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WAVES RECORDED AT PORT TALBOT ON THE SOUTH WALES COAST

by

B C H FORTNUM and P J HARDCASTLE

Data for December 1975 to February 1976

and March 1977 to November 1977

at position 51 34'N, 03 48'W

Summary Analysis and Interpretation Report

Report No 78

1979

NATURAL ENVIRONMENT RESEARCH COUNCIL

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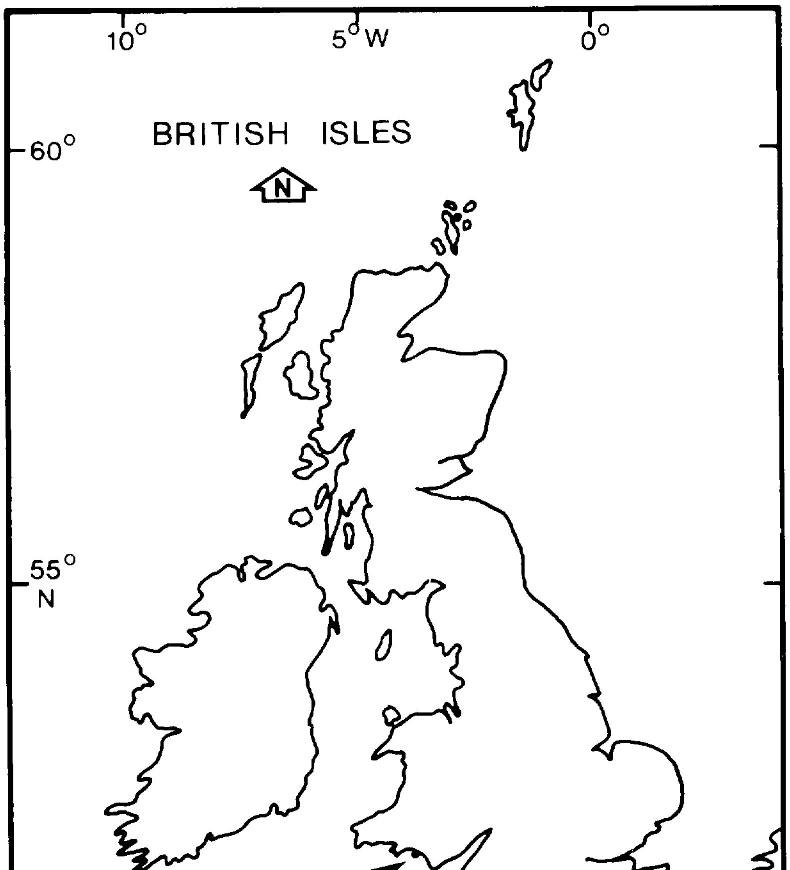
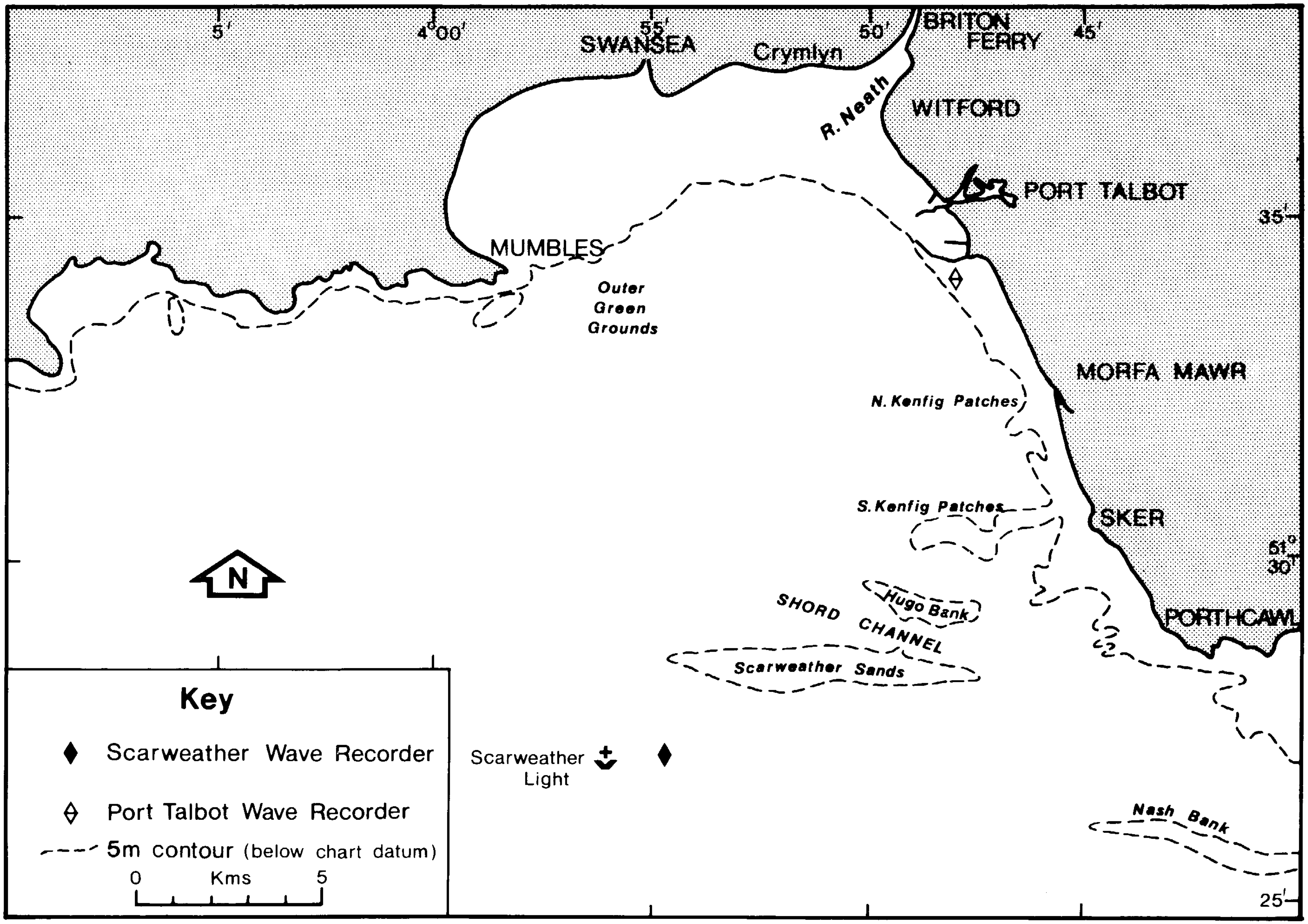
Map to show location of Port Talbot Wave Recorder



Map showing positions of Wave Recorders in relation to local topography



INTRODUCTION

The wave data presented in this report have been collected using frequency modulated pressure recorders (Harris et al (1963), Hardcastle (1967)). The pressure unit was sited off the South Wales coast south-east of the Port Talbot tidal harbour as shown in the figure at the beginning of this report. It was situated about one kilometre from the high water mark in water of mean depth of approximately twelve metres and with a tidal range of over ten metres, and was connected by armoured cable to a shore-based recorder. The variations in pressure were recorded for ten minutes every three hours on magnetic tape cassettes. The pressure recorders were calibrated directly in metres of sea water using a static technique (see Appendix), so that the signals obtained on replay were in fact analogues of pressure, scaled in metres of sea water. During replay each ten-minute record was analysed to give the mean rectified wave height, the number of zero up-crossings, the number of crests, and the mean height of the water column above the pressure unit. From these figures the significant wave height, the zero up-crossing period and crest period were derived. In order to determine the significant wave height, a correction was made to adjust for the hydrodynamic attenuation of the pressure signal; the correction applied was that described in Draper (1957), the representative period used being the mean zero up-crossing period of the pressure signal. However the uncorrected values of significant wave height will be available from the data-bank of the Marine Information and Advisory Service (MIAS). 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 periods for which data have been analysed in this report, together with the percentages of valid data, are as follows:

Period	Valid data (per cent)
December 1975 to February 1976	96.7
March 1977 to November 1977	97.9

The cumulative probability distributions of Hmax(3hr) 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 formulas are used in this report, as follows:

1. Weibull

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

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

2. Log-Normal

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

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 height. 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 on the basis of Figure 21, with the condition that the three-month period in 1975/76 should form one season. Therefore the resulting division into seasons is:

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

Persistence diagrams are not included in this report due to the discontinuity of data between February 1976 and March 1977.

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 4 we see that during winter the significant wave height exceeded two metres for five per cent of the time.

Figures 6 to 10. Frequency histograms for Tz.

It may be seen from these figures that the highest wave periods were up to 18.5 seconds and occurred in the winter season. With the exception of the spring season, the most frequent values of Tz were between 8 and 8.5 seconds. Two facts should be borne in mind when interpreting these figures. The first is that due to the hydrodynamic attenuation of the pressure fluctuations, waves of periods less than five seconds cannot be detected by the pressure transducer. The second is that the frequency response of the recording/replay system is limited at higher frequencies (3dB down at 0.4 Hz, see Hardcastle (1978)), and this results in larger values of Tz than those recorded by other systems.

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 as shown (contouring) gives a representation of the bivariate probability distribution and illustrates the correlation between Hs and Tz. 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. Partly because of the short period cut-off at about five seconds the data are not adequate to allow limiting steepness lines to be drawn on these figures.

Figure 16. Frequency histogram for ε .

It is seen from the figures that all values of ε lie between 0.14 and 0.92. The lower limit corresponds very nearly with the theoretical minimum of 0.128. (This lower, non-zero, limit is determined by the low cut-off wave period. For a five second cut-off period, Nz for a ten-minute record is 120; therefore the minimum non-zero value of ε is obtained when Nc is 121, that is 0.128).

Figures 17 to 20. Cumulative distribution of Hmax(3 hr).

The cumulative distribution of Hmax(3 hr) 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 20, the Gumbel III distribution, since, having an upper bound, it may be expected in principle to be more appropriate to waves in water of this depth (although the value of the upper bound, A, of 209 metres has no obvious physical significance considering the water depth of twelve metres at the site). From Figure 20 the height of the wave with a 50-year return period is found to be about 11.9 metres.

Figure 21. Month-to-month variability of significant wave height.

The mean value of significant wave height for each month is calculated and plotted.

The highest mean wave height is between 1.3 metres and 1.4 metres (for November), and the lowest is about 0.4 metres (for June). The magnitudes of the monthly mean wave heights are, as expected, smallest in summer, but the winter period shows two surprisingly low mean wave heights (each about 0.5 metres).

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. Since the wave data referred to in this report have been taken from two quite separate periods, the wind data are considered in two parts also: (1) March to November, 1970 to 1977; (2) December to February 1970/71 to 1976/77. In addition 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 analysed in this report. The data used are mean hourly wind speeds, and no data are available for September, October and November 1977.

Figure 22. 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 rom 1970 are shown. As can be seen from the figure, three months (May, December and February) show a mean wind speed for the period covered by this report, which is lower than for the seven year period examined: the other six months for which all the data are available show higher average wind speeds. The greatest differences are for April and January, when the mean wind speeds during the period of wave recording are about two metres per second (about forty per cent) higher than for the seven-year period.

Figures 23 and 24. Year-to-year variability of wind speeds.

The mean of the highest N values of wind speed for N = 1, 5, 10, 20, 50, 100 is plotted for March to November (Figure 23) and for December to February (Figure 24). Considering Figure 23, the period during which waves were measured has lower maximum values of wind speed than the previous seven such periods, but a relatively high mean wind speed. Whilst from Figure 24 it can be seen that the maximum values of wind speed during the period when waves were measured are higher than those for the other six periods: the overall mean wind speed lies in the middle of the range of mean wind speeds.

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APPENDIX - Instrumental Aspects

The pressure unit was calibrated in a pressure tank against a standard pressure transducer before installation. This calibration was to an accuracy of better than one per cent. The calibration was checked after a year's operation on site, using pressure changes due to measured changes in tide height. The change in the frequency from the pressure unit was compared with the corresponding change in tide height. Tide height changes may be measured with low percentage errors at this site as the maximum tidal range is over ten metres. It was estimated that this check calibration had an accuracy of the order of ± 2 per cent. The original calibration of the pressure unit agreed with the check to within this accuracy.

The data logging system used is accurate to within ± 1 per cent for the measurement of the significant wave height.

The major inaccuracy in the data lies in the conversion of bottom pressure to wave height. First a correction corresponding to the zero up-crossing period has been used, whereas ideally the correction should have been applied to the individual frequencies in a wave spectrum, the corrected spectrum then being used to calculate Hs and Hmax(3 hr). Second, there is some uncertainty in the correction factors which should be applied; those used were derived empirically by Draper (1957), and can increase waveheights by up to fifteen per cent compared with classical wave theory.

