I.O.S.

WAVES RECORDED AT ALDEBURGH, DUNWICH AND SOUTHWOLD ON THE EAST COAST OF ENGLAND

by
B C H FORTNUM and P J HARDCASTLE

Data for June 1975 to May 1977 at positions
between 52°9′N and 52°20′N, and
between 1°37′E and 1°42′E

Summary Analysis and Interpretation Report

Report No 65

1979

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF
OCEANOGRAPHIC
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Institute of Oceanographic Sciences
Crossway
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INTRODUCTION

The wave data presented in this report have been collected using frequency modulated pressure recorders (Harris et al (1963), Hardcastle (1967)). The pressure units were sited off the Suffolk coast as shown in the two figures at the beginning of this report. Those offshore from Southwold and Dunwich were in water of mean depth of approximately eight metres, while that off Aldeburgh was in water of mean depth of just over six metres. All the pressure units were approximately 150 metres offshore, and each 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 data were gathered for the Sizewell-Dunwich Bank project (B J Lees (1977)) which is supported financially by the Department of the Environment.

The periods for which data have been analysed in this report, together with the percentages of valid data, are as follows:

Site	Period	Valid data (per cent)
Aldeburgh	June 1975 to May 1977	96.0
Dunwich	June 1975 to May 1977	98.8
Southwold	June 1975 to May 1976	98.2
All site-years		97.5

Since the data have been recorded concurrently, analysis has been carried out separately on the three data sets. However, time-series plots of the three data sets show very little difference between data from the three sites; this is not unexpected considering their proximity.

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 formulae are used in this report, as follows.

1. Weibull

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

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

2. Log-Normal

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

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

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

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

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

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

(see below*)

where $\bar{x}$ is the mean of the observations, and n is the number of observations.

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

METHOD OF ANALYSIS

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

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)).

DISCUSSION OF RESULTS

The division of the year into four three-month seasons was made on the basis of Figure 83. By examining the magnitudes of the mean values of Hs for each month the most obvious grouping of the months into seasons is:

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

Figures 1 to 25. 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 1 we see that during summer 1975 at the Aldeburgh site, the significant wave height exceeded 0.6 metres for 11 per cent of the time.

Figures 26 to 50. Frequency histograms for Tz.

In general the higher wave periods were more frequent in the winter season than in other seasons, and the highest wave period of almost fifteen seconds occurred in the winter of 1975–76 at the Dunwich site. 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 four 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 51 to 55. 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. However, both significant wave height and zero-crossing period are average quantities and the maximum wave steepness found on figures such as these is usually less steep than the theoretical figure above. (Steepness would be defined for this purpose as $\frac{2\pi H_s}{g T_z^2}$.) Partly because of the short period cut-off at about four seconds there are too little data to allow limiting steepness lines to be drawn on the figures.

Figures 56 to 60. Frequency histograms for ε.

It is seen from the figures that all values of ε lie between 0.12 and 0.88. The lower limit corresponds very nearly with the theoretical minimum of 0.115. (This lower, non-zero, limit is determined by the low cut-off wave period. For a four second cut-off period, Nz for a ten-minute record is 150; therefore the minimum non-zero value of ε is obtained when Nc is 151, that is 0.115.)

Figures 61 to 70. 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 nine hours with Hs smaller than two metres to complete a particular job at the Dunwich site. It may be seen from Figures 63 and 64 that there were eleven occasions during 1975/76 and twelve occasions during 1976/77 when the job could have been done.

Strictly, persistence diagrams require series of data with no gaps whatsoever. Although the data sets analysed in this report do contain gaps, persistence diagrams are presented from the data as the data returns are comparatively high. (Persistence information for Dunwich and Southwold, with data returns of 98.8 and 98.2 per cent respectively, are likely to be slightly closer to the truth than Aldeburgh with a 96.0 per cent data return.) 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 71 to 82. Cumulative distribution of Hmax(3hr).

Three cumulative distributions of Hmax(3hr) are plotted, each containing all the data available from one of the three sites. Each cumulative distribution 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).)

Each of the twelve plots shows a tendency for the distribution to 'turn upwards', implying that there is a limiting height to the waves encountered at these locations. Such an upper limit certainly exists for the height of waves in shallow water and it is of the same order of magnitude as the water depth; at high water this is approximately nine metres at the Aldeburgh site and eleven metres at the Dunwich and Southwold sites. Therefore if the data follow any extreme-value distribution well, it is most likely to be a distribution with an upper bound; of the four distributions shown, only the Gumbel III has an upper bound (although, for completeness, three other distributions are also shown for each site). Visually, the fit of data to the Gumbel III distribution is not particularly good for any of the sites, although the heights of waves with a 50-year return period may tentatively be estimated from the plots as follows: Aldeburgh 7.3 metres (Figure 74); Dunwich 6.2 metres (Figure 78); and Southwold 6.8 metres (Figure 82). Perhaps the most significant aspect of these plots is that the upper bounds are in reasonable agreement with the maximum water depths (and hence the approximate limiting wave height). For Aldeburgh, the upper bound A is 11.1 metres and the water depth is about nine metres; for Dunwich the figures are 7.7 metres and about eleven metres; and for Southwold the figures are 10.2 metres and about eleven metres.

Figure 83. Month-to-month variability of significant wave height.
The average value of significant wave height for each of the sixty site-months of data, is calculated and for each of the months from June to May, the mean and standard deviation of the five averages are plotted. The justification for treating all the sites together here is the fact that the data are very similar from one site to the next (this fact is shown very clearly when the significant wave heights are plotted as time series for each site and compared).

The division of the year into four three-monthly seasons was made on the basis of this figure. Some months have relatively large standard deviations: for instance, May has a standard deviation of approximately 0.19 metres (50 per cent of the mean), and June has a standard deviation of approximately 0.08 metres (30 per cent of the mean). These relatively large values are due to large variations in wave conditions between 1975 - 1976, and 1976 - 1977 for those months; the variations between sites are insignificant for this purpose.

WIND DATA

The nearest wind data station to the three East Coast wave recording sites is Gorleston (52°35'N, 01°43'E) where wind data are available for fifteen years from 1962/63 to 1976/77 (a 'year' refers to twelve consecutive months from June to May). Only winds which have approached the site from the sea should be considered, those approaching from East Anglia (ie from directions 200° to

360°) being expected to affect wave conditions less due to limitations of fetch.

In fact in this analysis winds from directions 200° to 300° inclusive have been excluded. Although this different sector of wind directions has been used throughout the following comparisons of wind speeds, it is expected that the conclusions drawn about the variation of wind speeds from month to month and from year to year will not be significantly affected. The data used are mean hourly wind speeds.

Figure 84. 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 both for the years covered by this report and for the full fifteen years are shown. For every calendar month, with the exception of March, the mean wind speed for each month for the years 1975/76 to 1976/77 is less than the corresponding mean wind speed calculated for the years 1962/63 to 1976/77. For March the difference of 0.1 metre per second is of no significance.

Figure 85. 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 the maximum wind speeds recorded during 1975/76 and 1976/77 lie approximately in the top one-third of the range of maximum wind speeds recorded during the fifteen years from 1962/63 to 1976/77. It may also be seen that the means of all the data for the years 1975/76 to 1976/77 lie in the lowest part of the range of means for the years 1962/63 to 1976/77. Relating the wind conditions very simply to the wave conditions, this suggests that wave heights for the two-year period covered by this report are generally fairly representative for the location, but that the greatest wave heights are perhaps higher than might be expected in a typical year.

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REFERENCES

DRAPER, L. 1957. Attenuation of sea waves with depth. La Houille Blanche 12, 926 - 931.

FISHER, R.A. and TIPPETT, L.H.C. 1928. Limiting forms of frequency distribution of the largest or smallest member of a sample. Proceedings of the Cambridge Philosophical Society 24, 180 - 190.

GODA, Y. 1970. Numerical experiments on wave statistics with spectral simulation. Report of the Port and Harbour Research Institute 9, No.3, 3 - 57.

GODA, Y. 1974. Estimation of wave statistics from spectral information. Proceedings of the International Symposium on Ocean Wave Measurement and Analysis, 320 - 337.

GUMBEL, E.J. 1958. Statistics of Extremes. New York: Columbia University Press. 371 pp.

HARDCASTLE, P.J. 1967. Transistorised sea wave and tide recorder. Instrument Practice 21, 839 - 840.

HARDCASTLE, P.J. 1978. Sea wave recording system using magnetic tape cassettes. Institute of Oceanographic Sciences, Report No. 61.

HARRIS, M.J. and TUCKER, M.J. 1963. A pressure recorder for measuring sea waves. Instrument Practice 17, 1055 - 1059.

LEES, B.J. 1977. Sizewell-Dunwich Bank Project: Progress Report for the period Jan 1975 - Dec 1976. Institute of Oceanographic Sciences, Report No. 38.

LONGUET-HIGGINS, M.S. 1952. On the statistical distribution of the heights of sea waves. Journal of Marine Research 11, No.3, 245-266.

TANN, H.M. 1976. The estimation of wave parameters for the design of offshore structures. Institute of Oceanographic Sciences, Report No. 23.

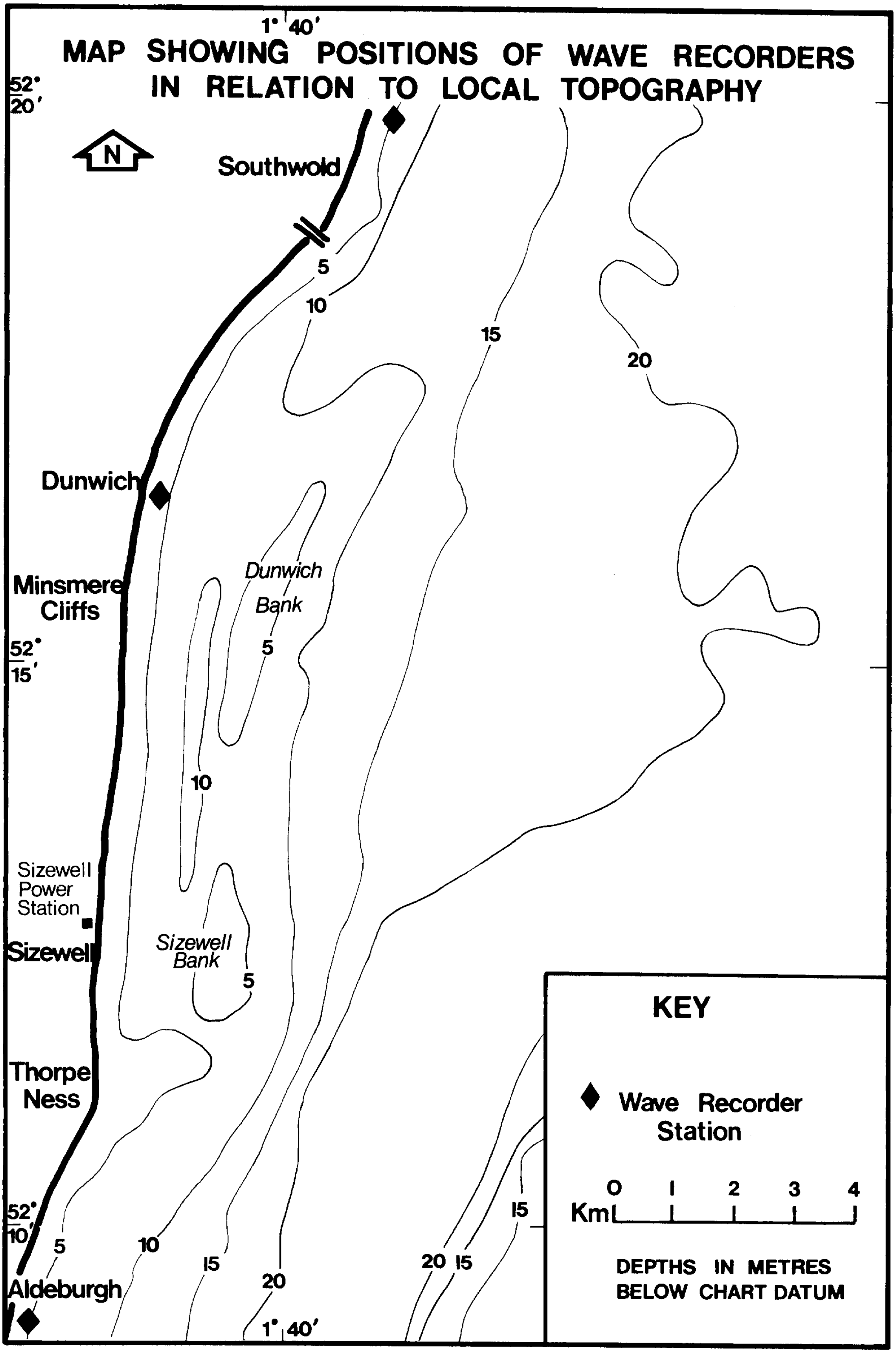
APPENDIX

The pressure units were calibrated in a pressure tank against a standard pressure transducer before installation. This calibration was to an accuracy of better than one per cent. After installation the calibrations were checked at yearly intervals, 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. Difficulties arise in measuring the tide height changes with low percentage errors at these sites as the maximum tidal range is less than three metres. It was estimated that these check calibrations had, at the best, accuracies of the order of ± 5 per cent. The original calibration of the pressure units agreed with the checks to within this accuracy.

