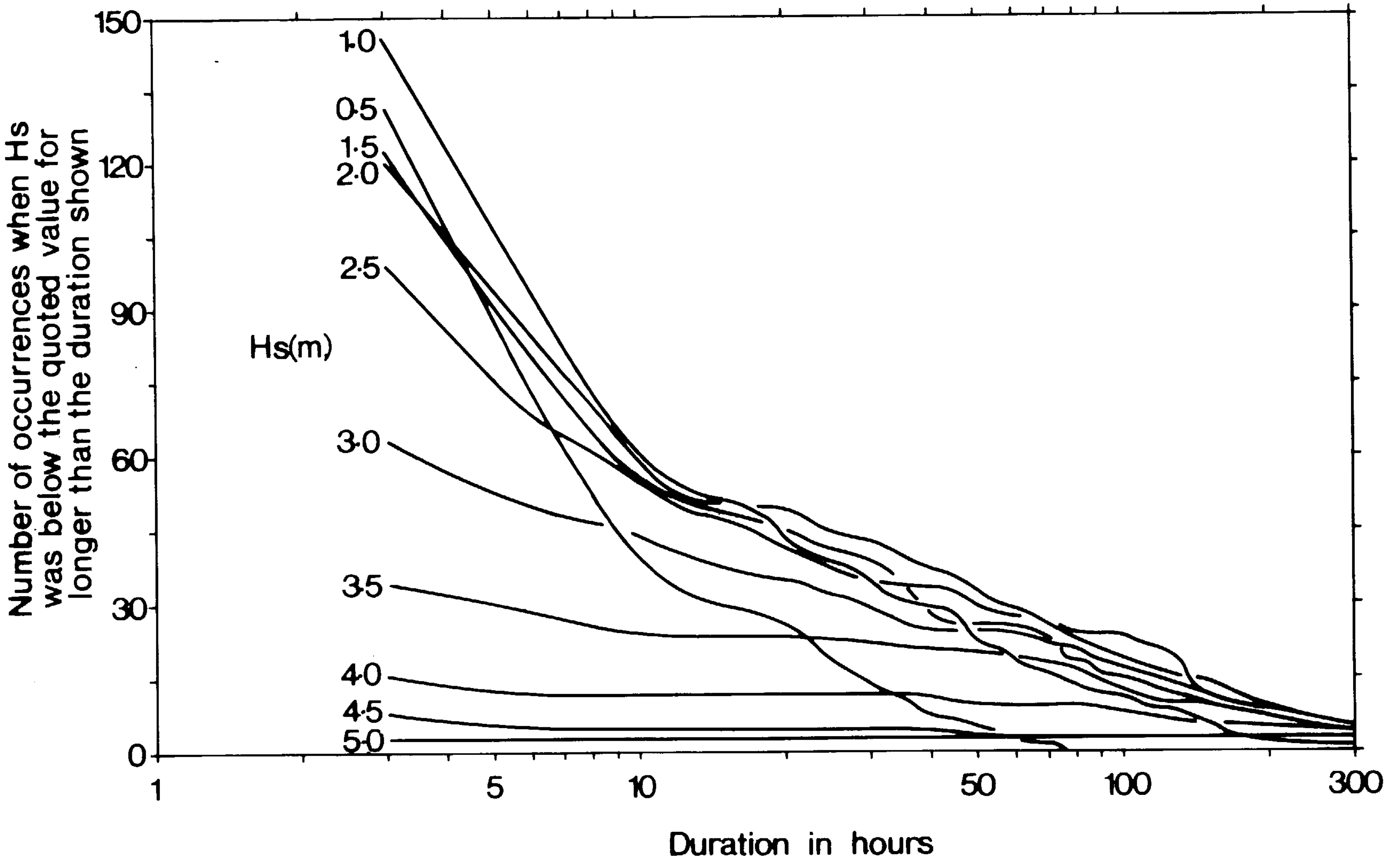

Persistence of Calms

Fig. 17

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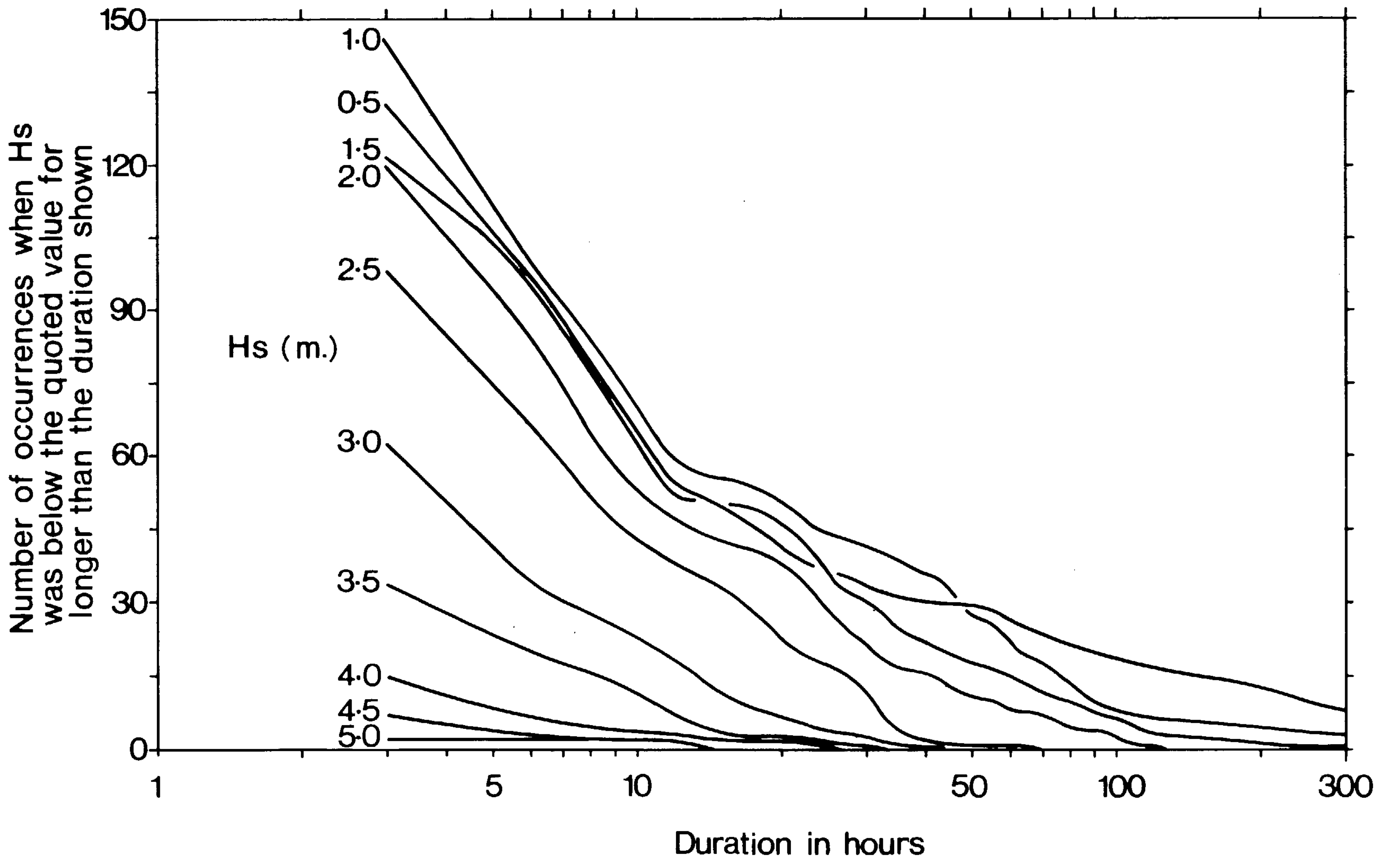