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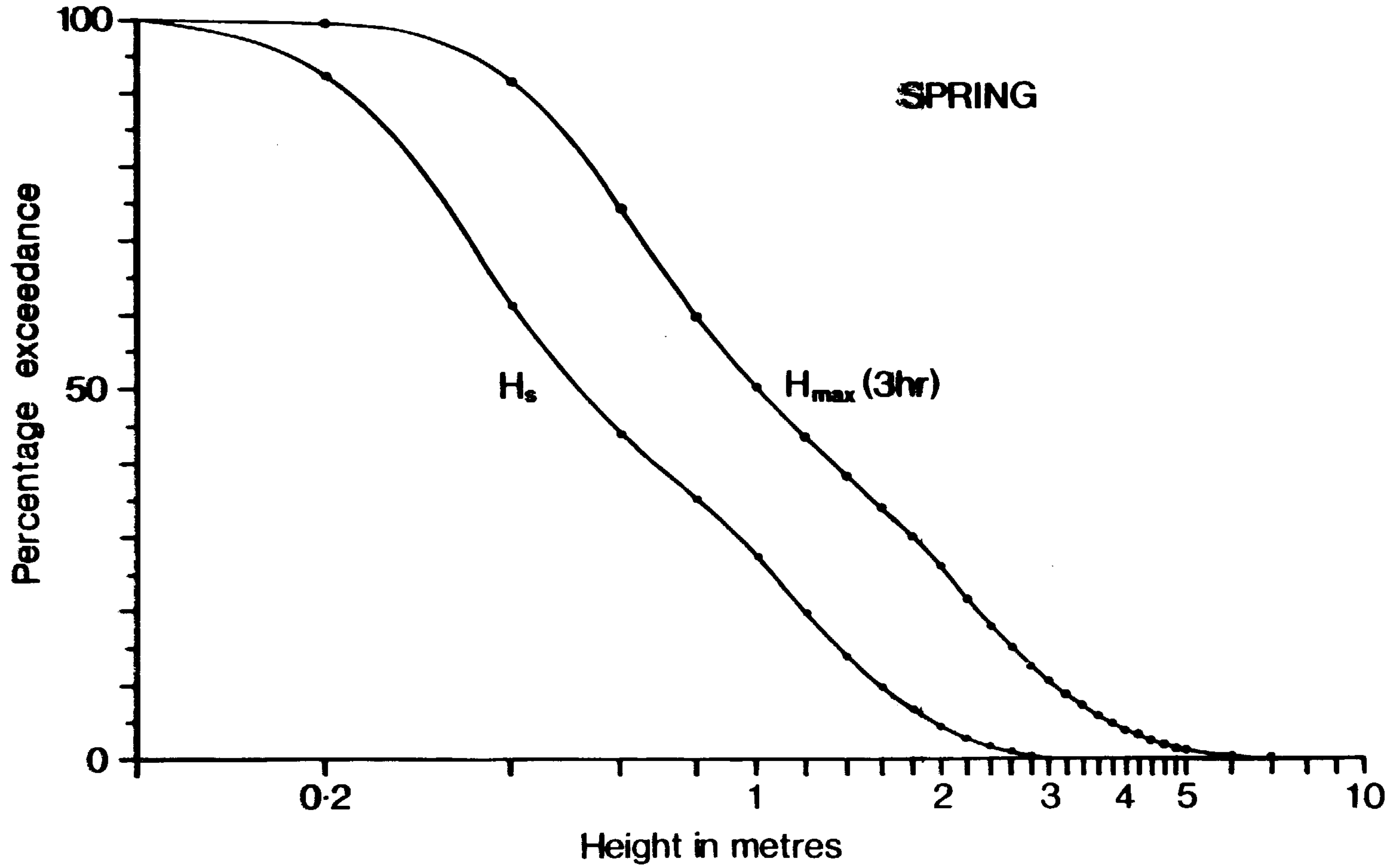

Percentage exceedance of H_s and H_{max} (3hr) – Spring 77

Fig.1

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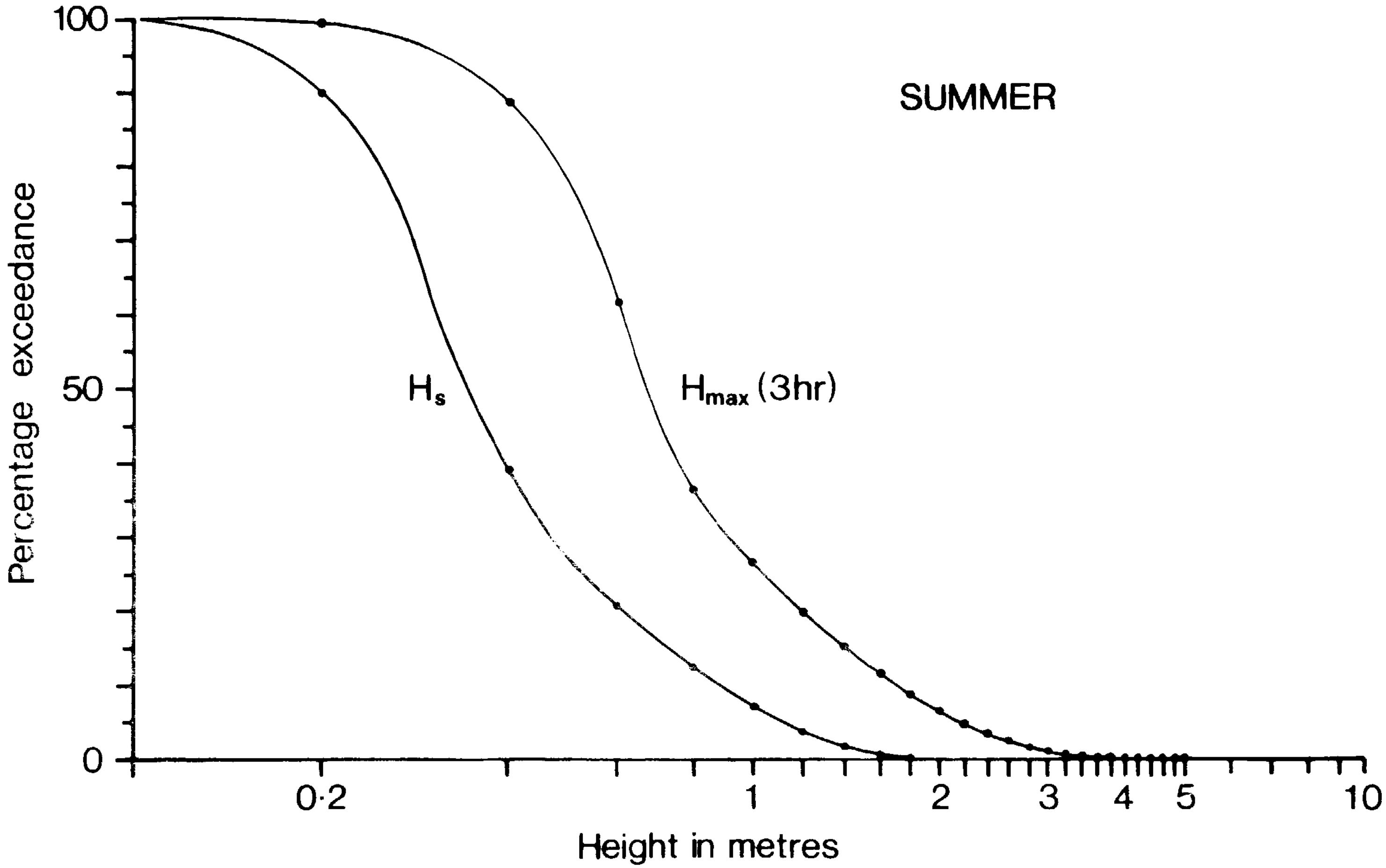
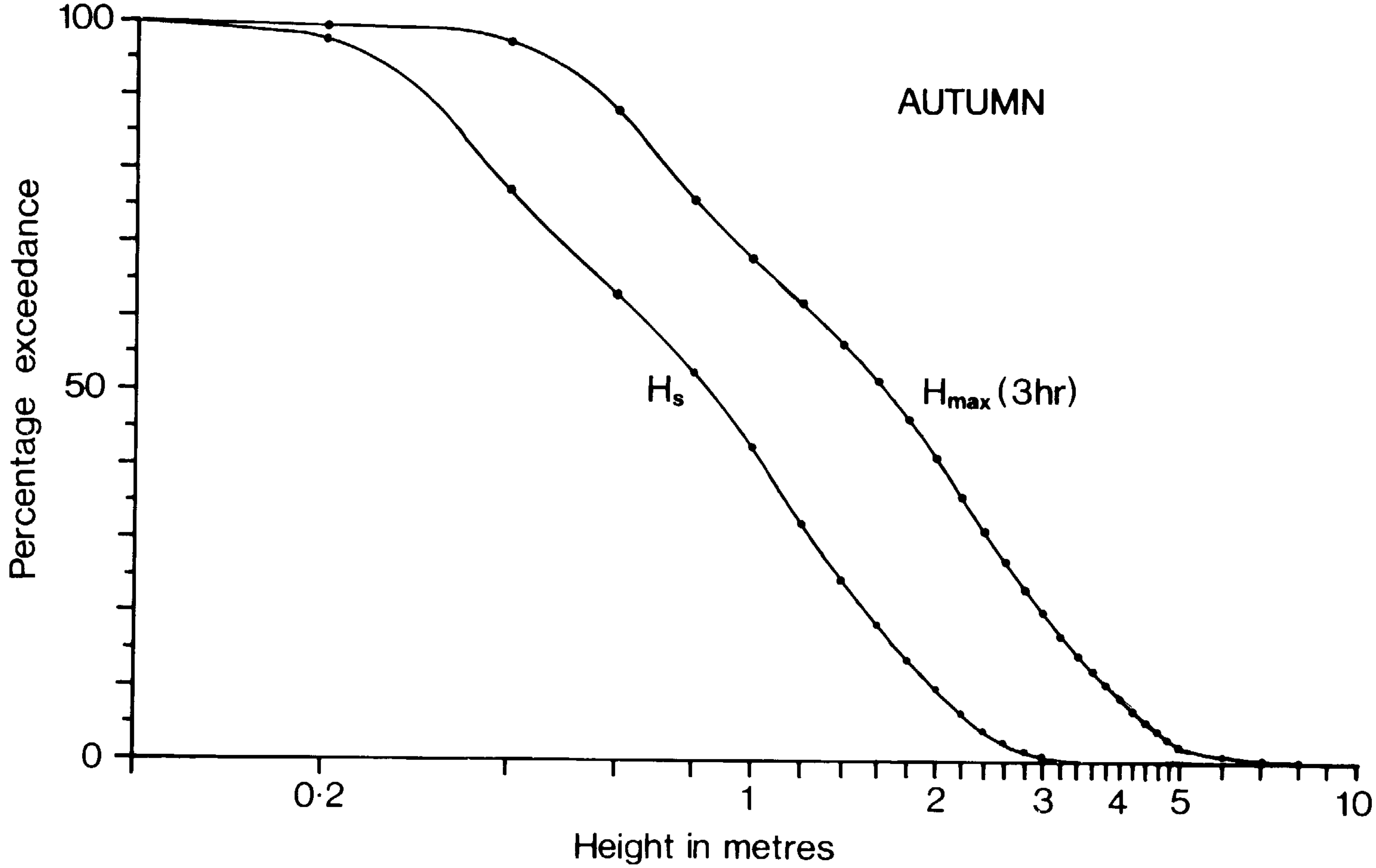