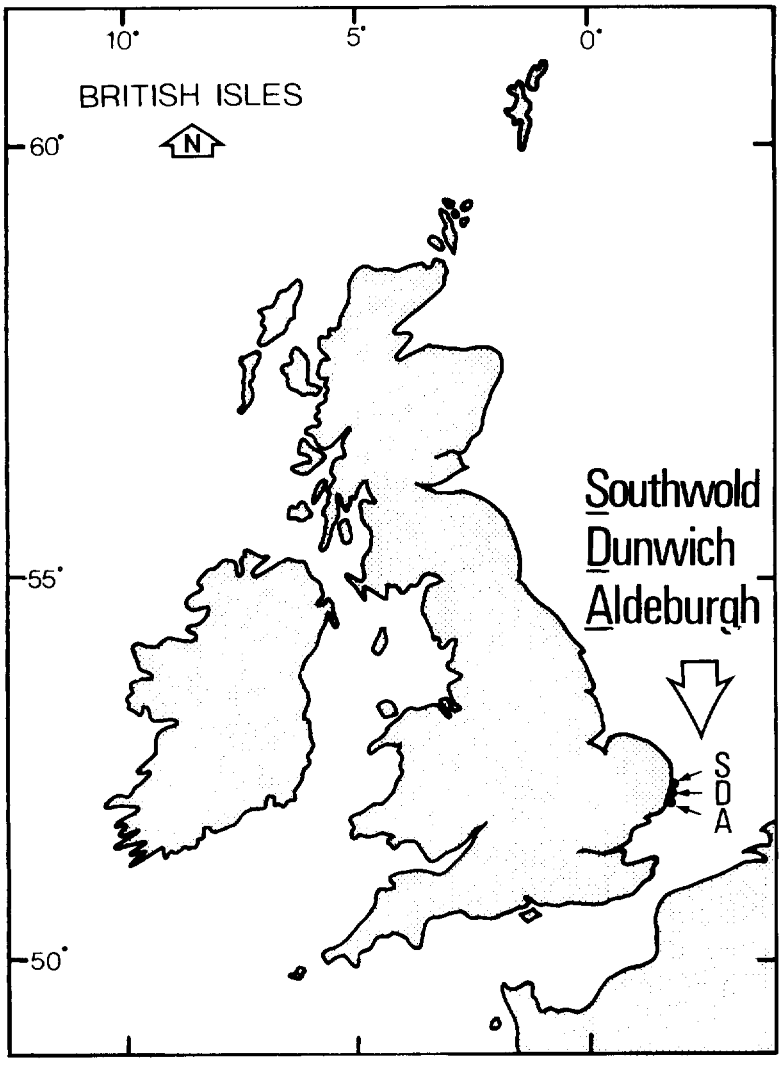
The data logging system used is accurate to within ± 1 per cent for the measurement of the significant wave height.

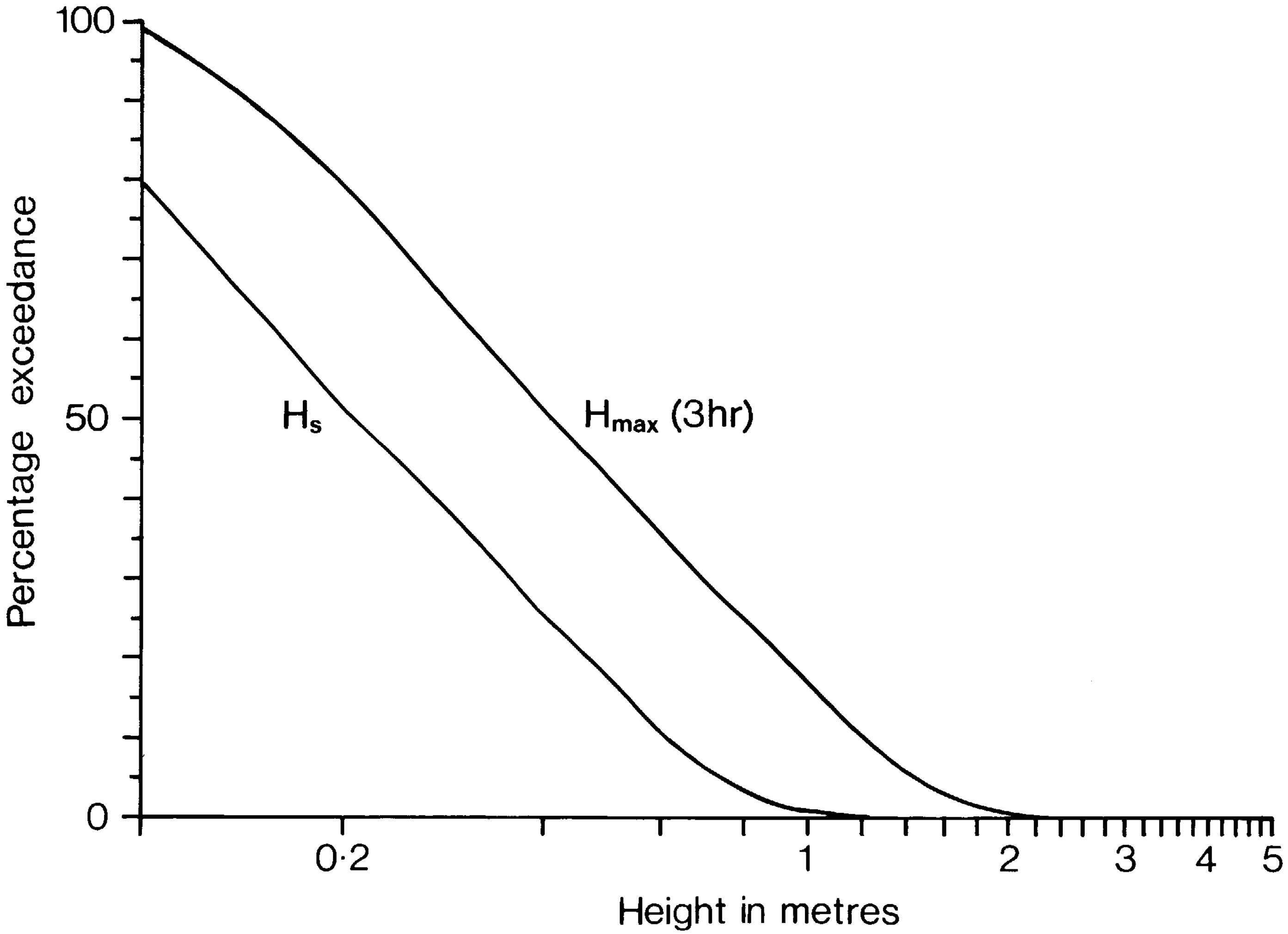
The major inaccuracy in the data lies in the conversion of bottom pressure to wave height. First, a correction corresponding to the zero up-crossing period has been used, whereas ideally the correction should have been applied to the individual frequencies in a wave spectrum, the corrected spectrum then being used to calculate Hs and Hmax (3hr). 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.