Persistence of storms

Fig. 18

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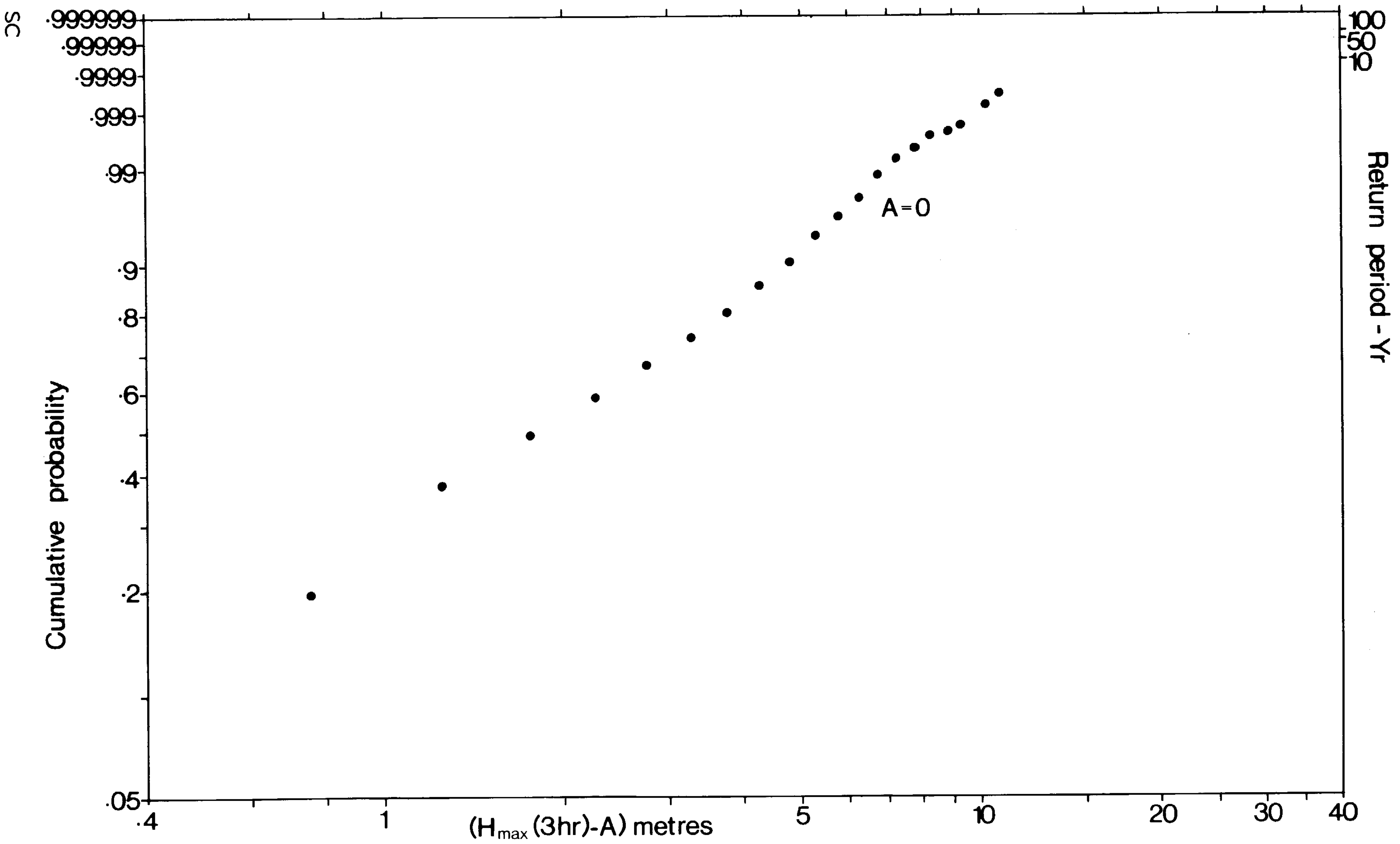