Percentage exceedance of H_s and H_{max} (3hr) – Summer 77

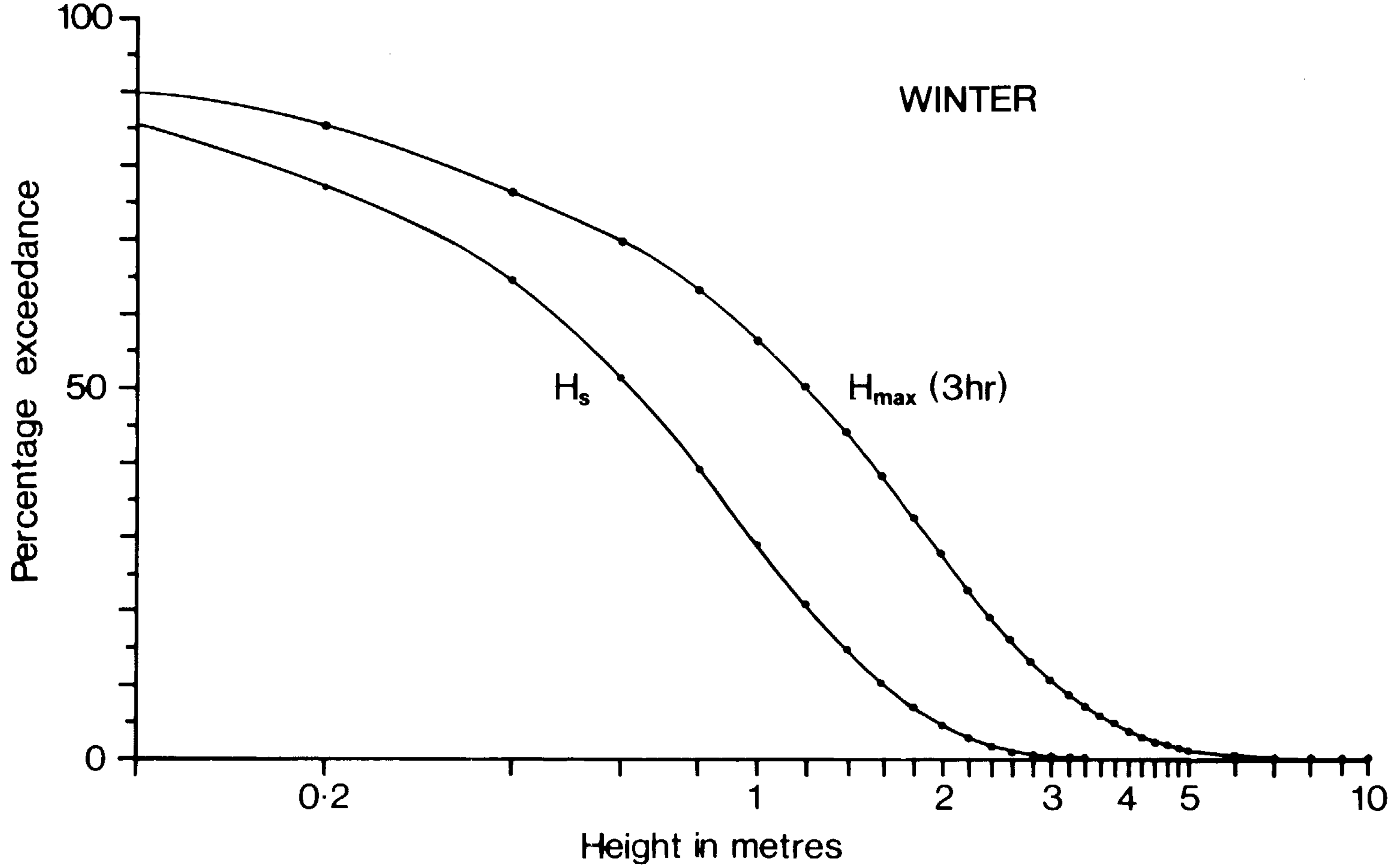
Fig. 2

PT



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

Fig. 3



Percentage exceedance of H_s and H_{max} (3hr) – Winter 75-76

Fig. 4

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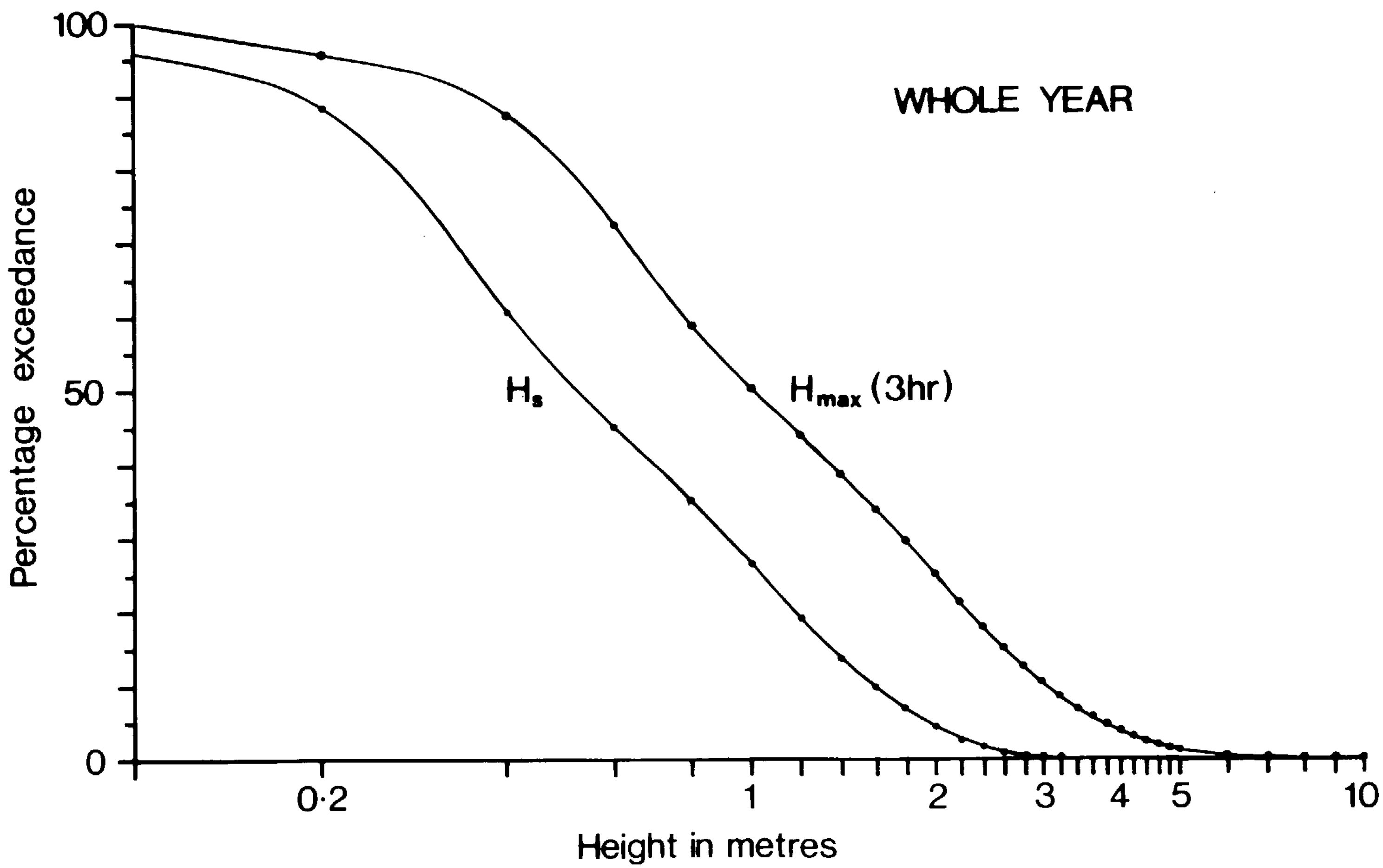
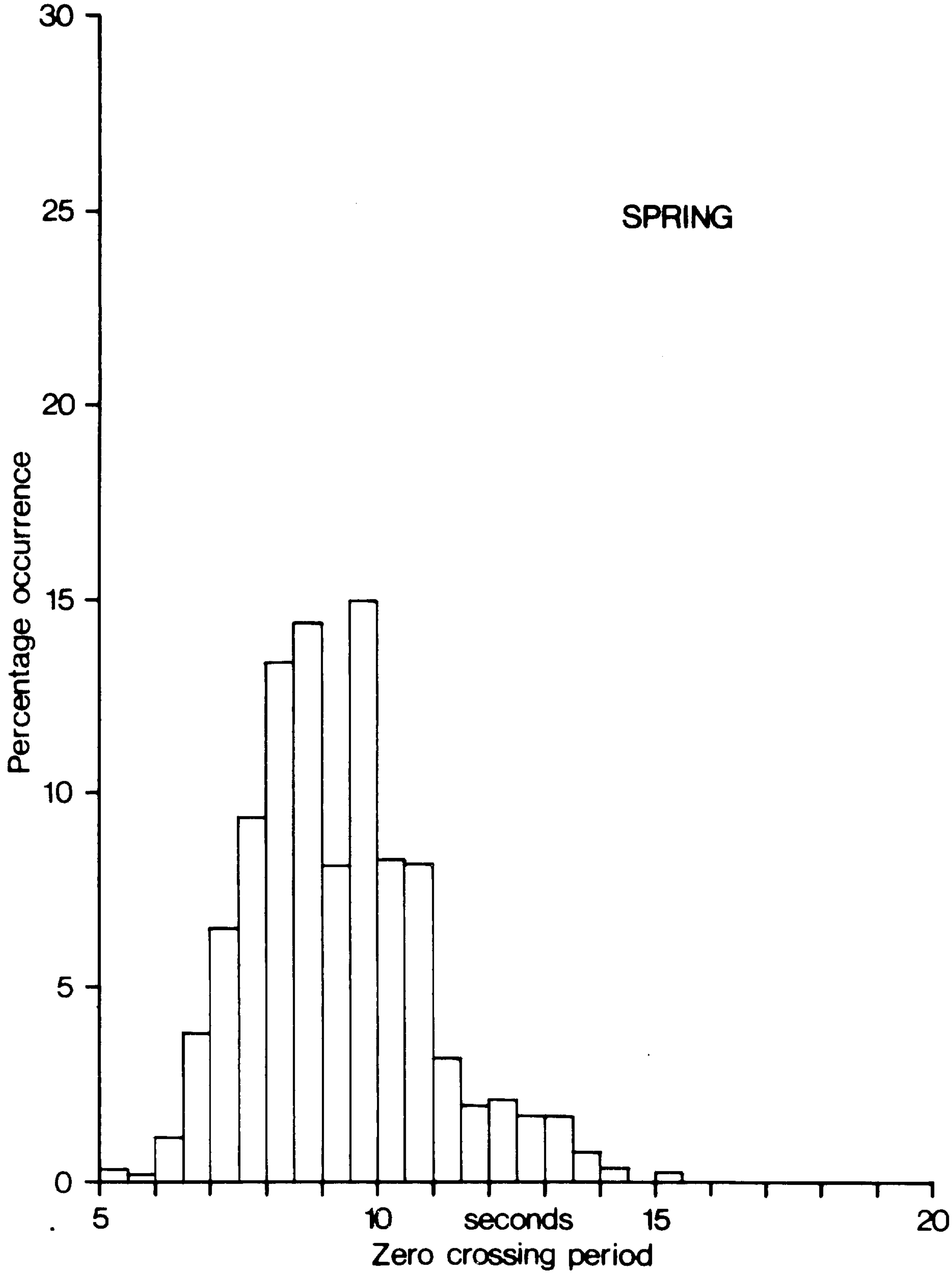


Percentage exceedance of H_s and H_{max}(3hr) - Whole year

Fig. 5



Frequency histogram for zero-crossing period - Spring 77

Fig. 6

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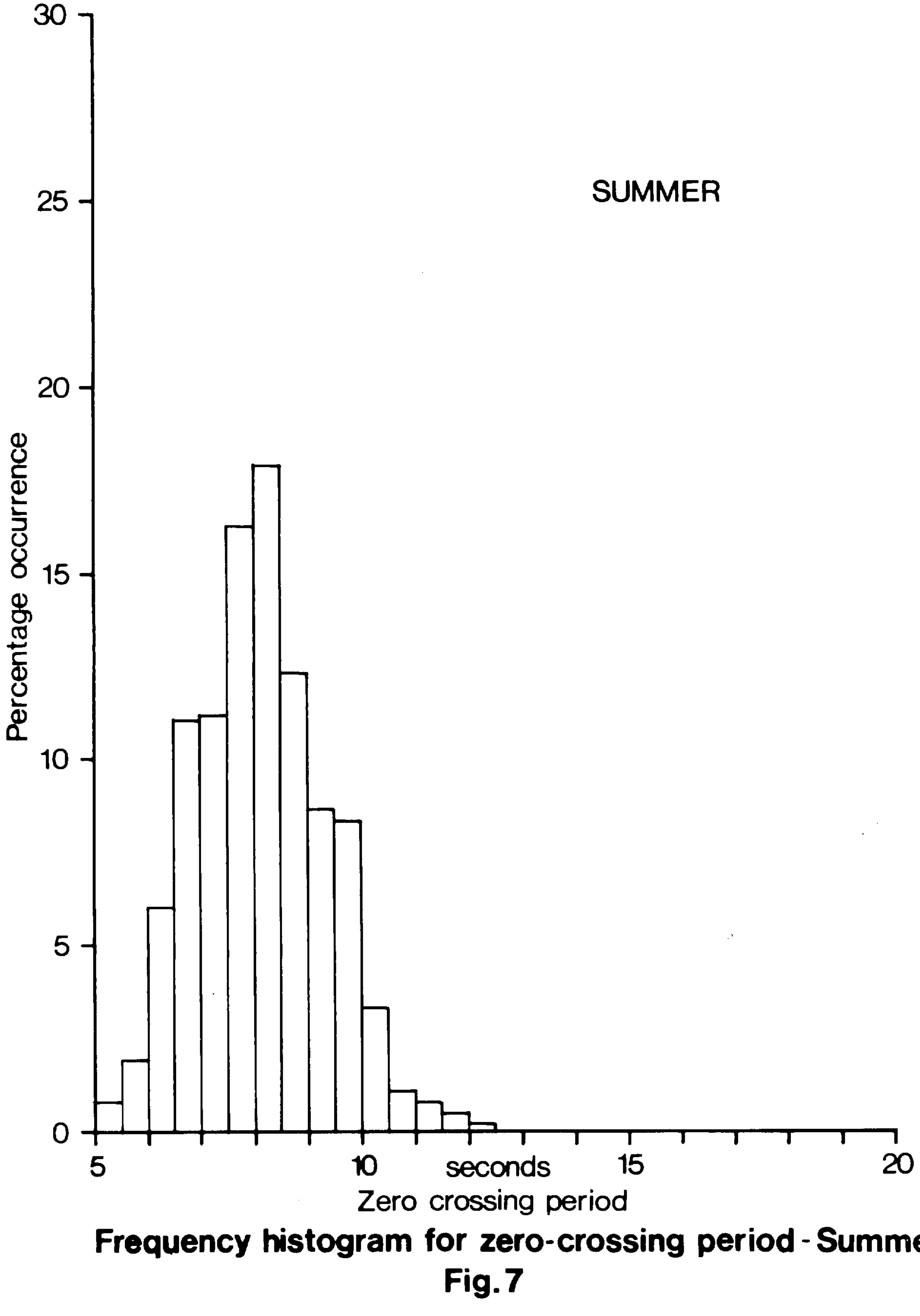