MAP SHOWING POSITIONS OF WAVE RECORDERS IN RELATION TO LOCAL TOPOGRAPHY



Map to show location of East Coast Wave Recorders

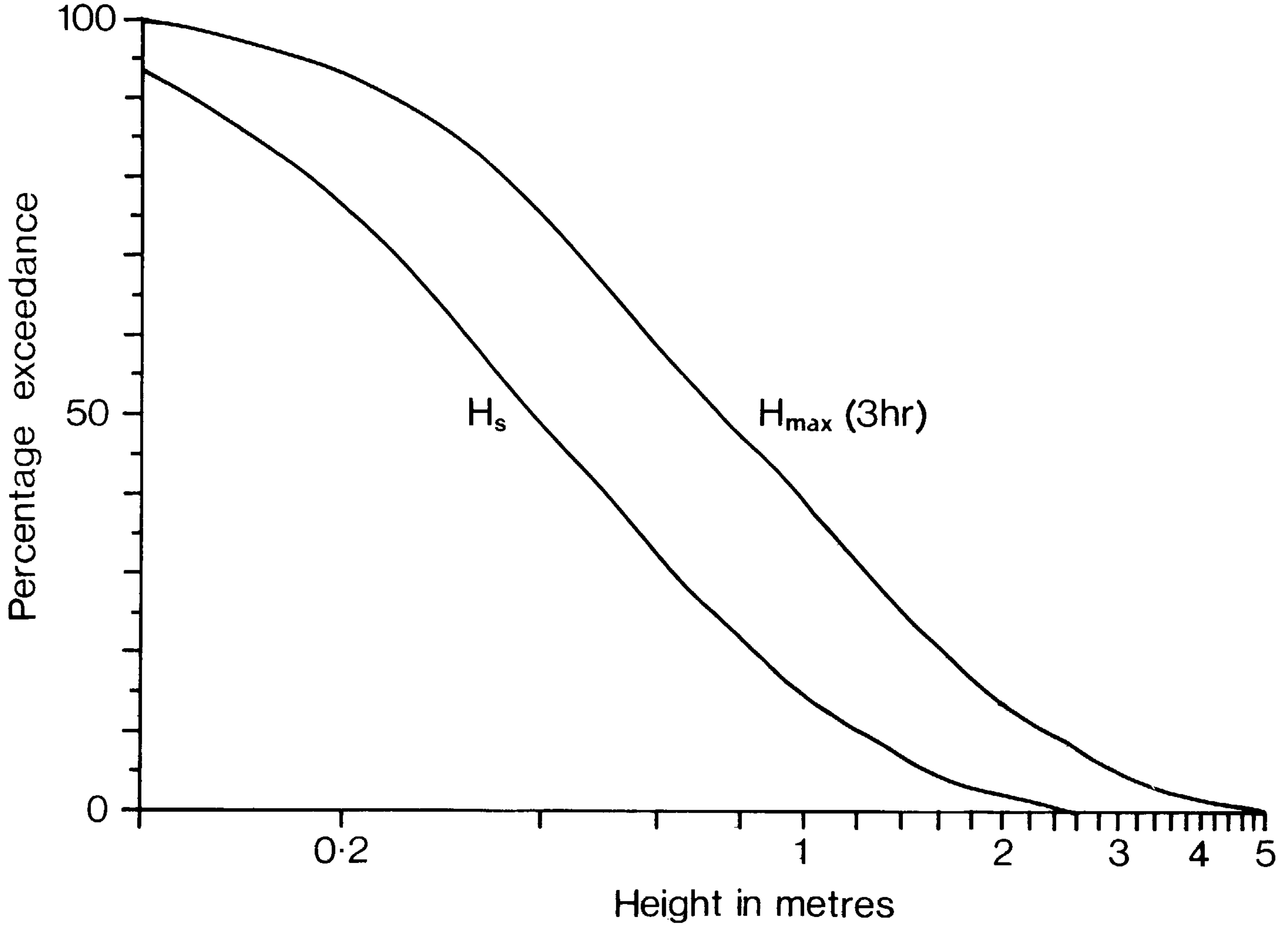




Percentage exceedance of H_s and H_{max}(3hr) – Summer '75 Aldeburgh

Fig. 1

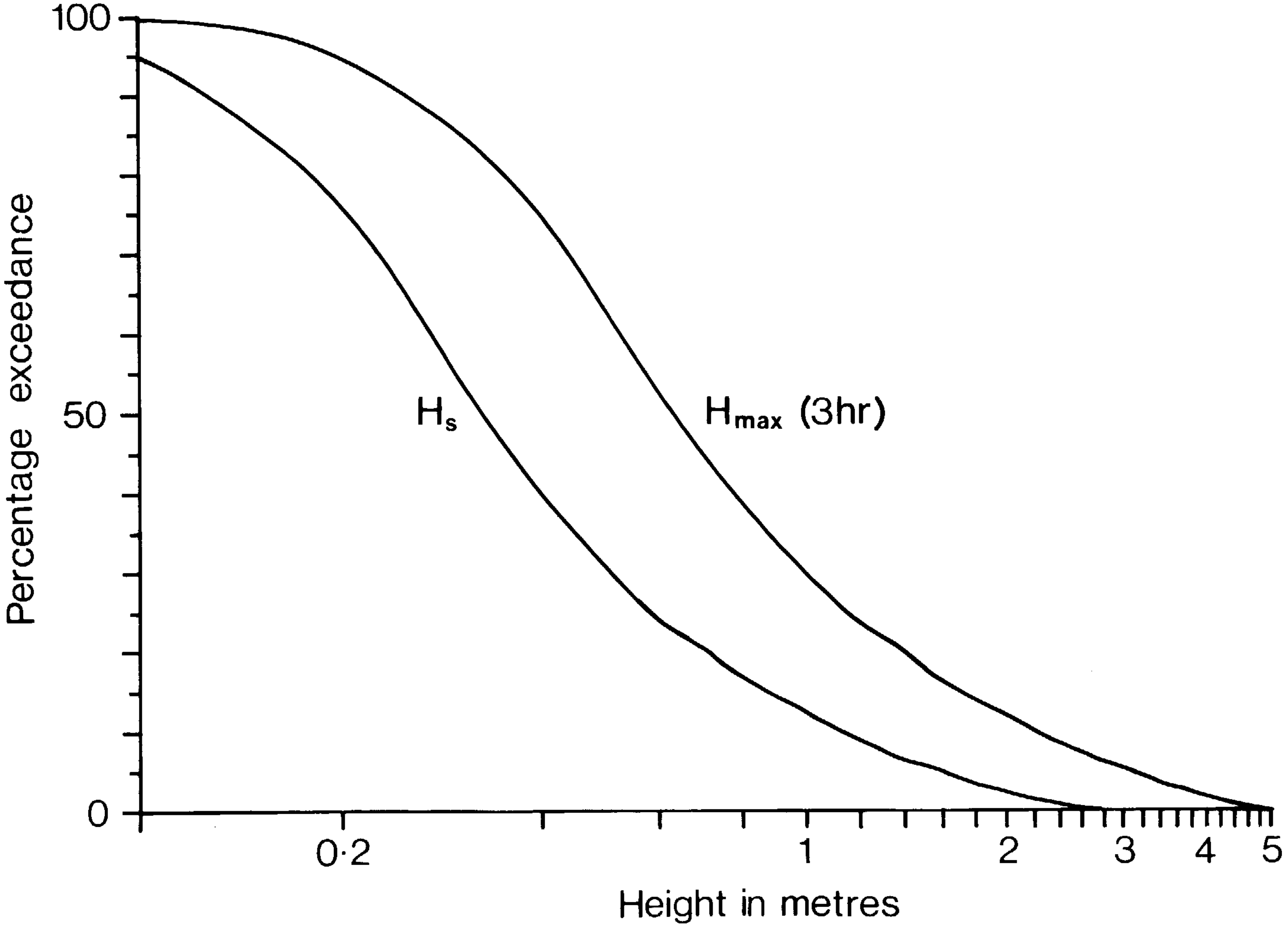
EC



Percentage exceedance of H_s and H_{max} (3hr) – Autumn '75 Aldeburgh

Fig. 2

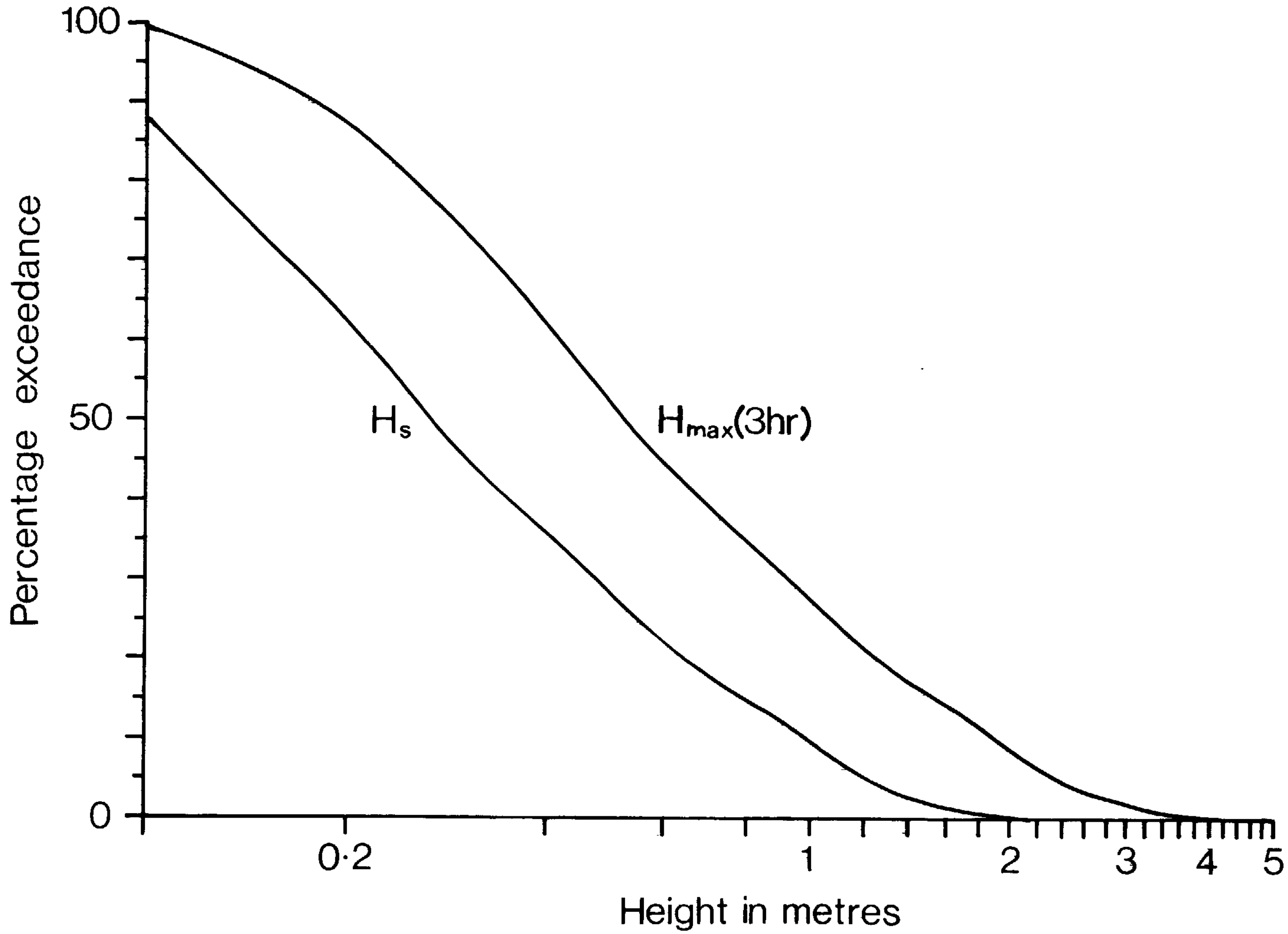
EC



Percentage exceedance of H_s and H_{max}(3hr) – Winter'75-6 Aldeburgh

Fig. 3

EC



Percentage exceedance of H_s and H_{max} (3hr) – Spring'76 Aldeburgh