Cumulative distribution of $(H_{max}$(3hr)-A) Weibull scale

Fig. 19

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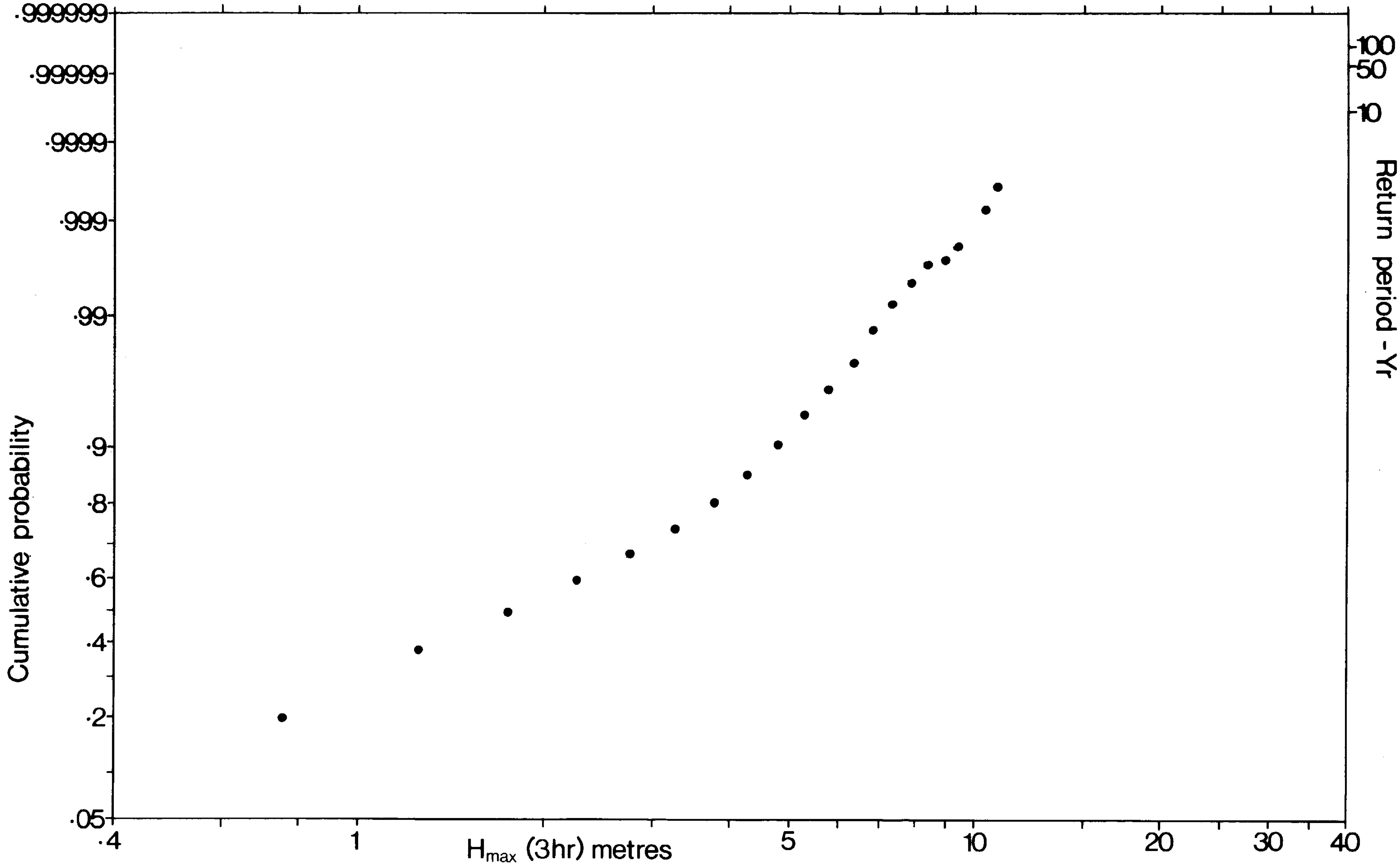
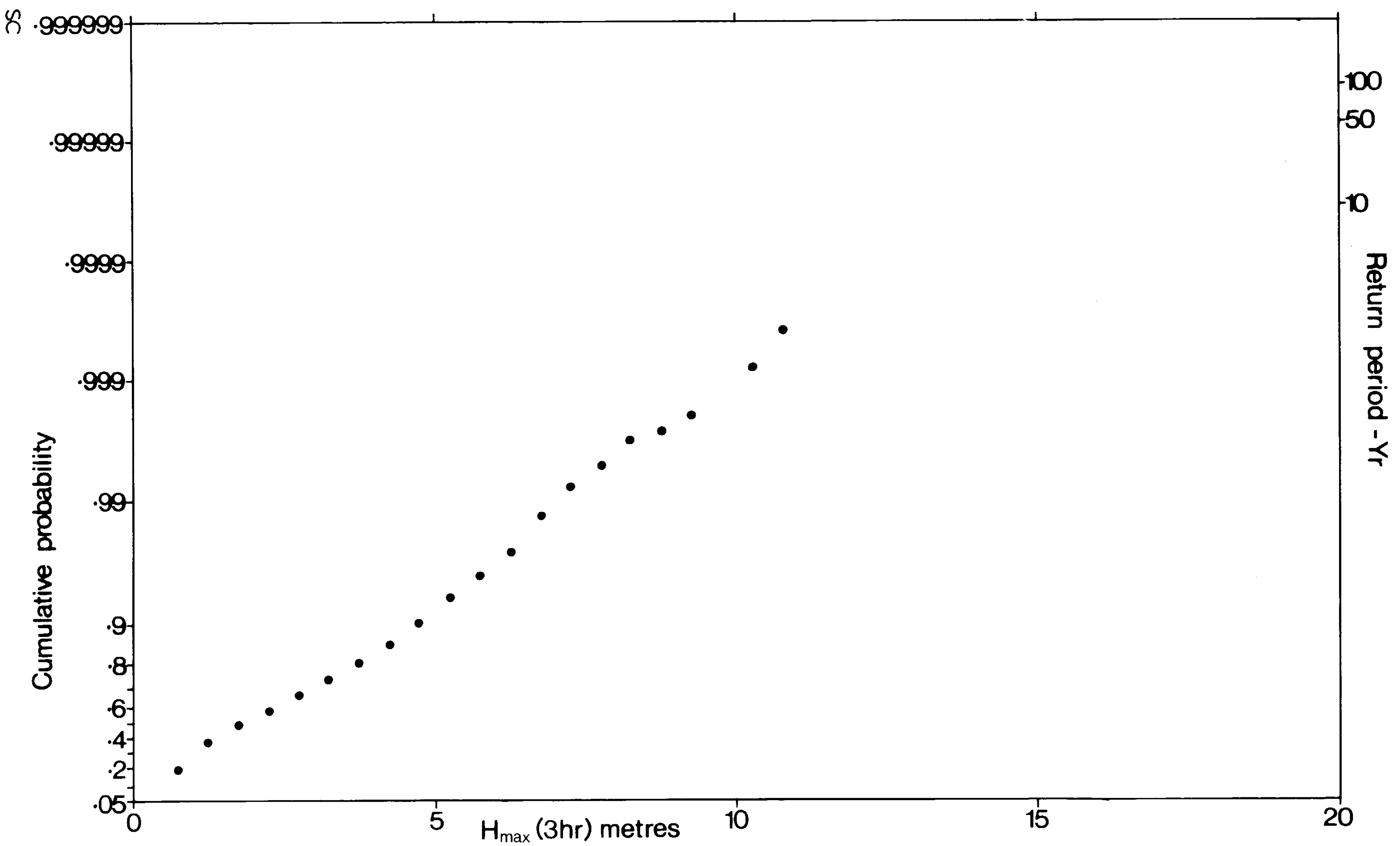