Frequency histogram for zero-crossing period - Summer 77

Fig. 7

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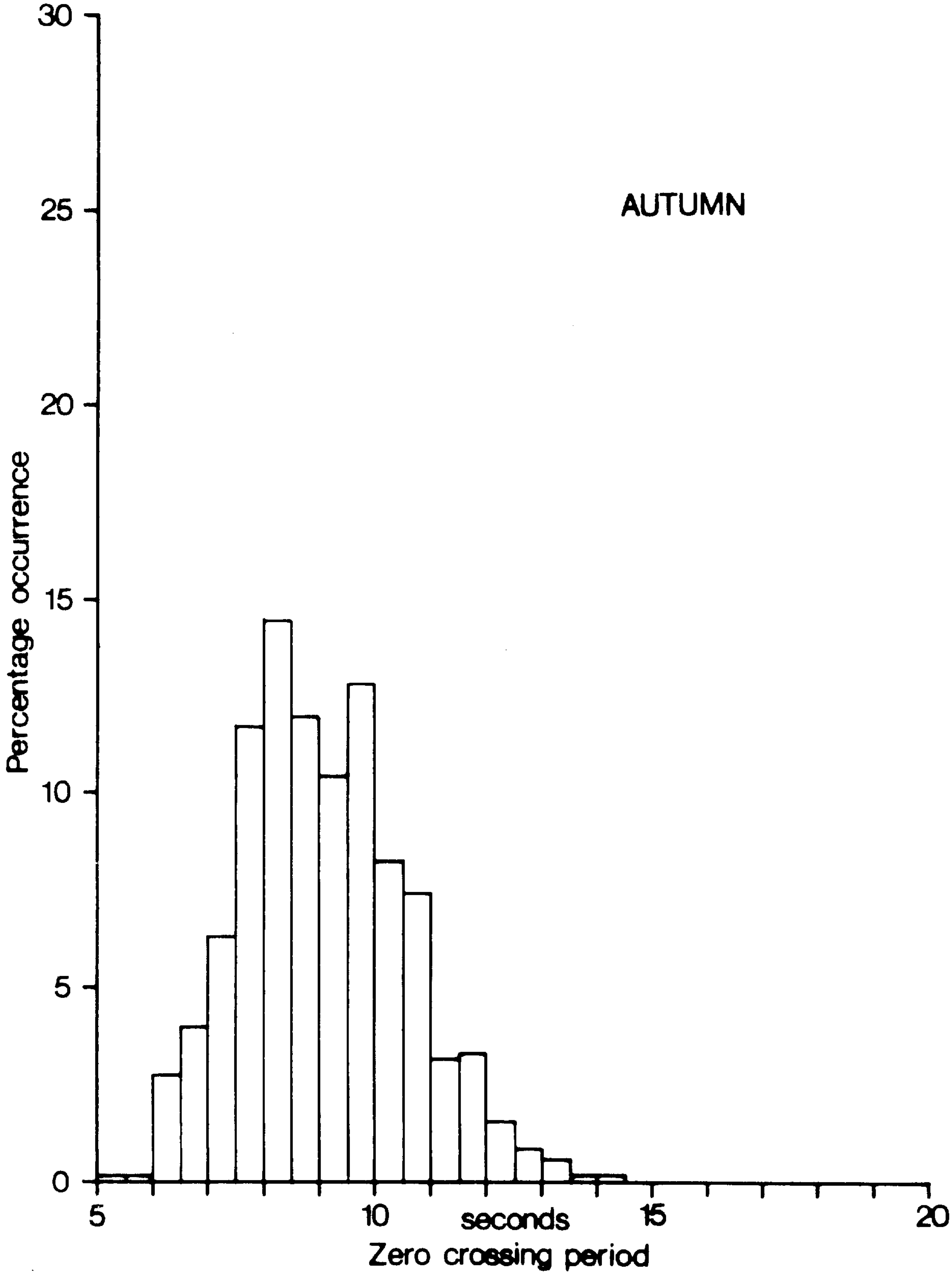

Frequency histogram for zero-crossing period - Autumn 77

Fig. 8

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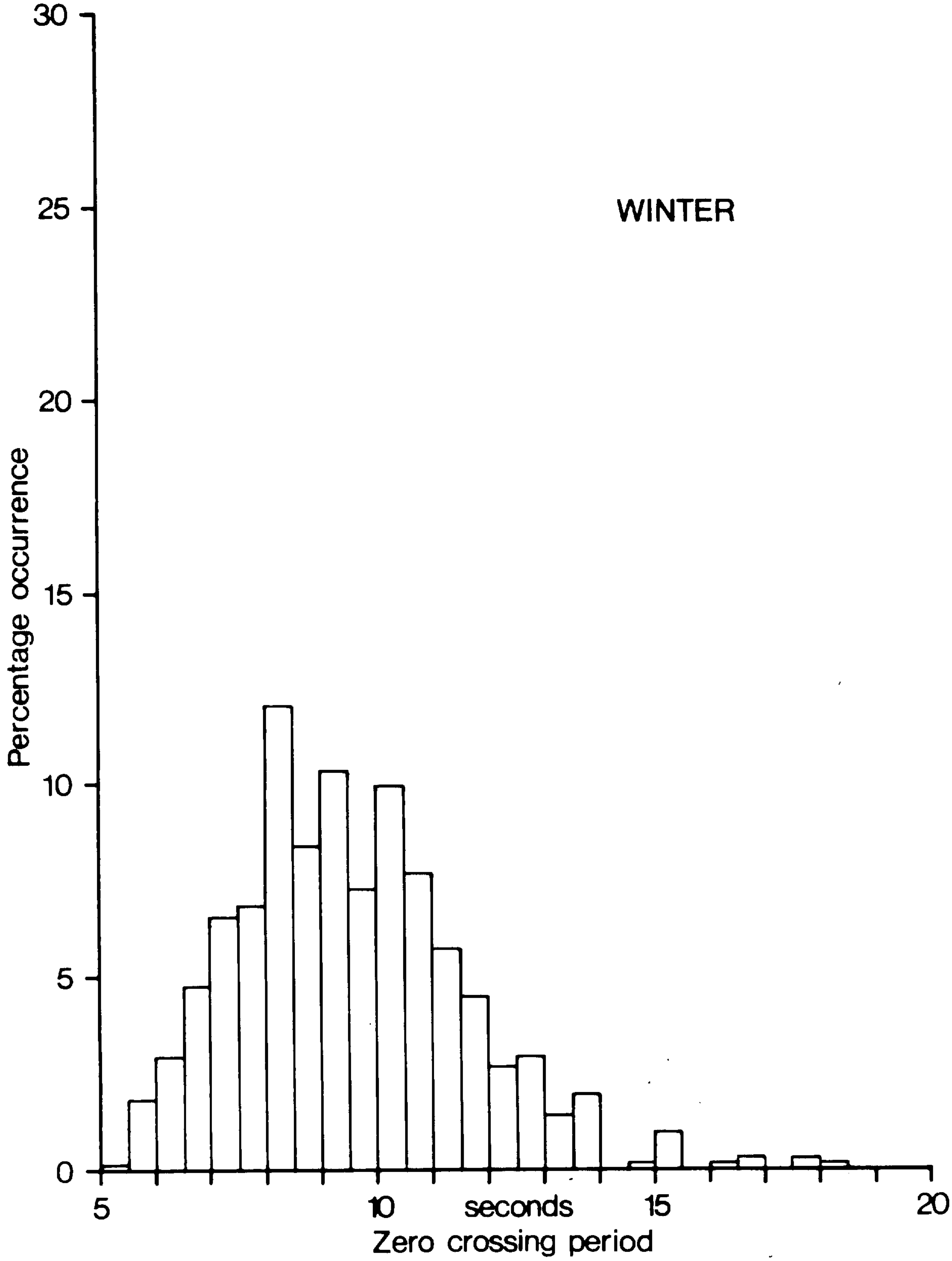

Frequency histogram for zero-crossing period - Winter 75-76

Fig. 9

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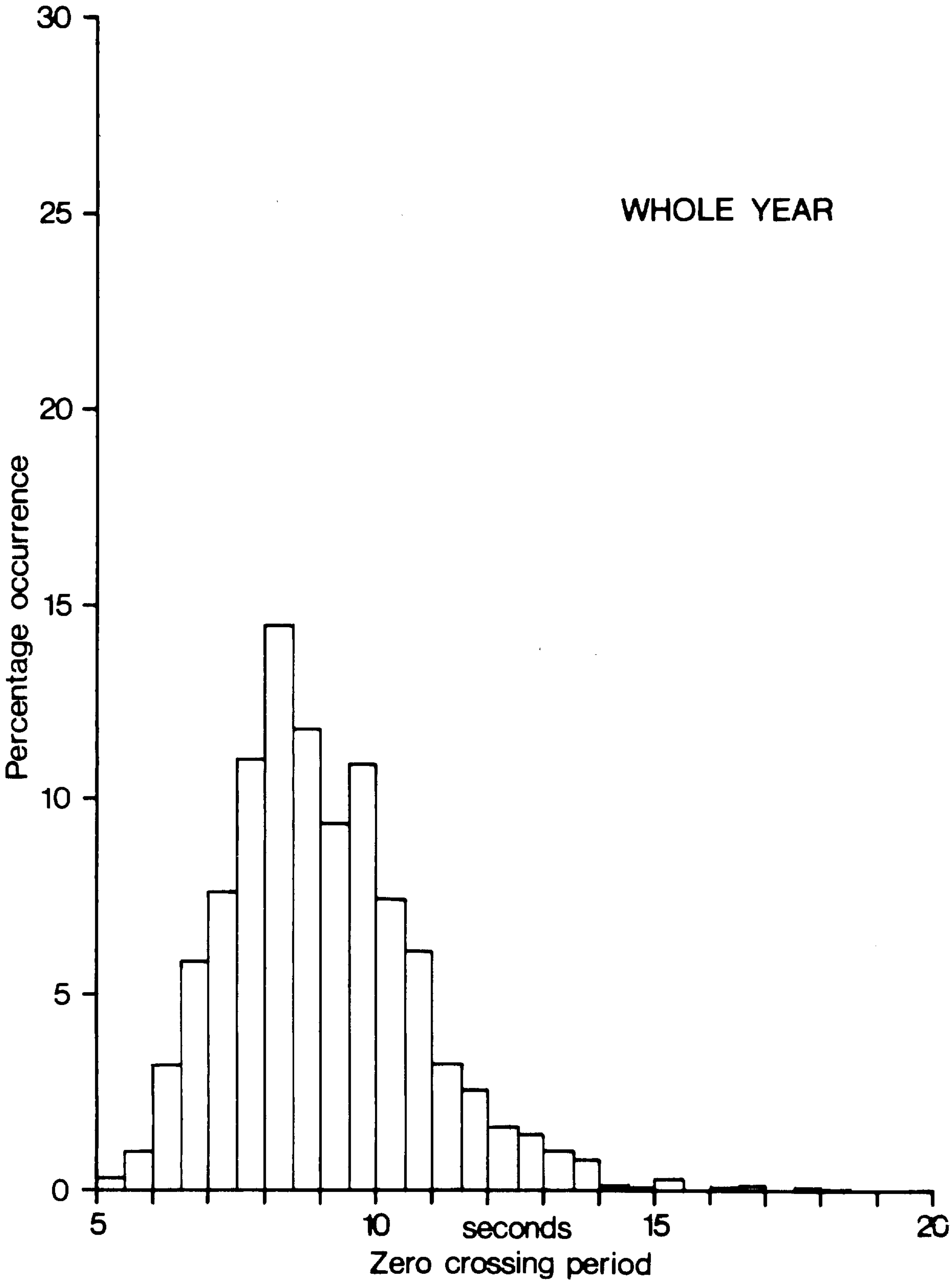