Fig. 4

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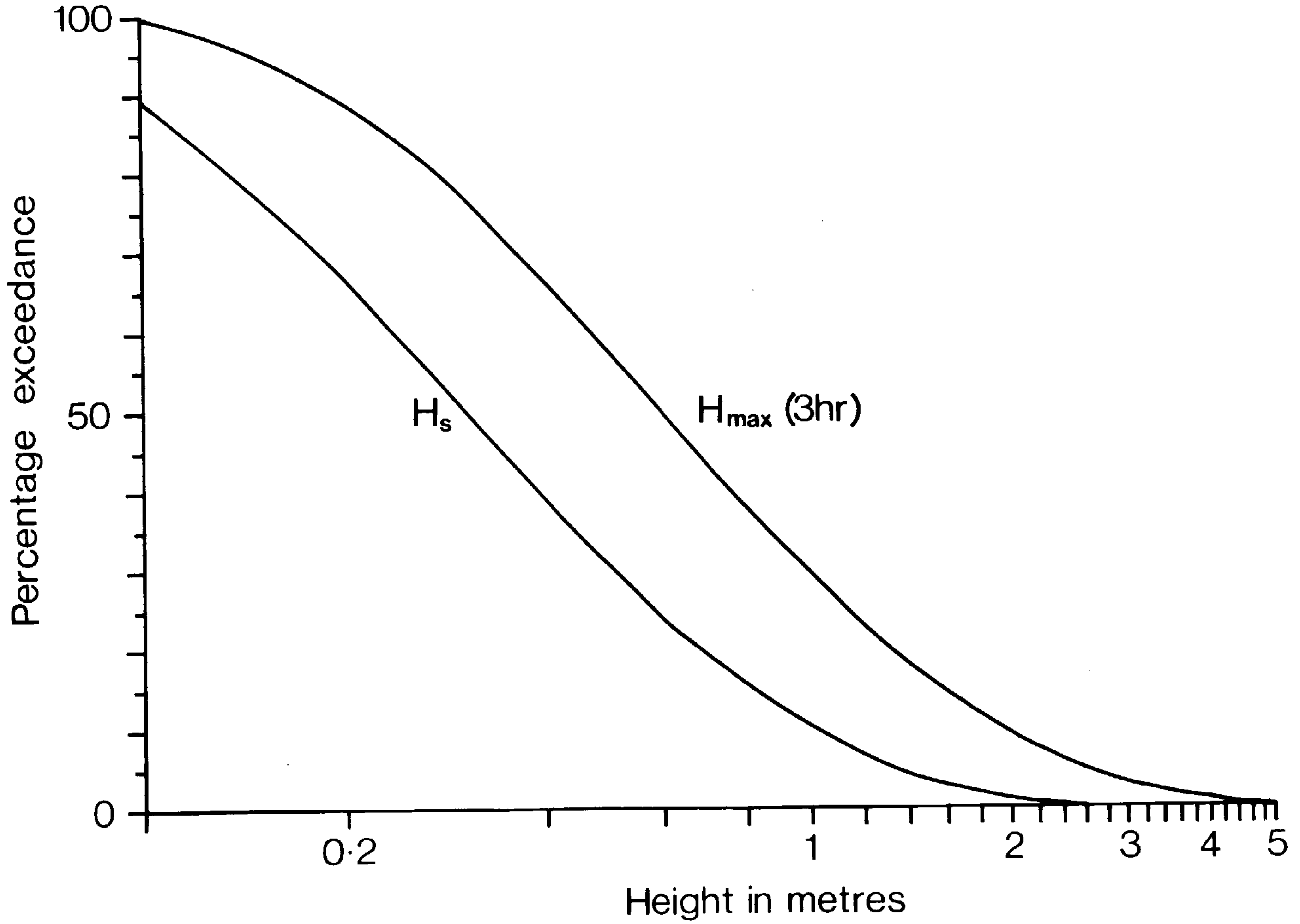
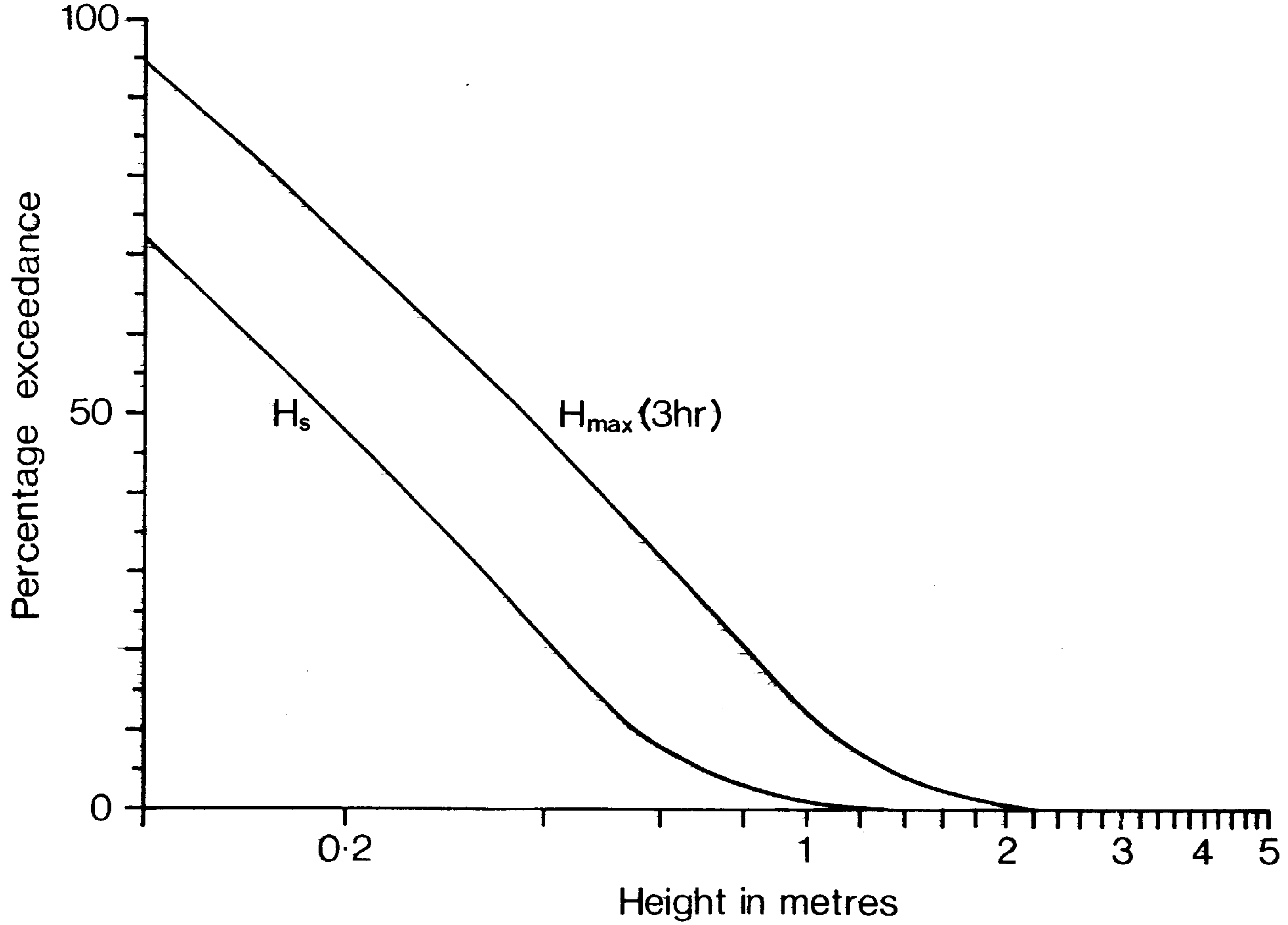


Percentage exceedance of H_s and H_{max}(3hr) – Annual'75-6 Aldeburgh

Fig. 5

EC



Percentage exceedance of H_s and H_{max}(3hr) – Summer'76 Aldeburgh

Fig. 6

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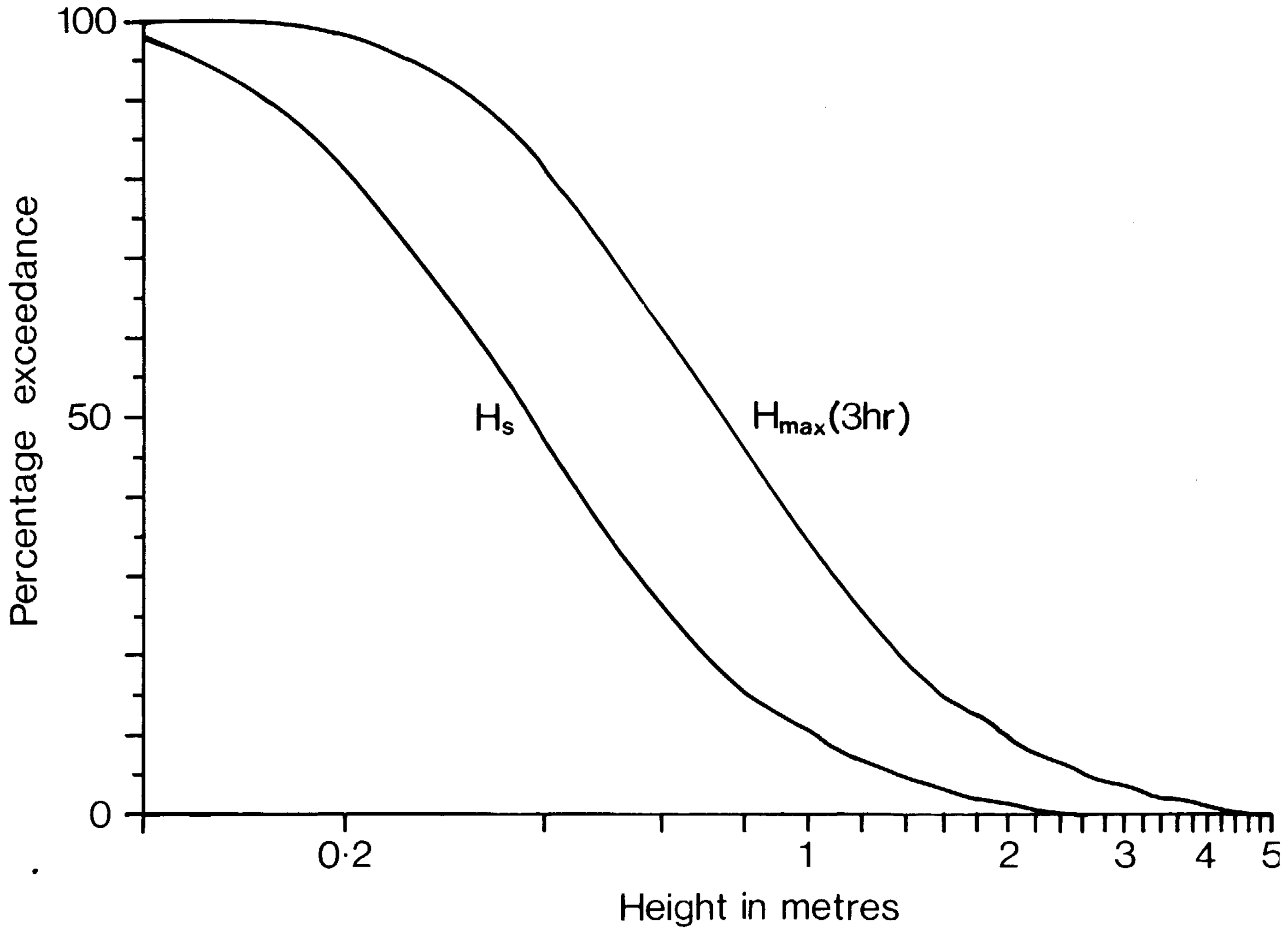

Percentage exceedance of H_s and H_{max}(3hr) – Autumn'76 Aldeburgh

Fig. 7

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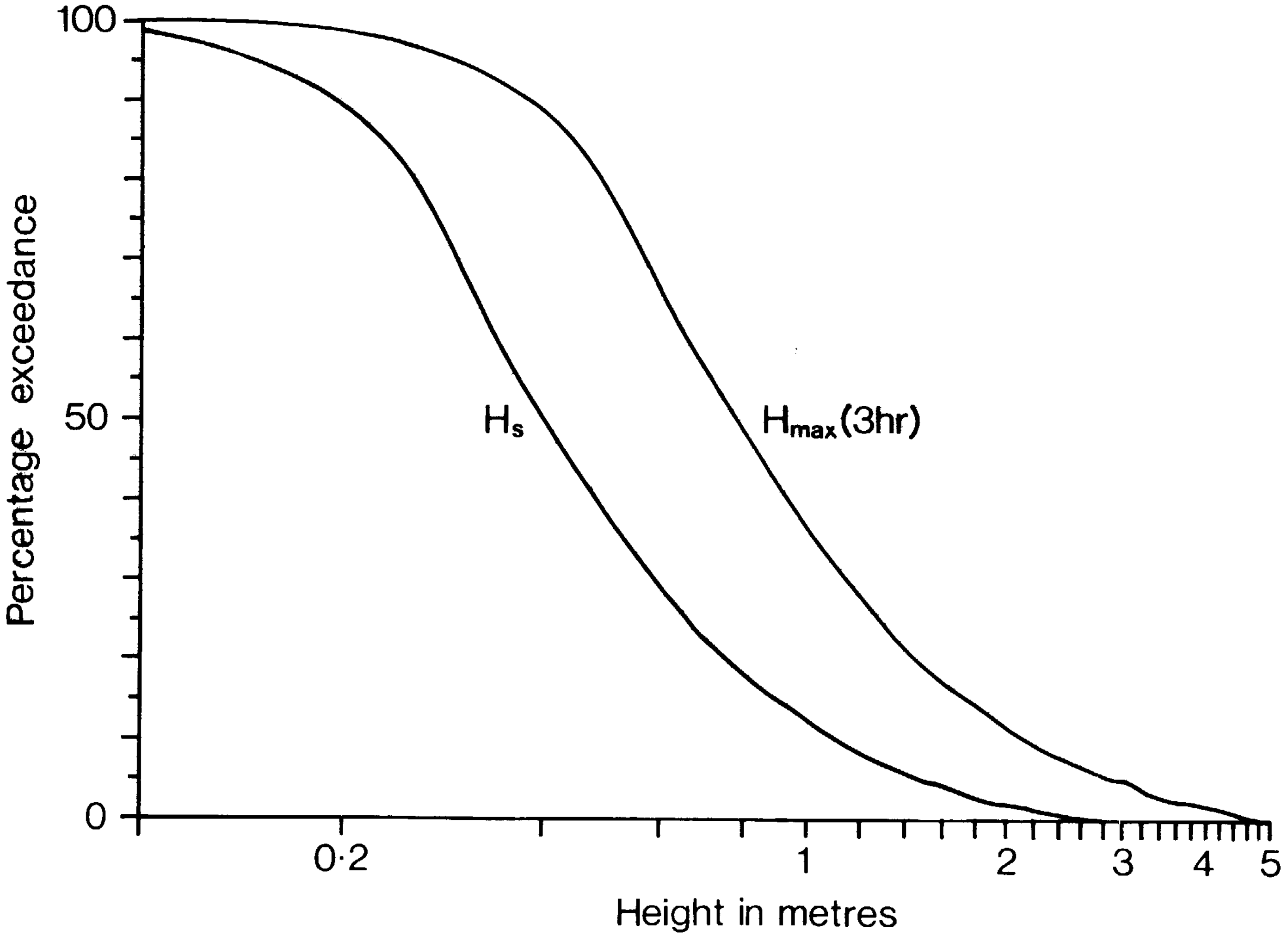