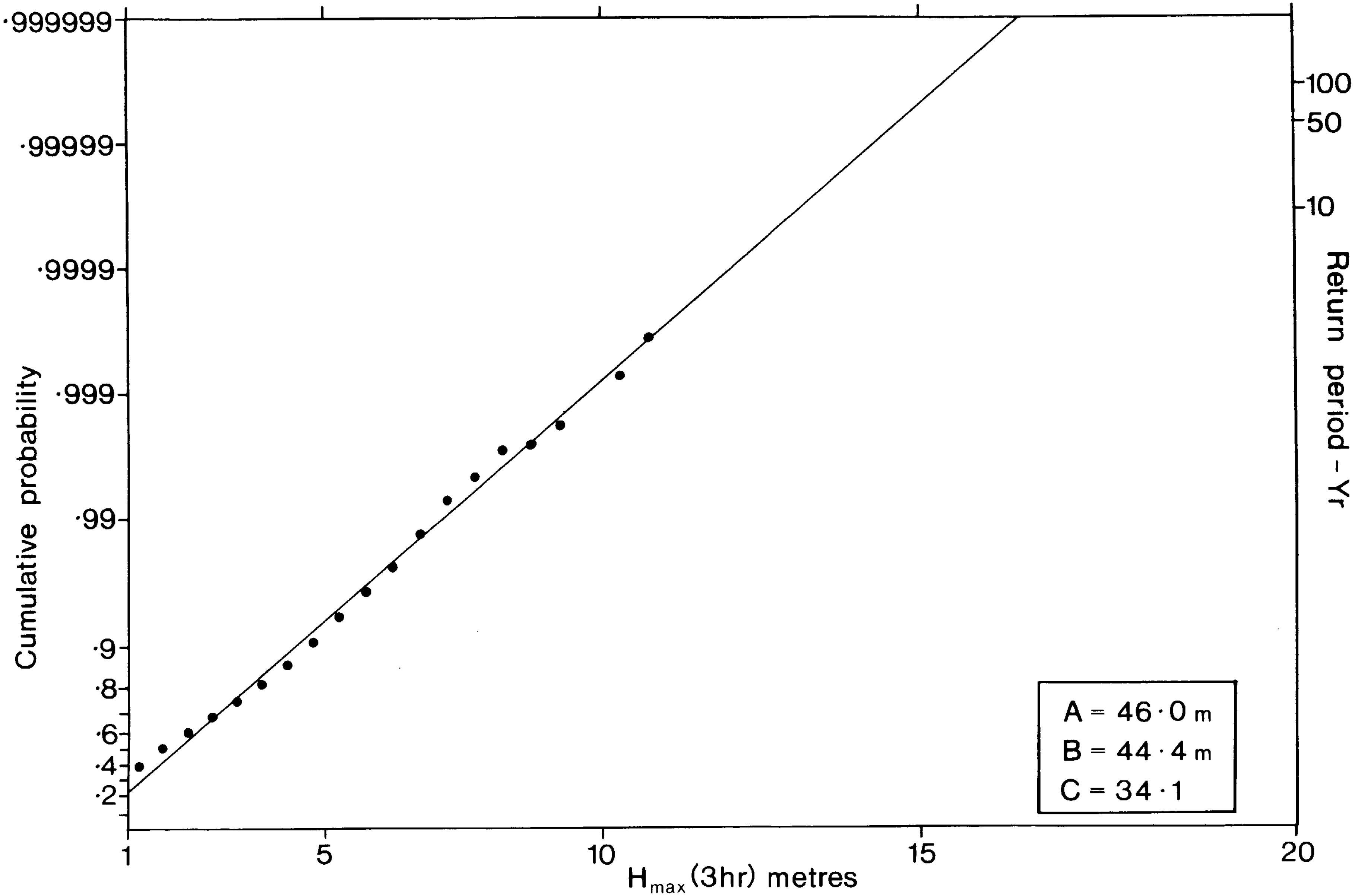
Cumulative distribution of H_{max} (3hr) Log normal scale