Frequency histogram for zero-crossing period - Whole year
Fig. 10

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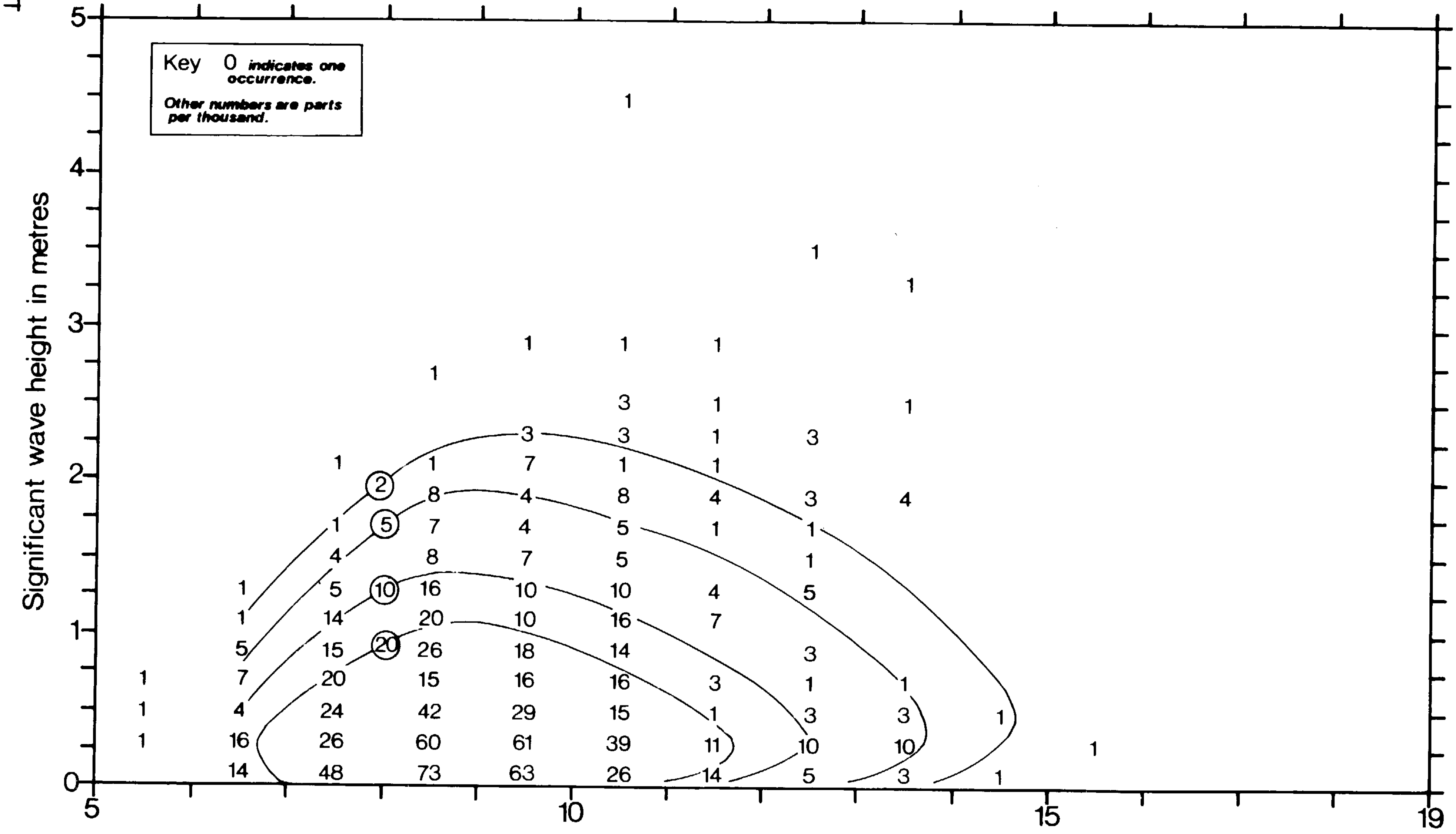
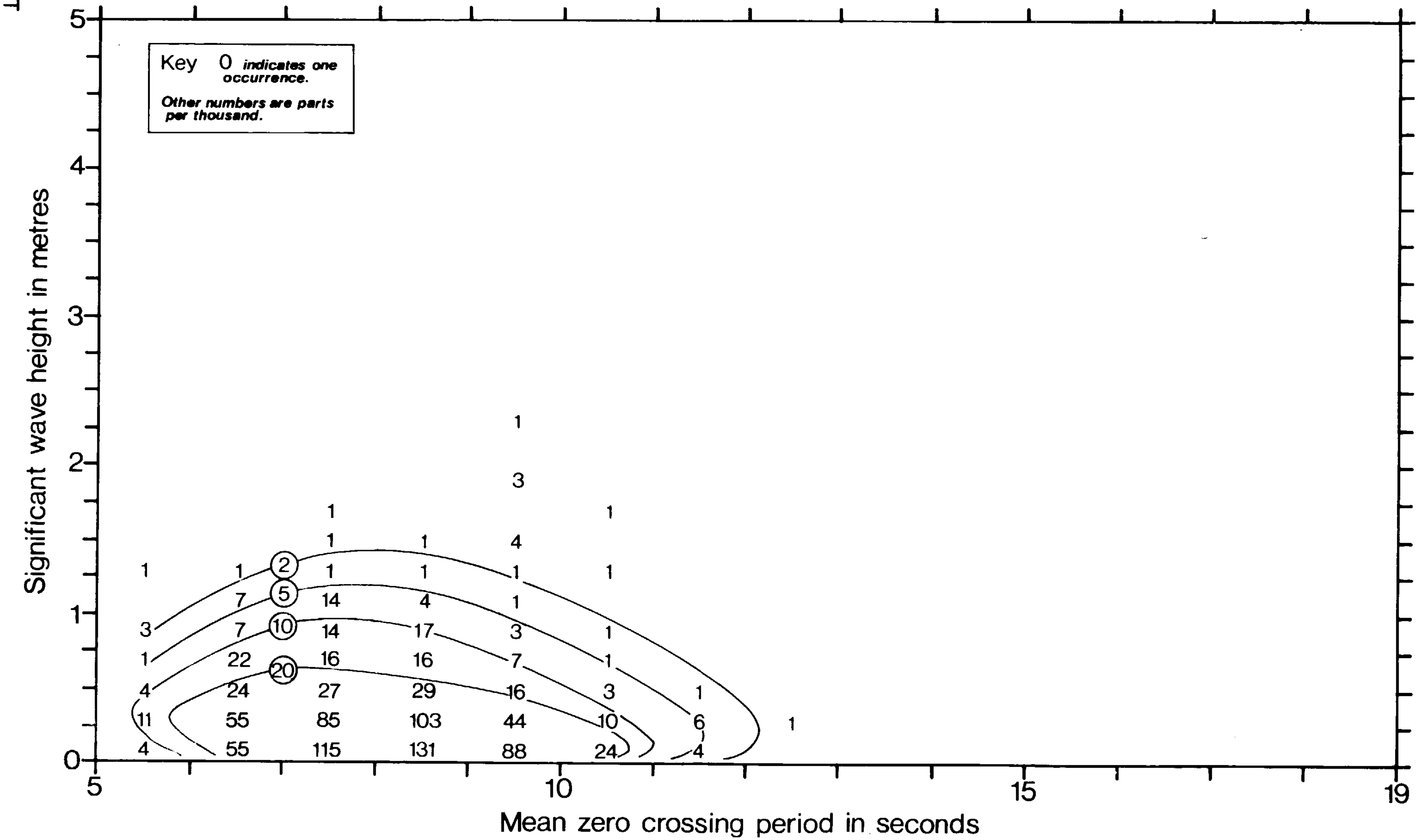


Scatter diagram in parts per thousand - Spring 77

Fig. 11



Scatter diagram in parts per thousand - Summer 77

Fig. 12

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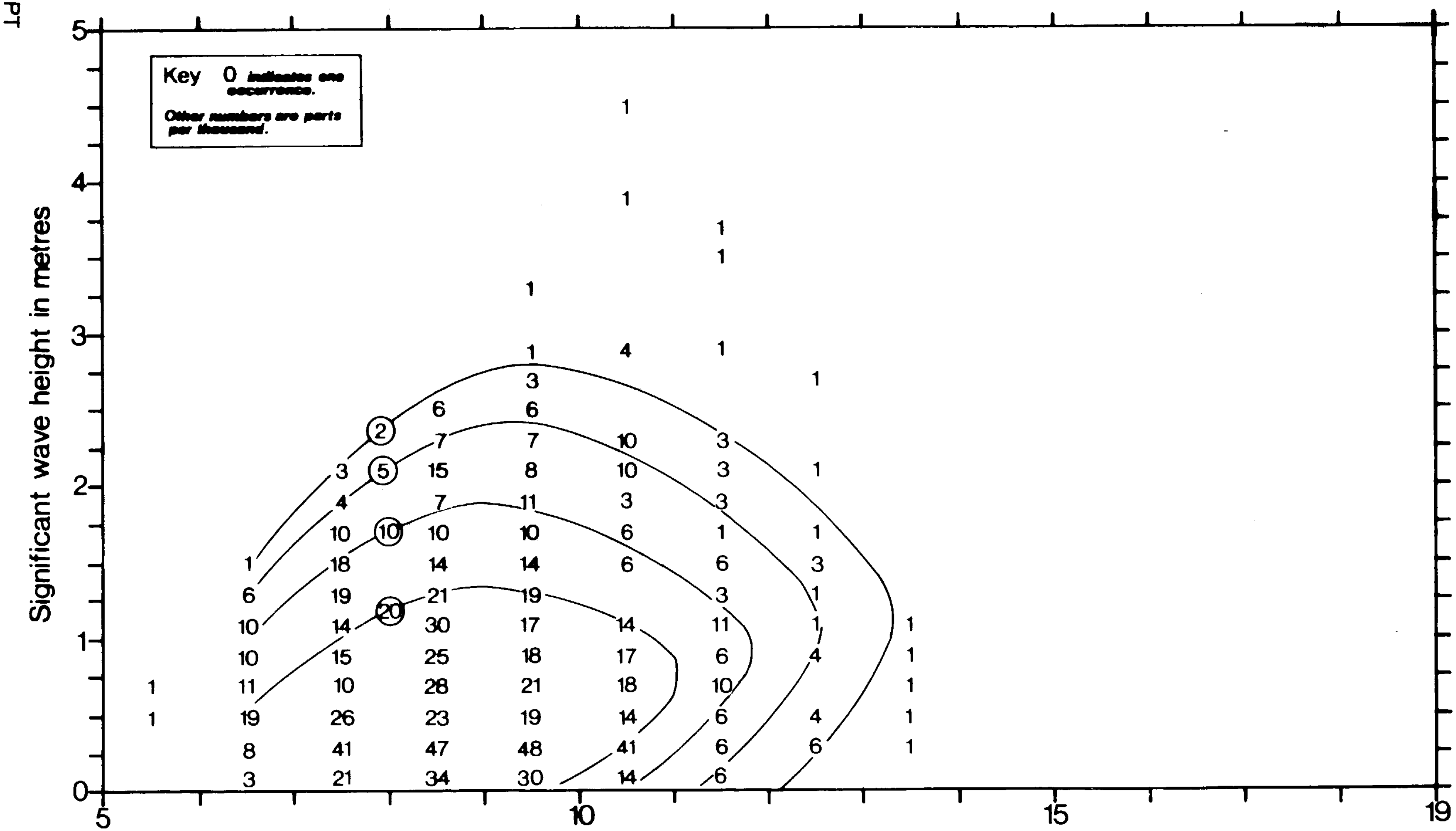

Scatter diagram in parts per thousand - Autumn 77

Fig. 13

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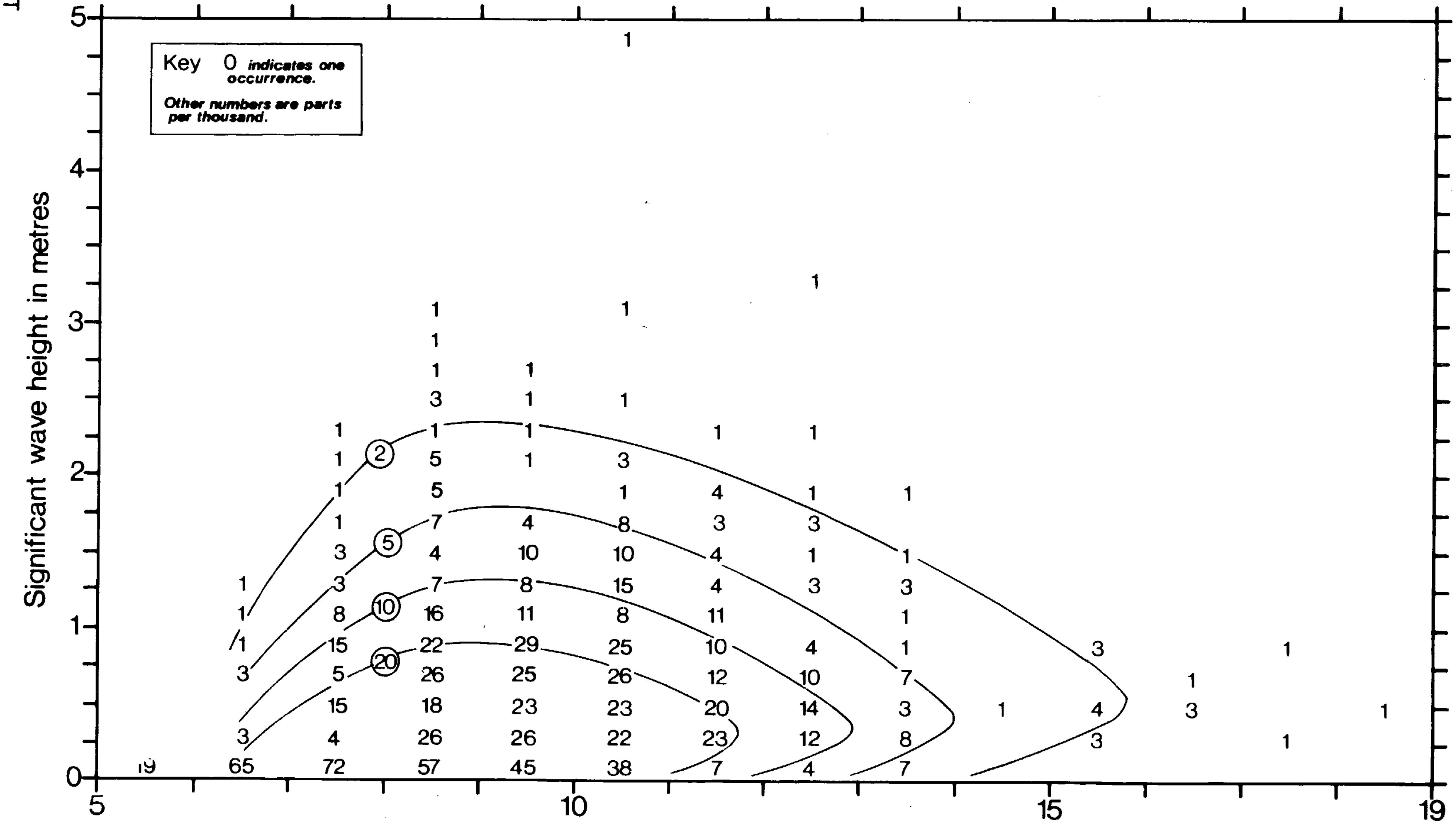