Percentage exceedance of H_s and H_{max}(3hr) – Winter '76-7 Aldeburgh

Fig. 8

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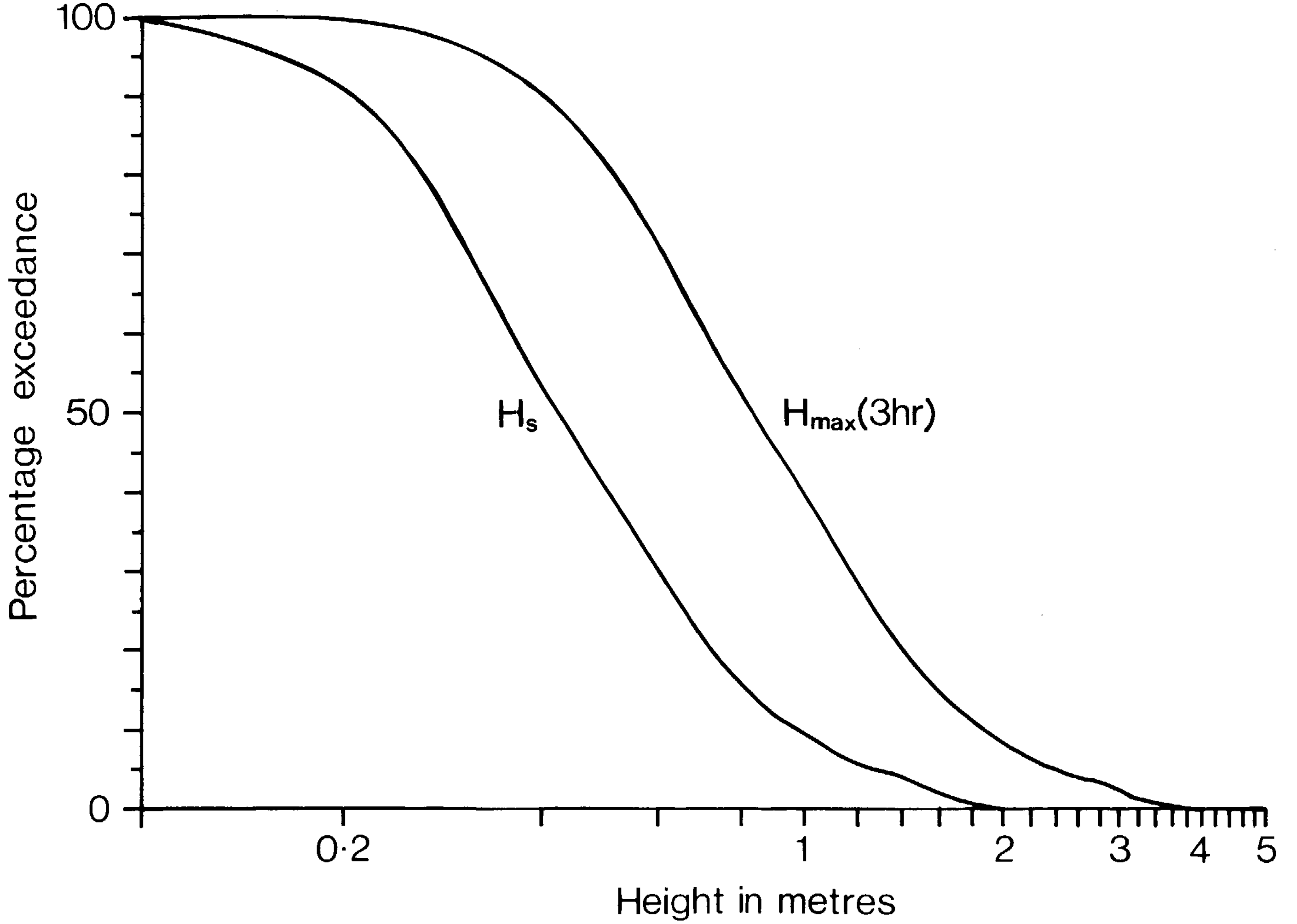

Percentage exceedance of H_s and $H_{max}(3hr)$ – Spring'77 Aldeburgh

Fig. 9

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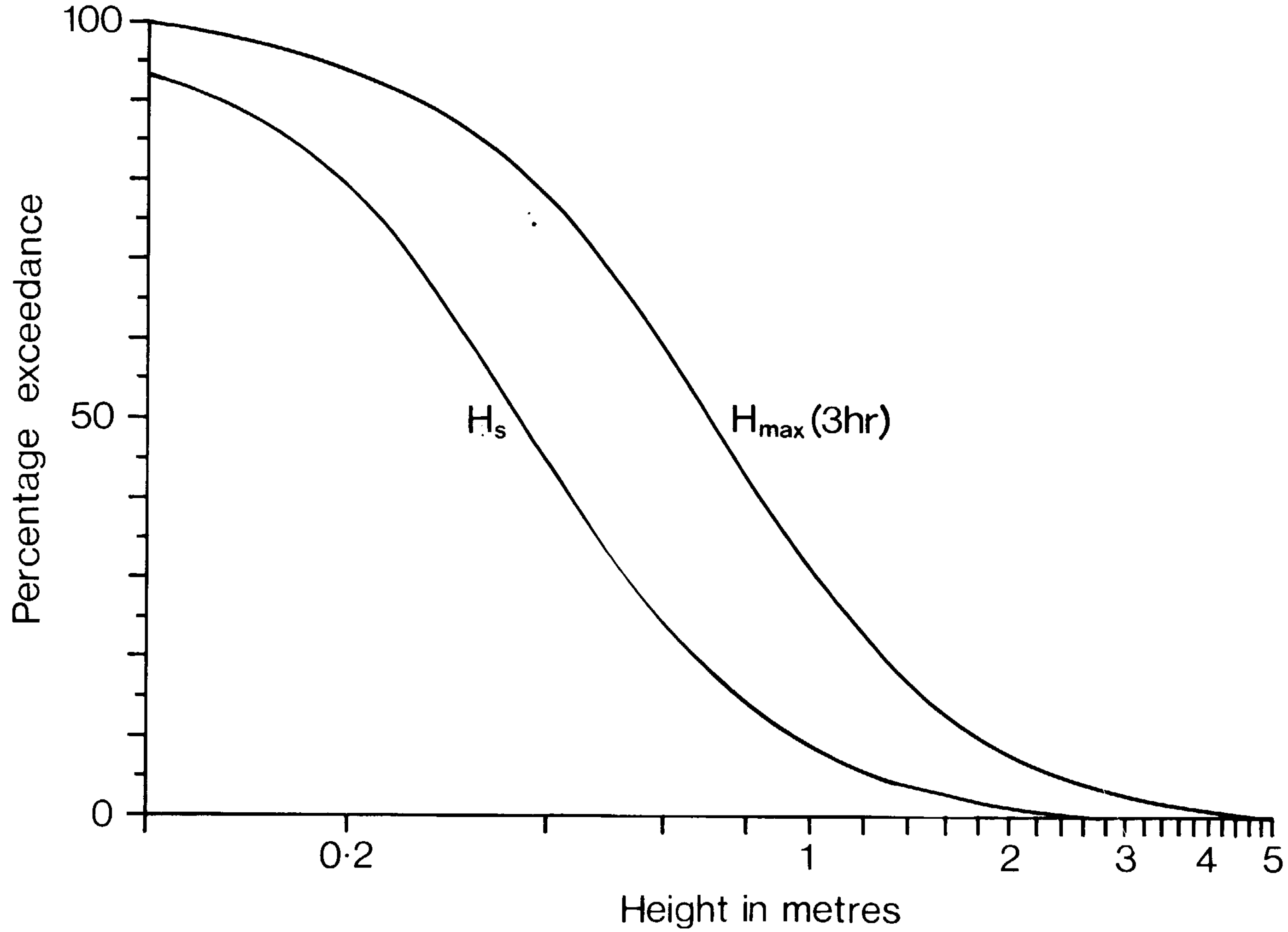
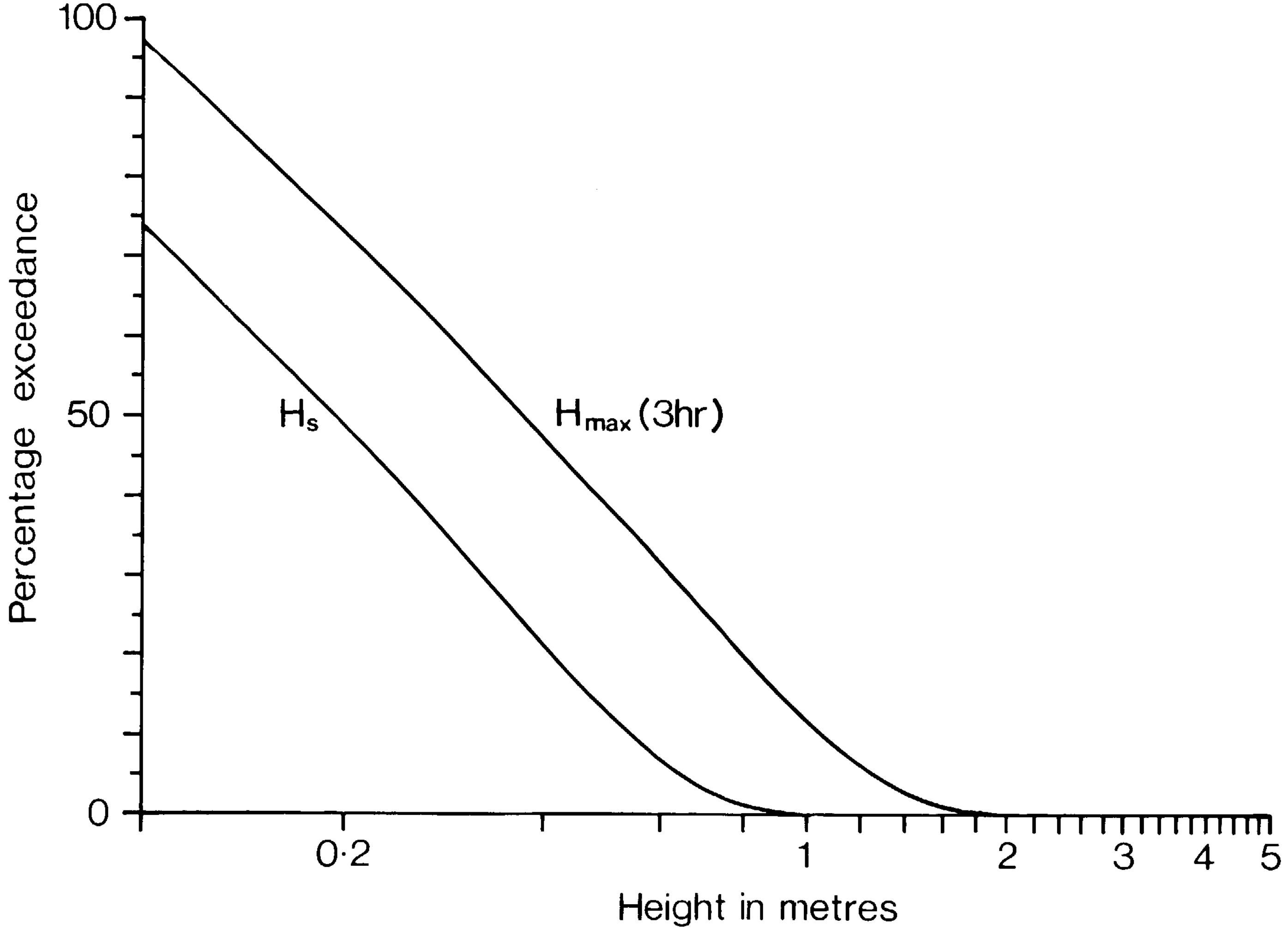