Fig. 20



Cumulative distribution of H_{max} (3hr) Gumbel I scale

Fig. 21



Cumulative distribution of H_{max} (3hr) Gumbel III scale

Fig. 22

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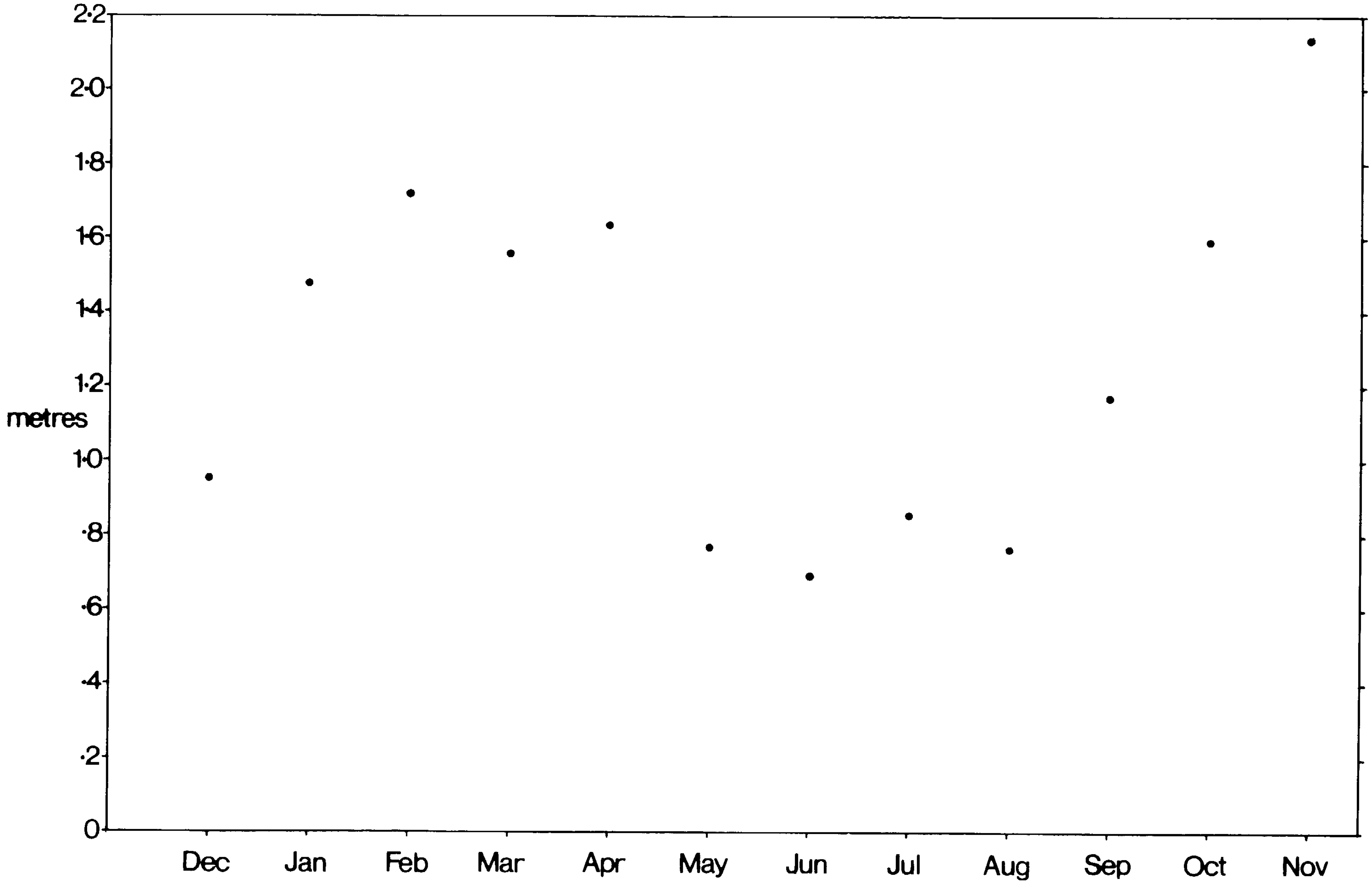