Scatter diagram in parts per thousand - Winter 75-76

Fig. 14

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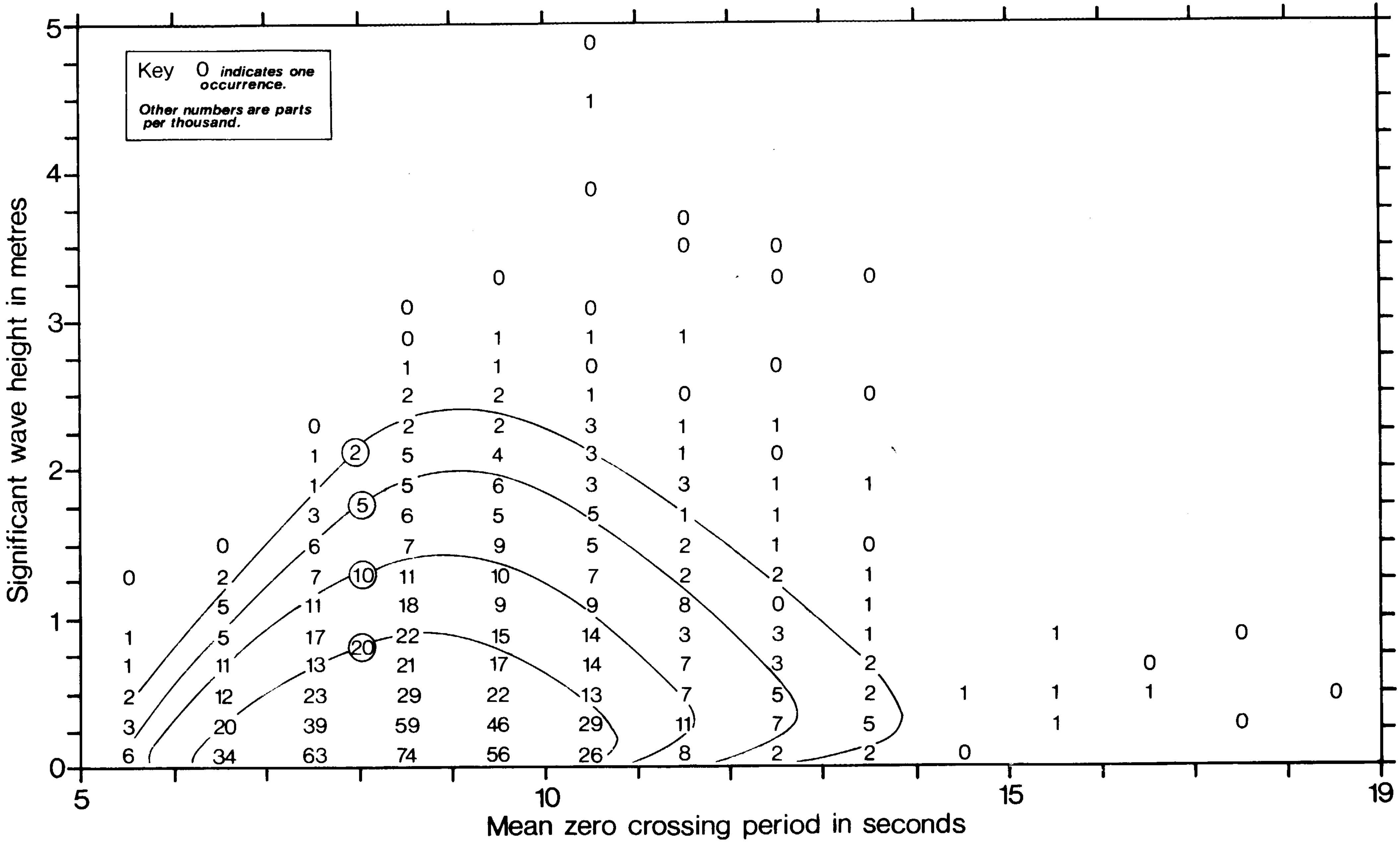
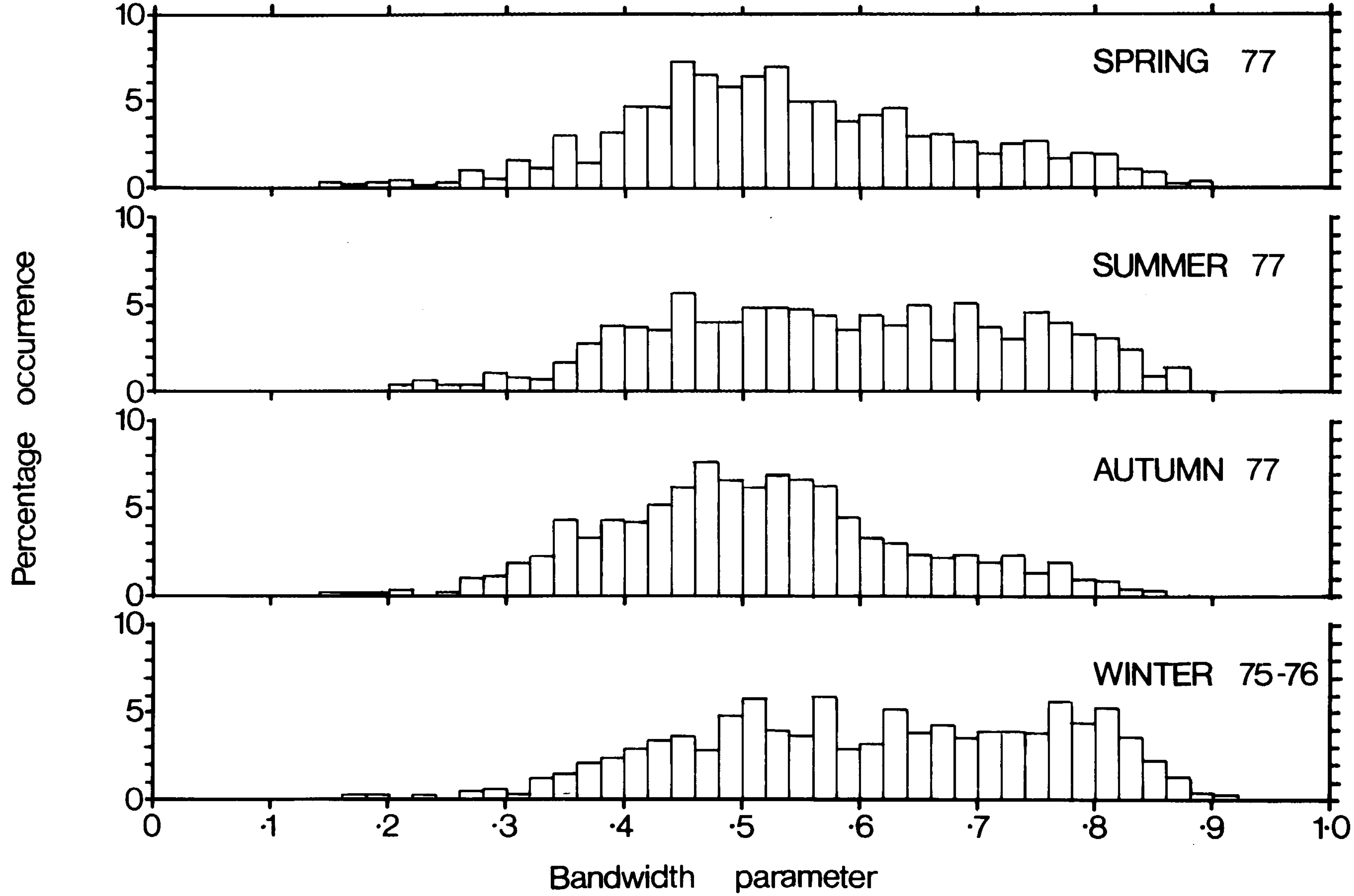


Scatter diagram in parts per thousand - Whole year

Fig.15



Frequency histograms for Bandwidth parameter

Fig. 16

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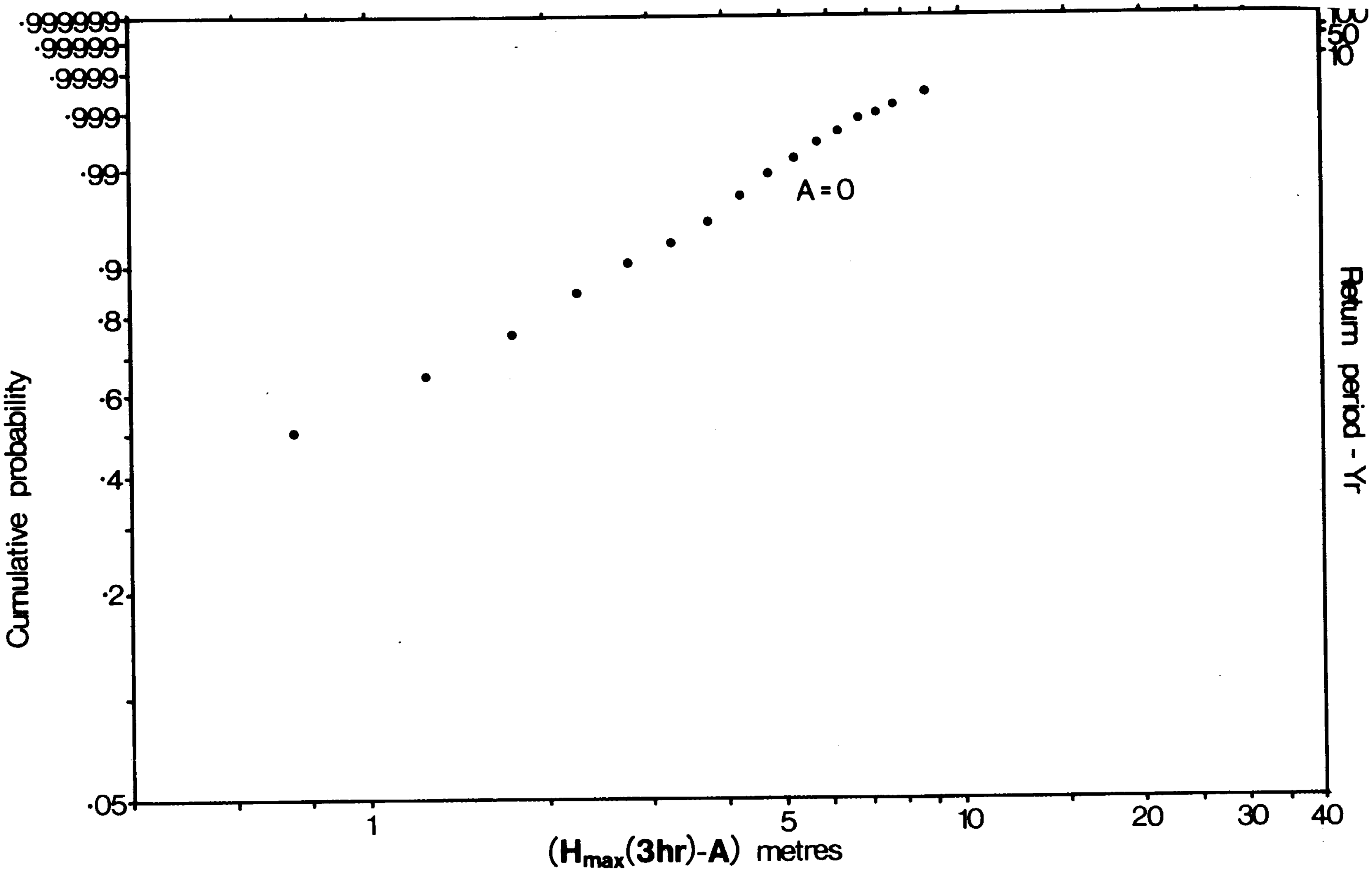