Percentage exceedance of H_s and H_{max} (3hr) – Annual'76-7 Aldeburgh

Fig. 10

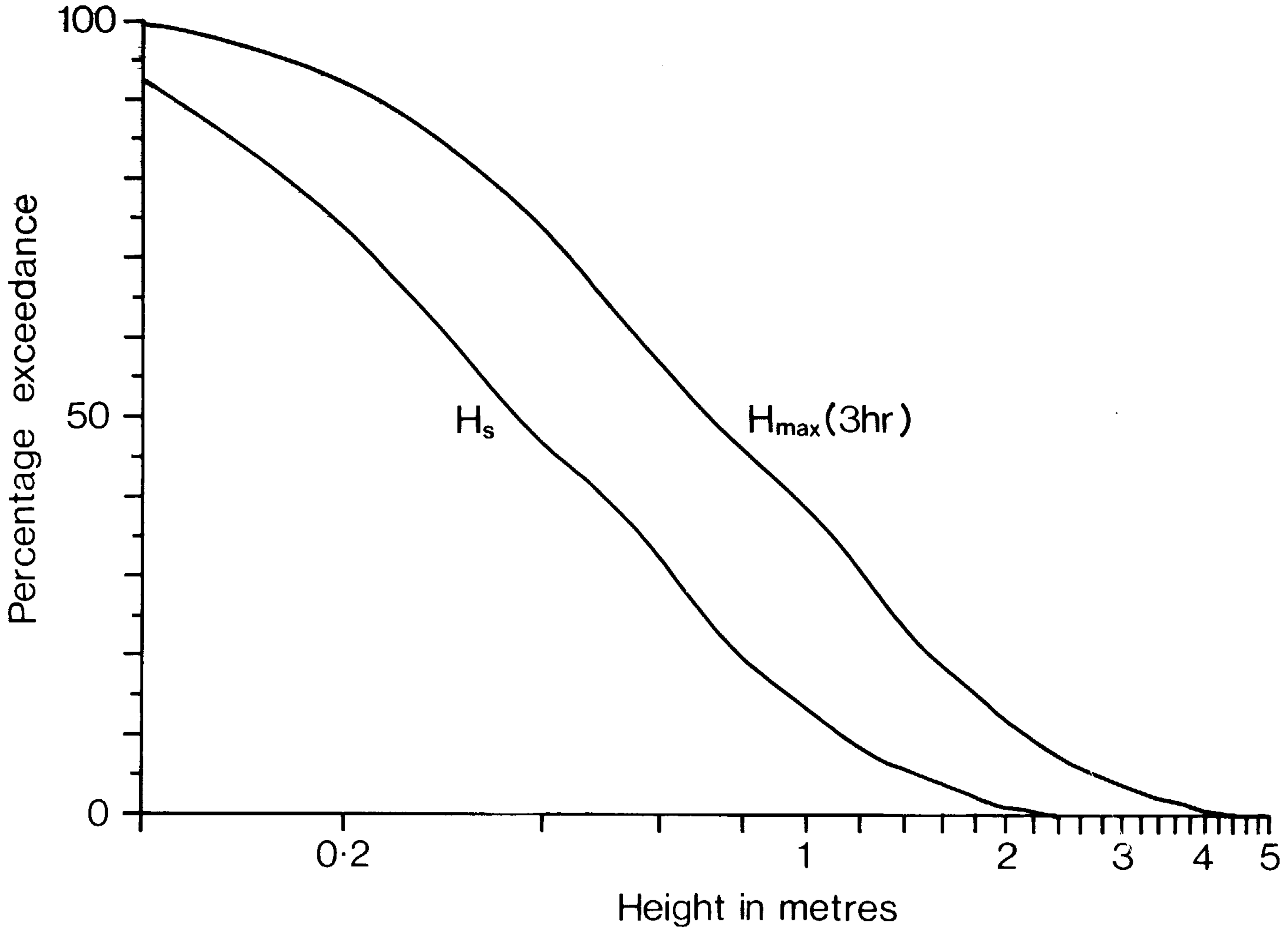
EC



Percentage exceedance of H_s and H_{max} (3hr) – Summer '75 Dunwich

Fig. 11

EC



Percentage exceedance of H_s and H_{max}(3hr) – Autumn'75 Dunwich

Fig. 12

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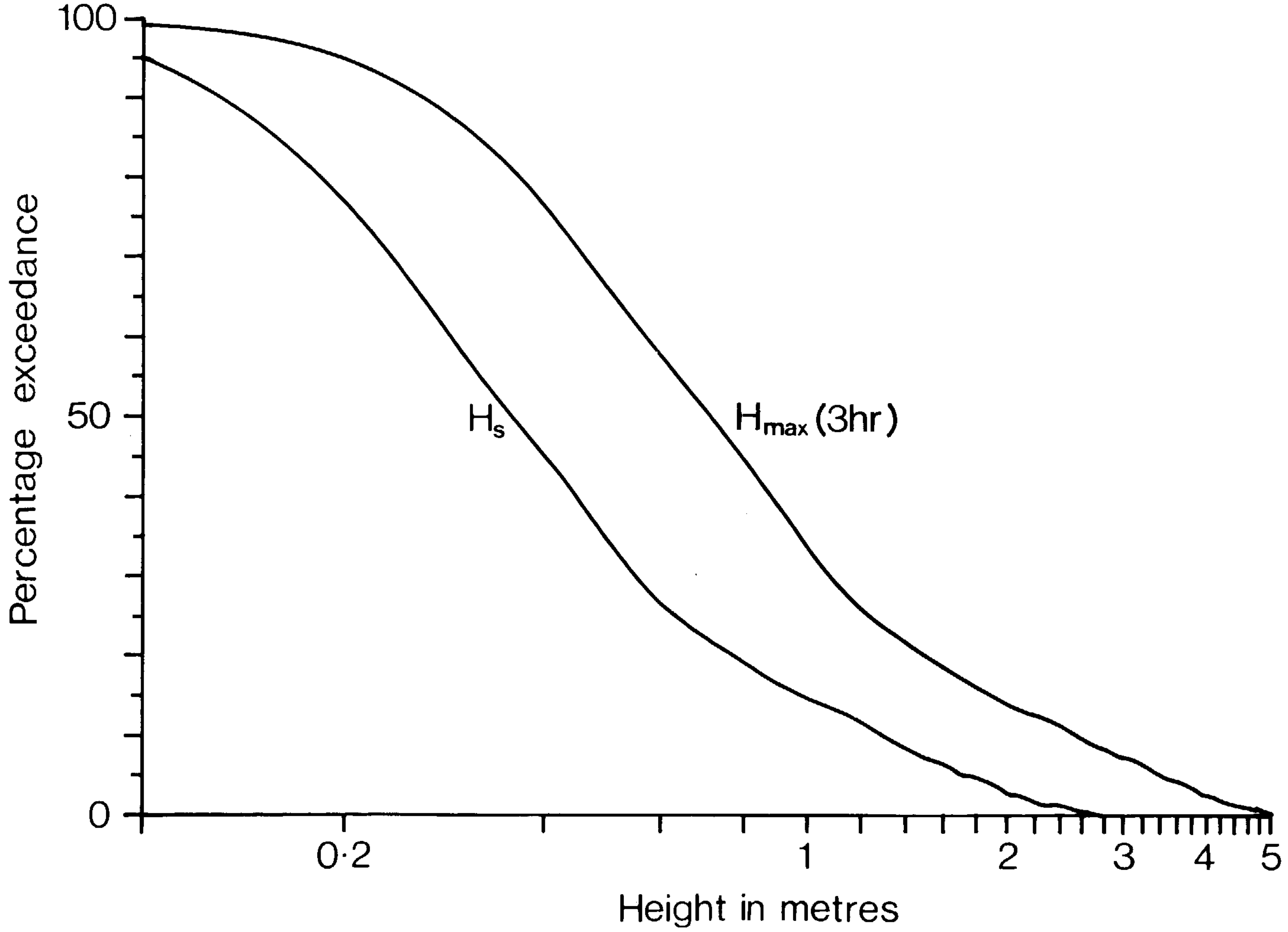
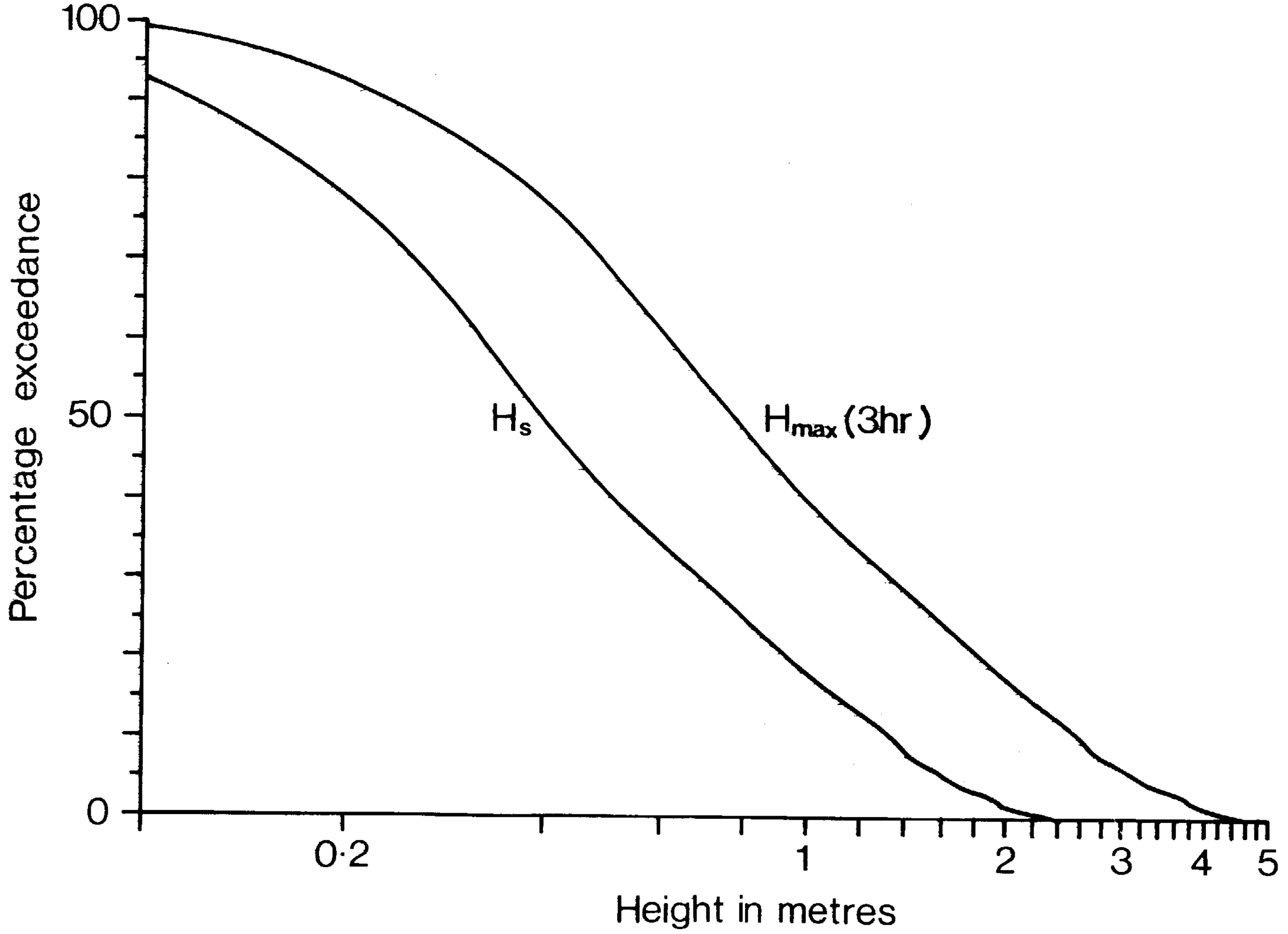