The mean value of significant wave height for each month

Fig. 23

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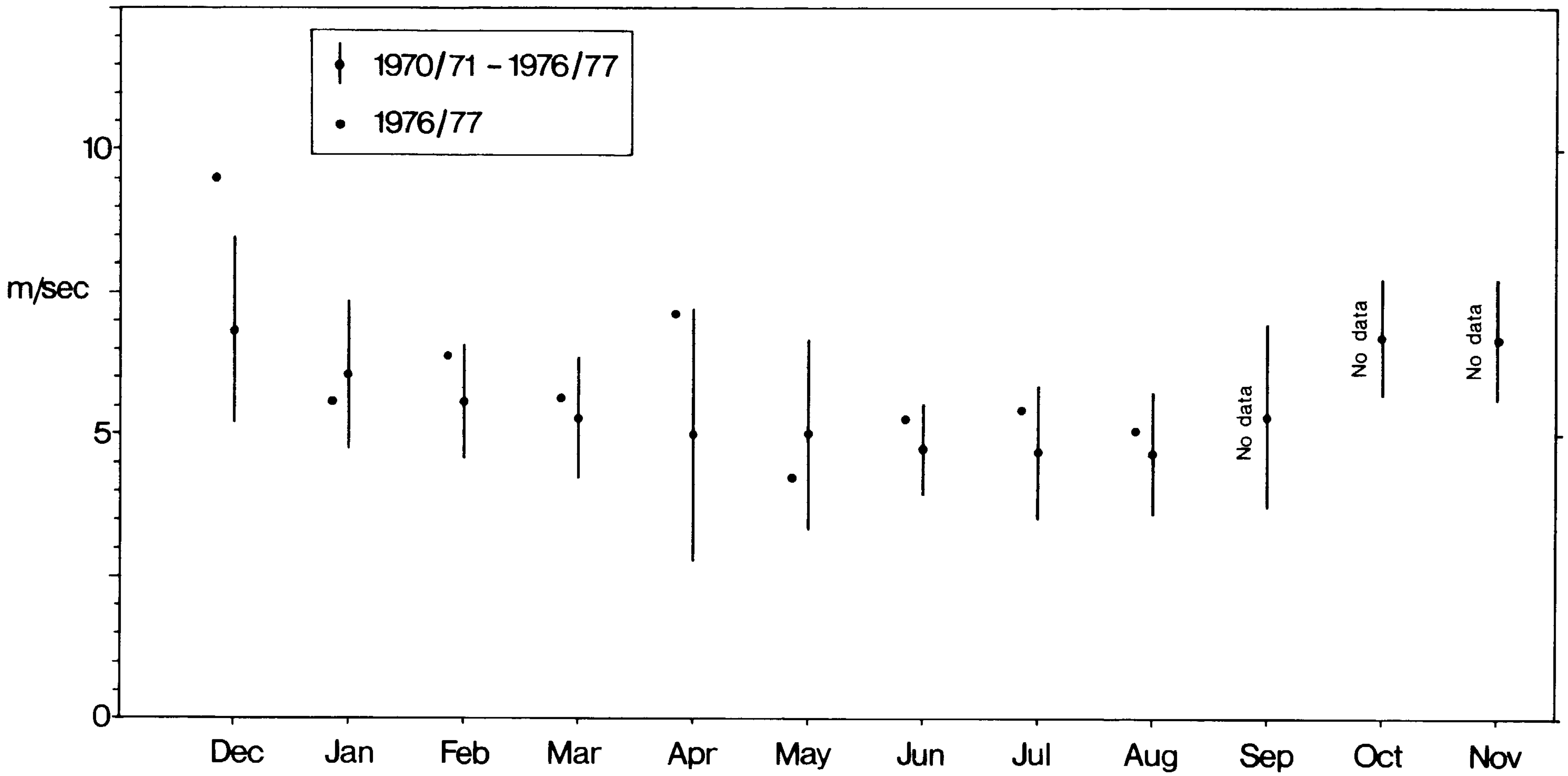