Cumulative distribution of (H_{max}(3hr)-A) Weibull scale

Fig. 17

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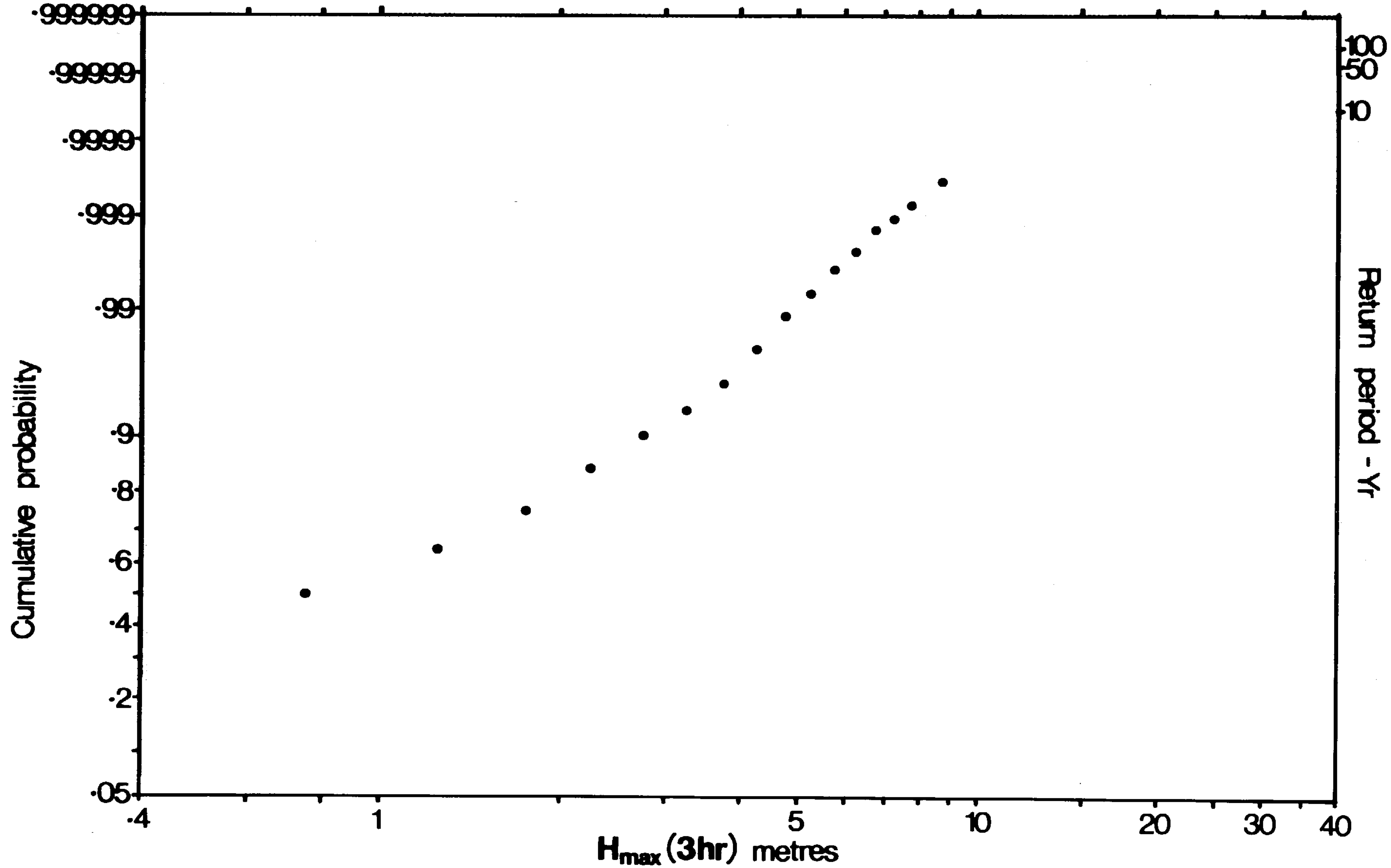
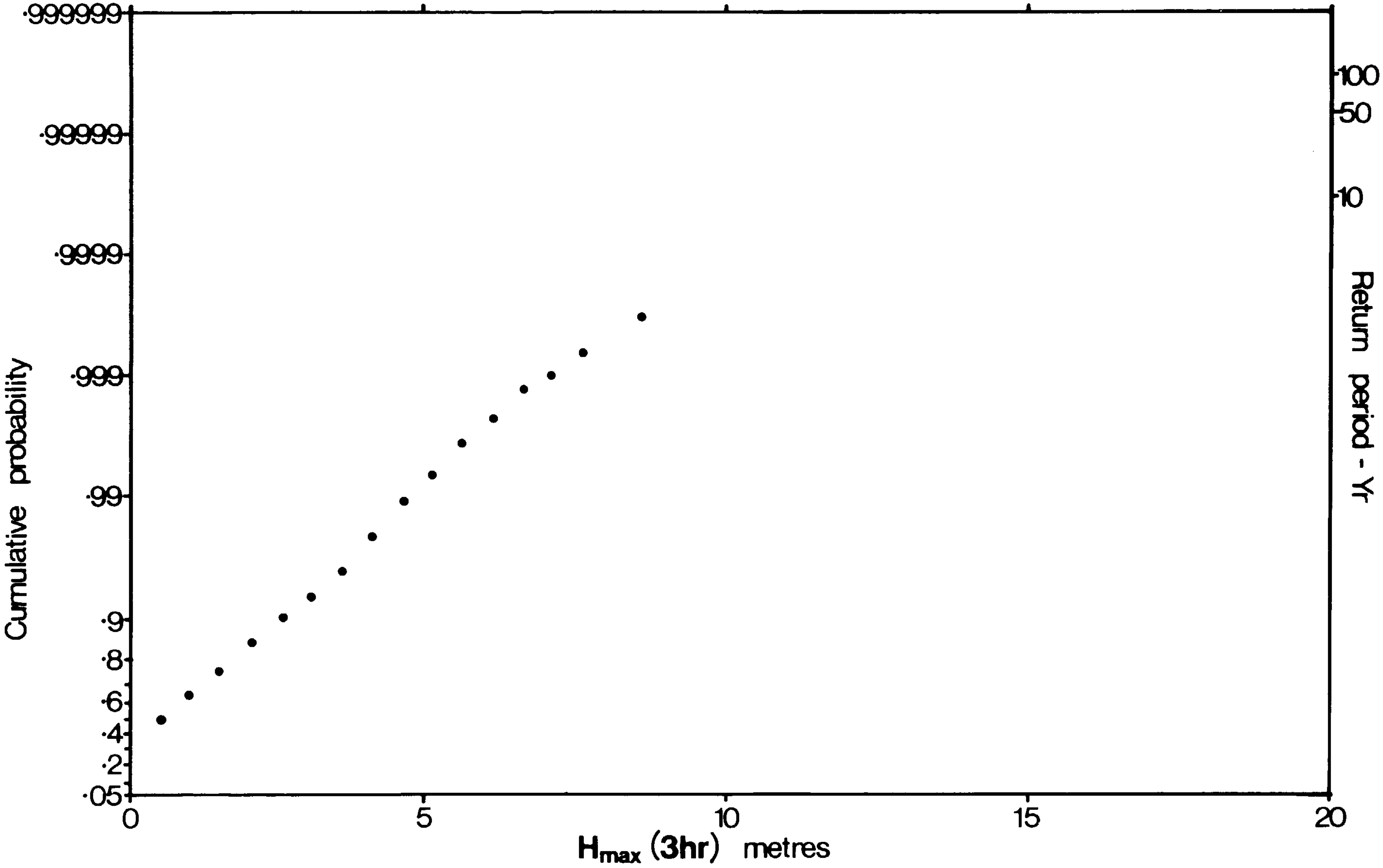


Cumulative distribution of H_{max} (3hr) Log-normal scale

Fig. 18



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

Fig. 19

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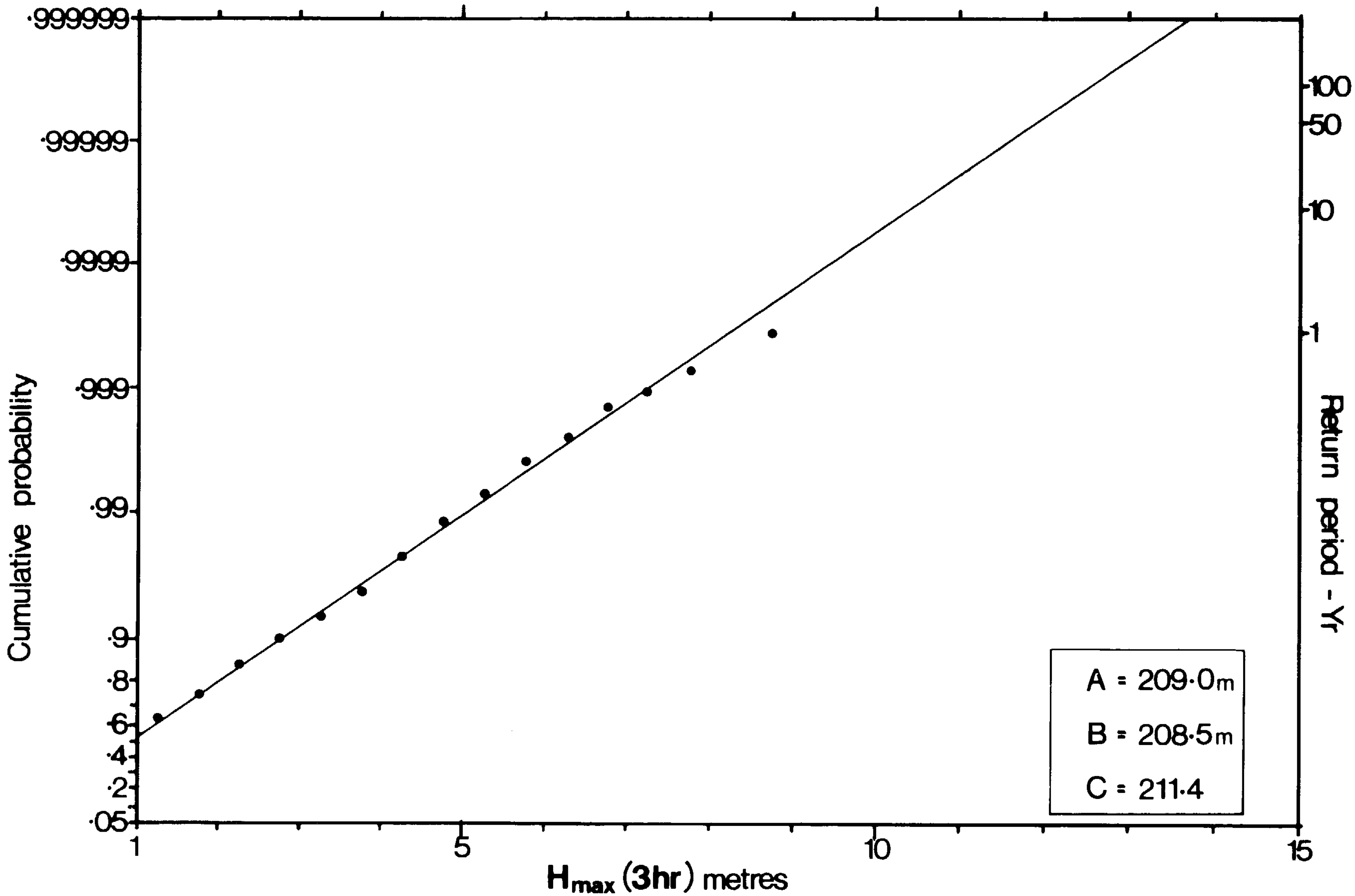

Cumulative distribution of H_{max} (3hr) Gumbel III scale

Fig. 20

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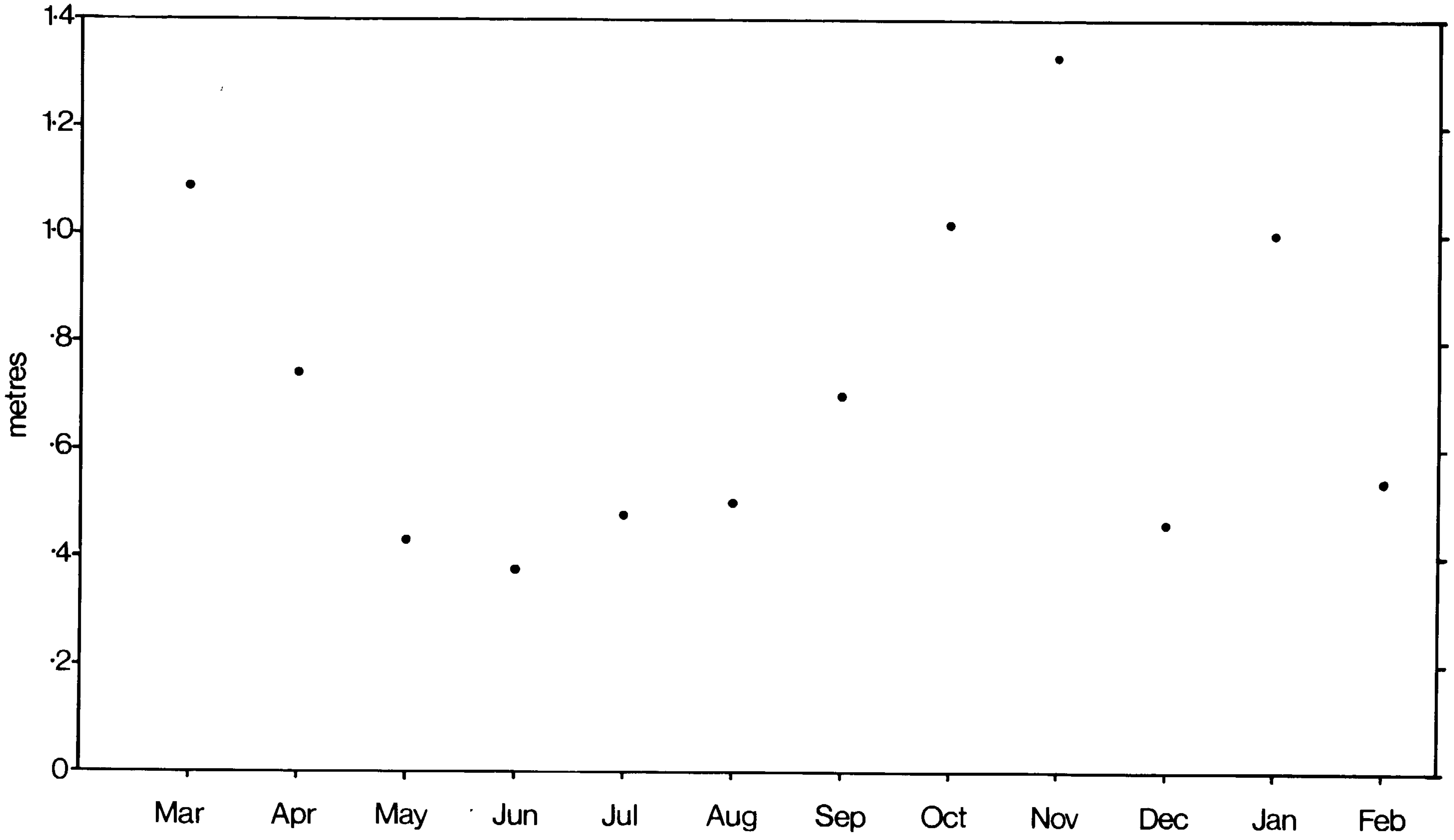