Percentage exceedance of H_s and H_{max}(3hr) – Winter '75-6 Dunwich

Fig. 13

EC



Percentage exceedance of H_s and H_{max} (3hr) – Spring'76 Dunwich

Fig. 14

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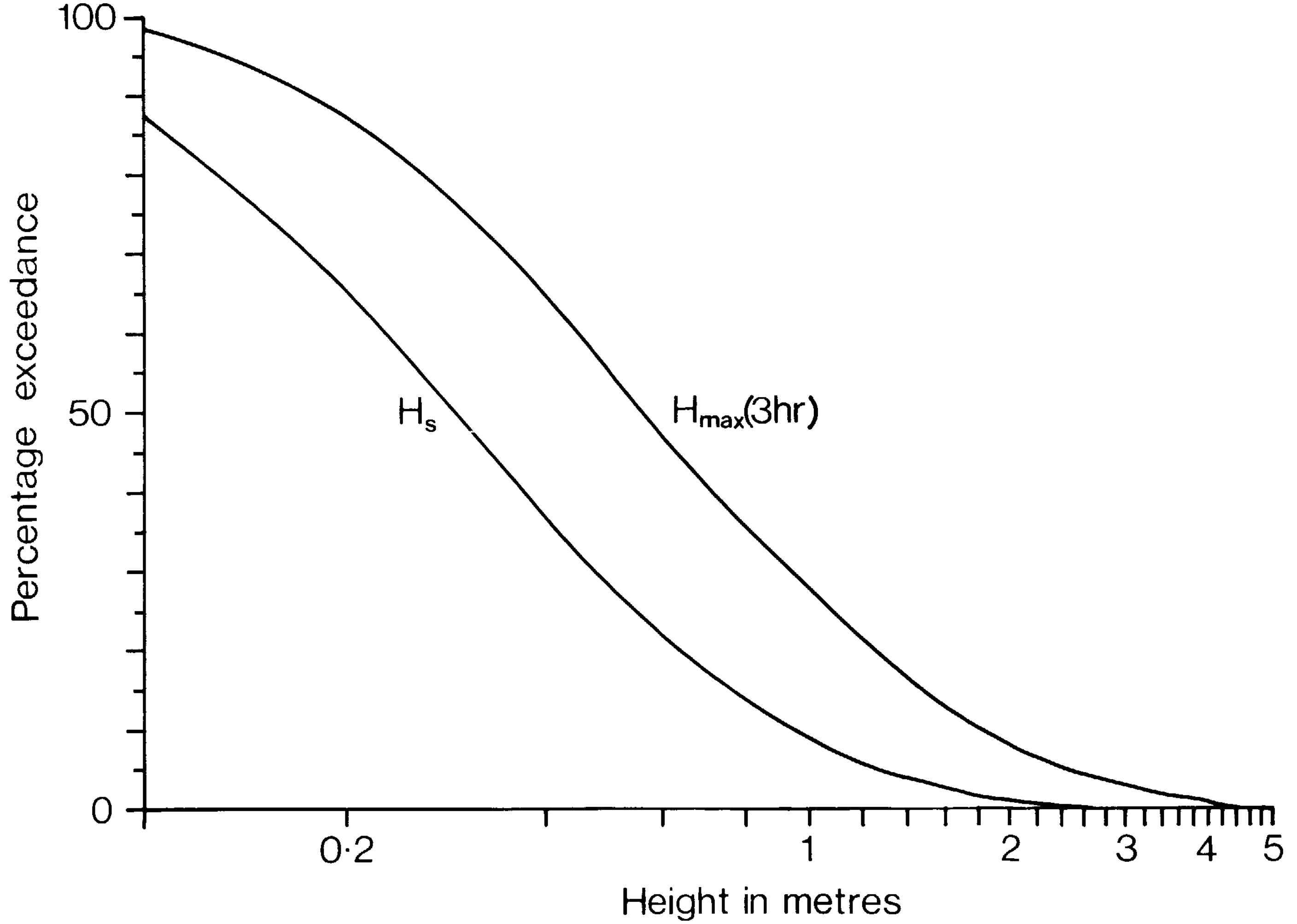
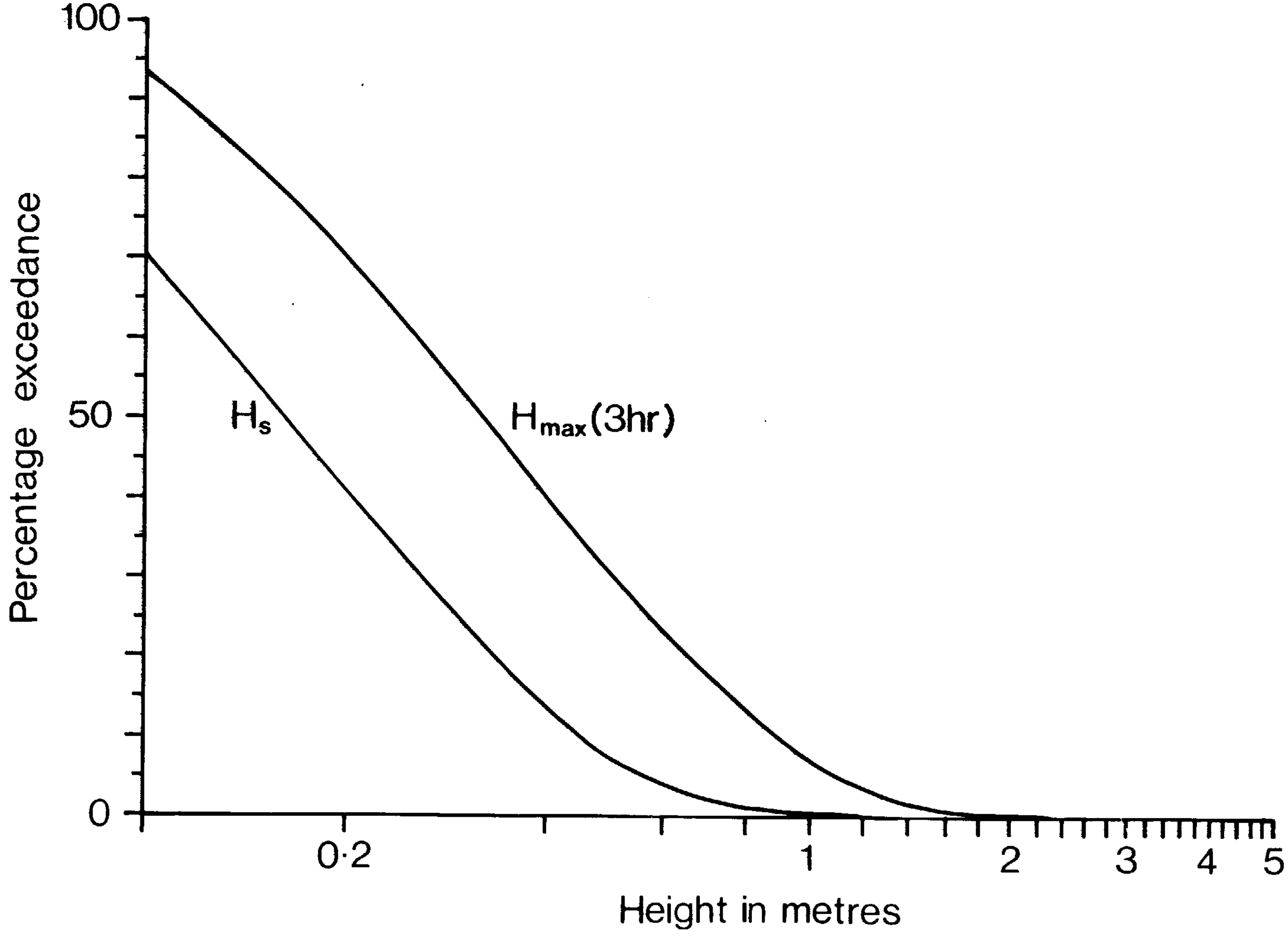