The mean and standard deviation of the average value of wind speed for each month

Fig. 24

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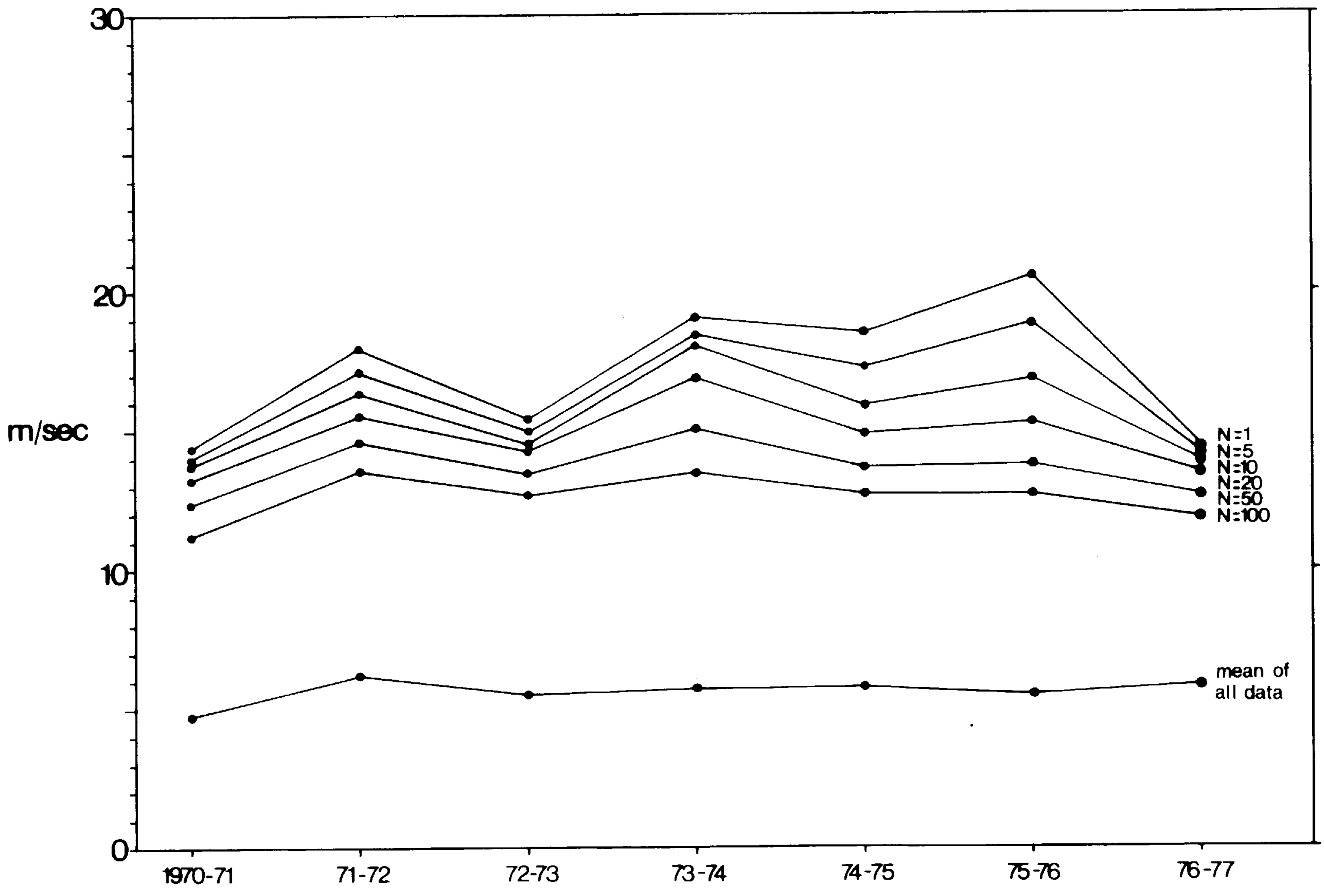

The mean of the largest 'N' values of wind speed

Fig. 25