The mean value of significant wave height for each month

Fig. 21

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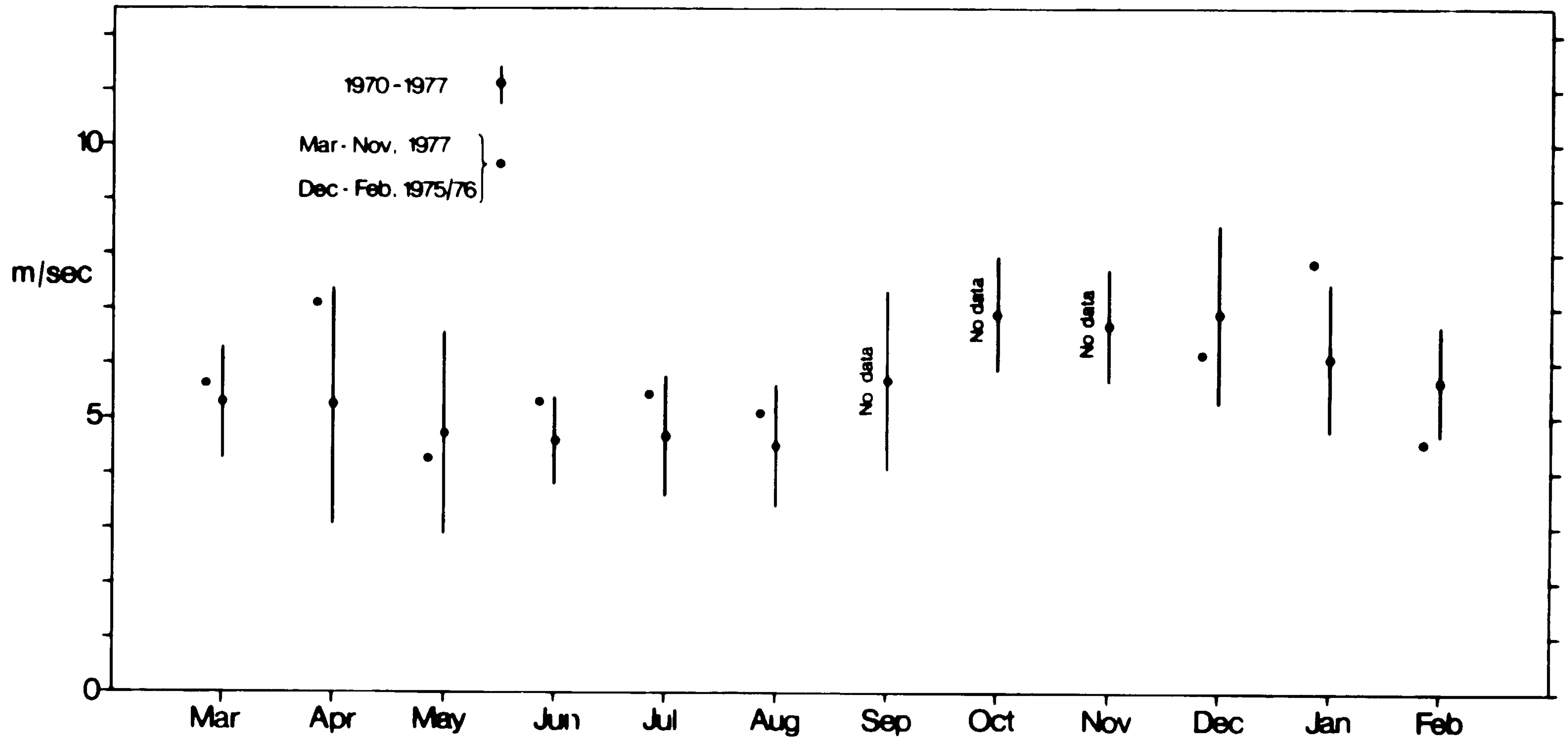

The mean and standard deviation of the average value of wind speed for each month.

Fig. 22

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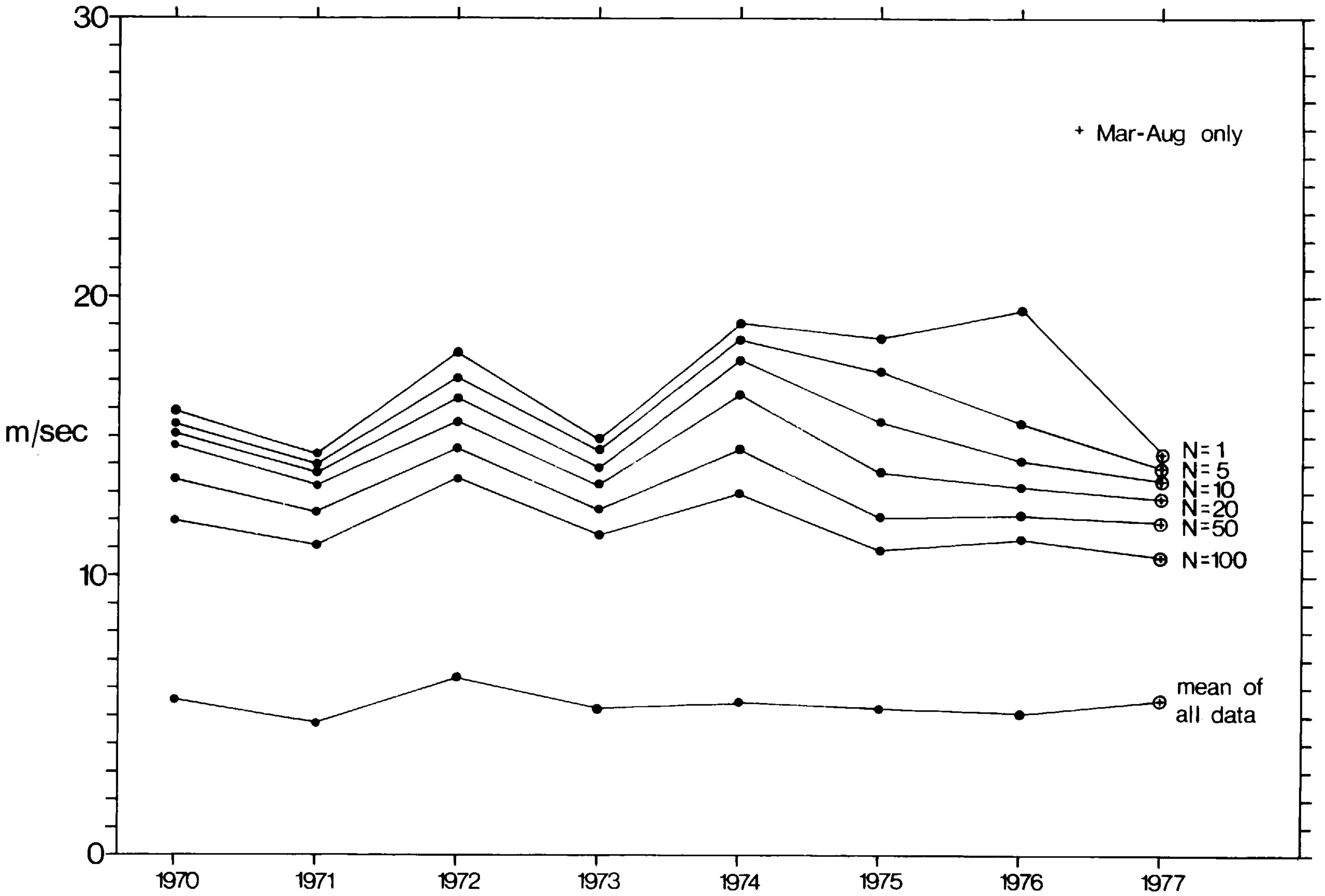

The mean of the largest 'N' values of wind speed (Spring, Summer and Autumn.)

Fig. 23

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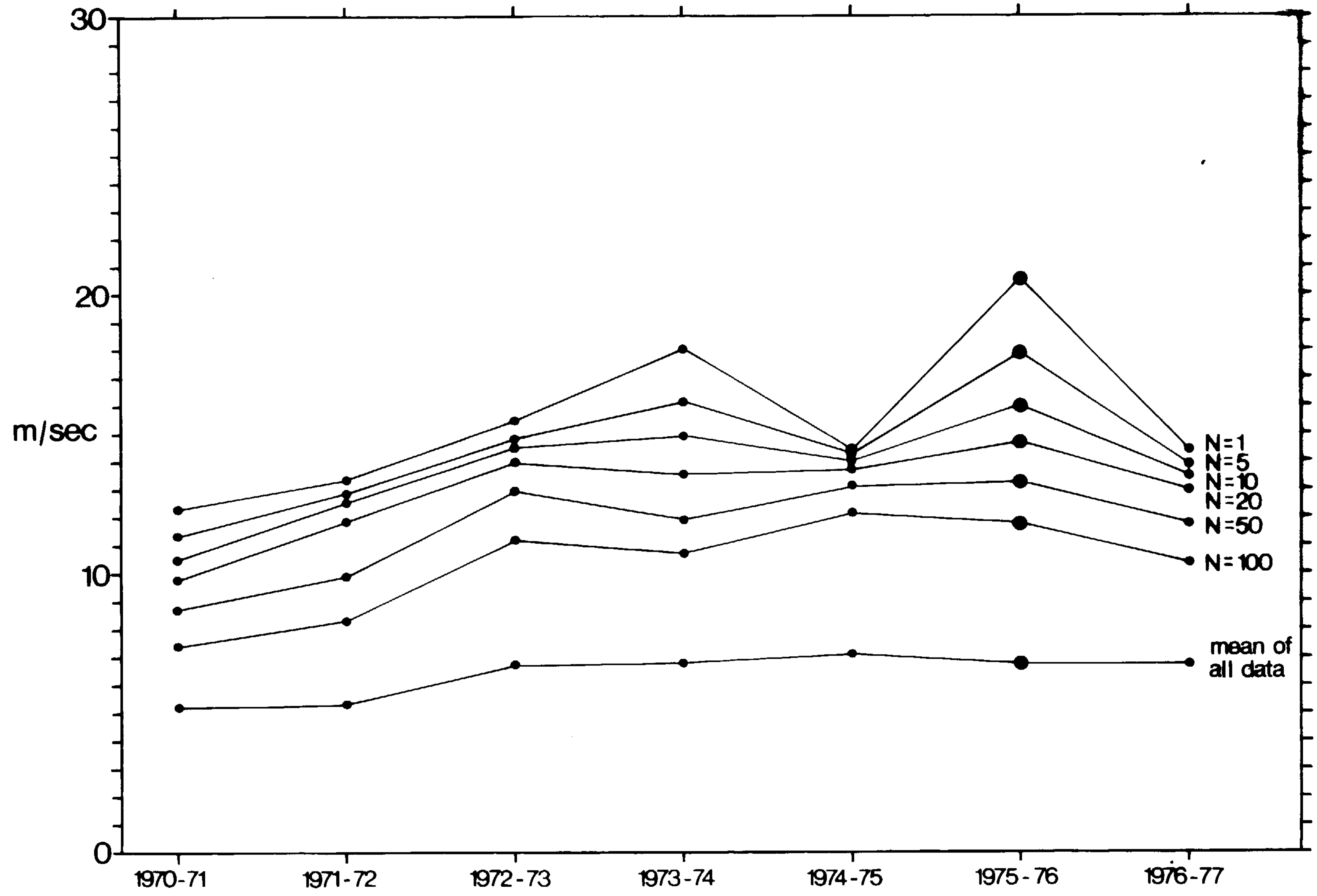

The mean of the largest `N´ values of wind speed (Winter.)

Fig. 24

PT