Percentage exceedance of H_s and H_{max}(3hr) – Annual'75-6 Dunwich

Fig. 15

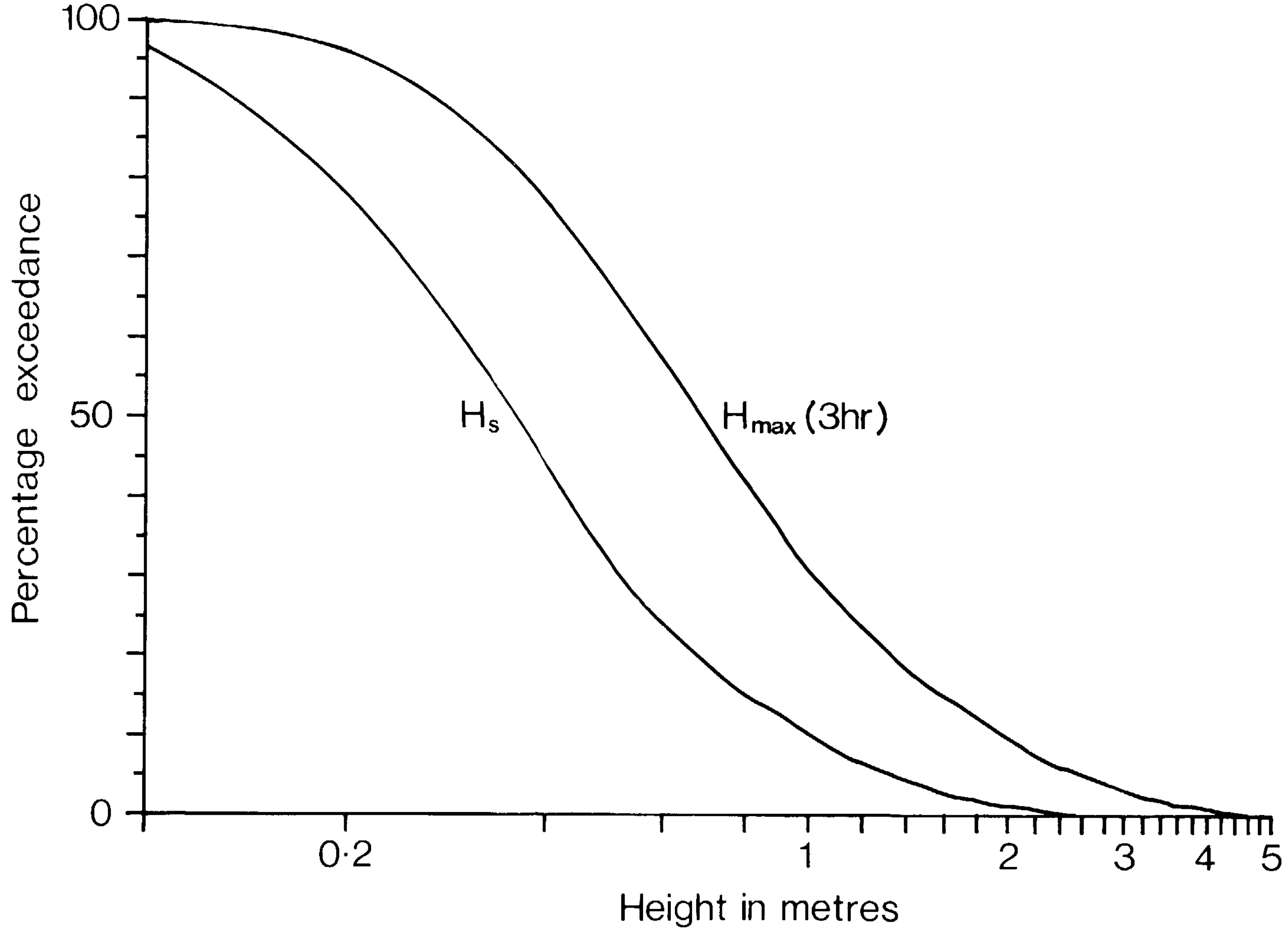
EC



Percentage exceedance of H_s and $H_{max}(3hr)$ – Summer'76 Dunwich

Fig. 16

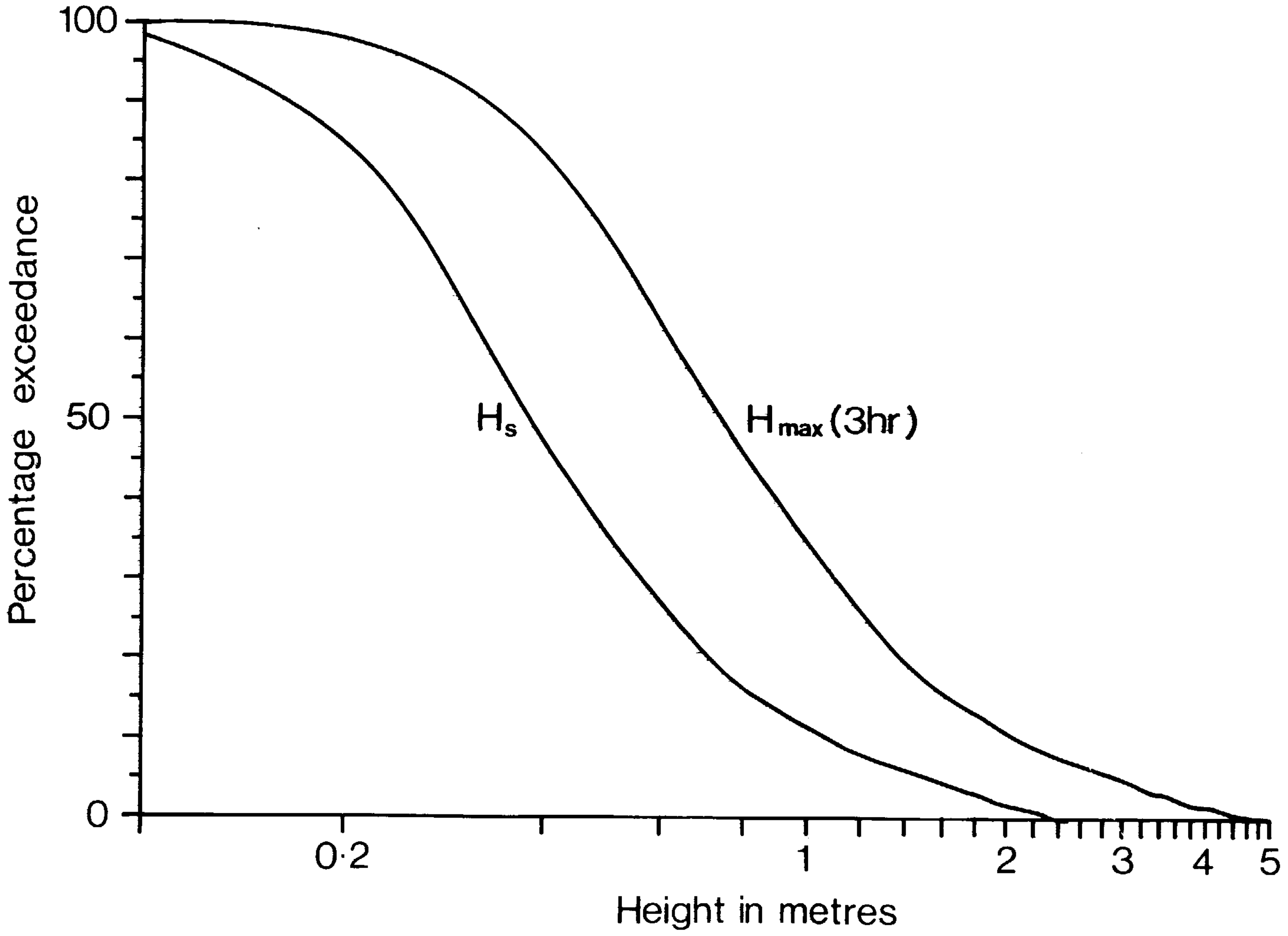
EC



Percentage exceedance of H_s and H_{max} (3hr) – Autumn' 76 **Dunwich**

Fig. 17

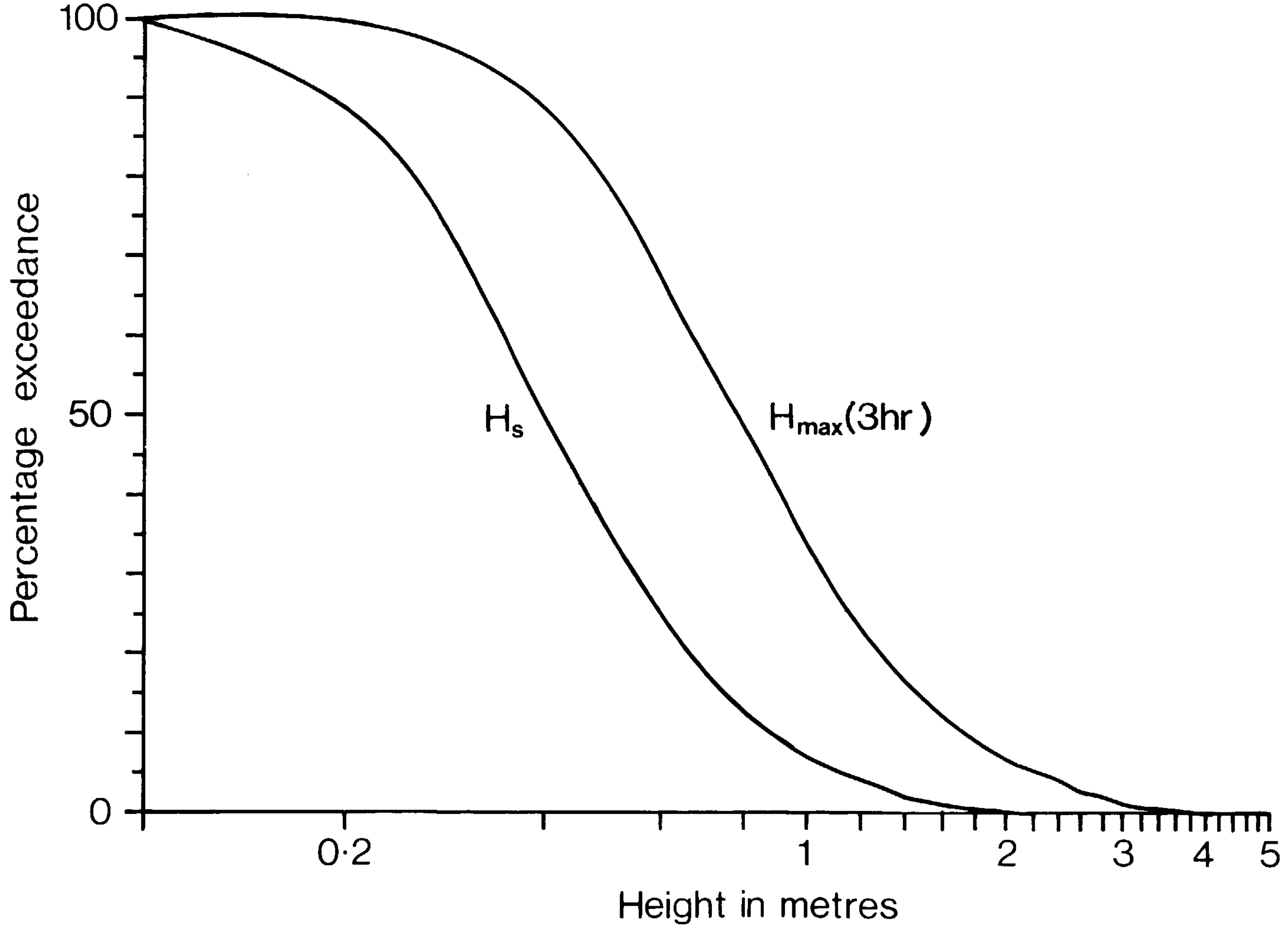
EC



Percentage exceedance of H_s and H_{max}(3hr) – Winter '76-7 **Dunwich**

Fig. 18

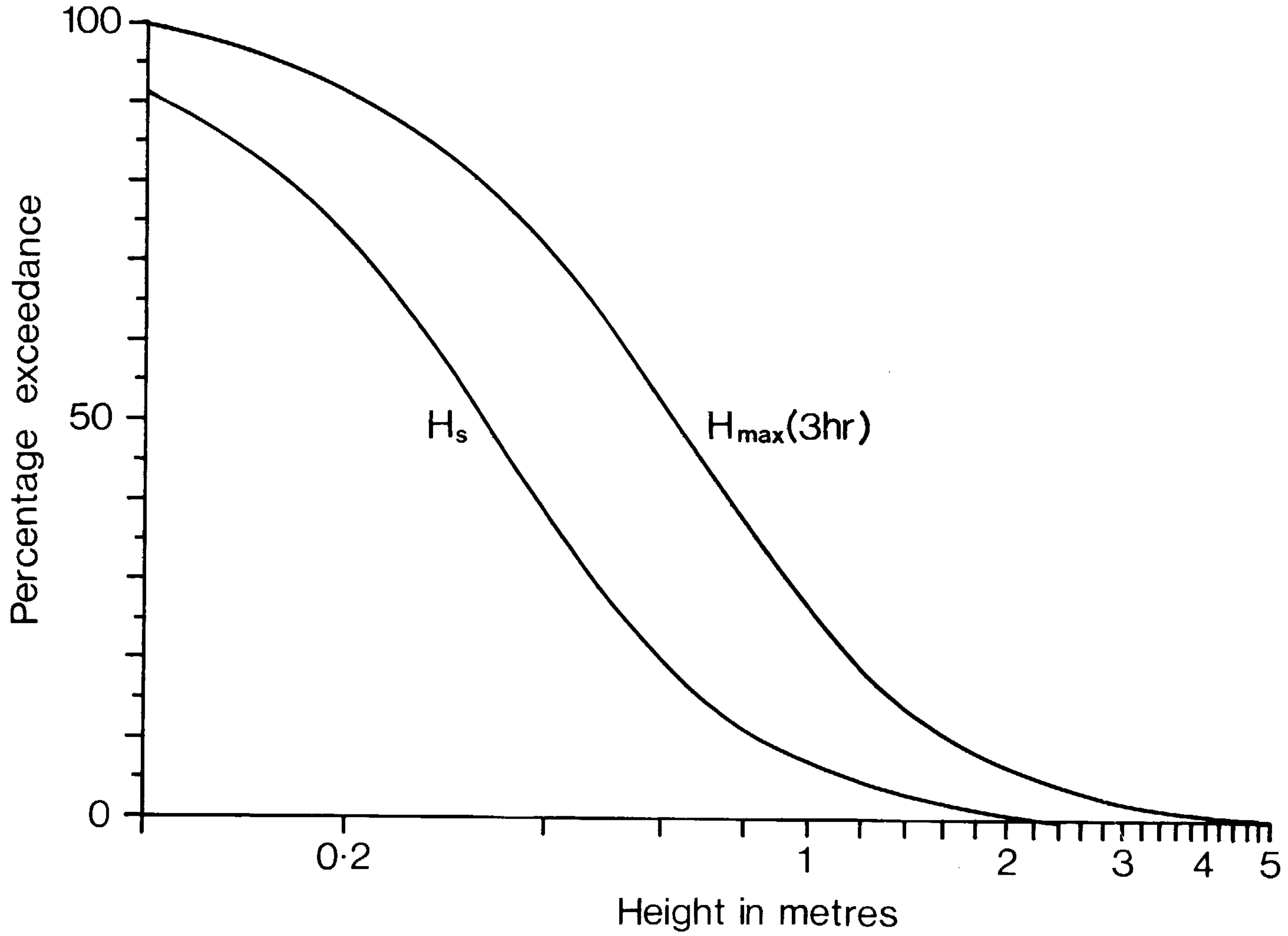
EC



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

Fig. 19

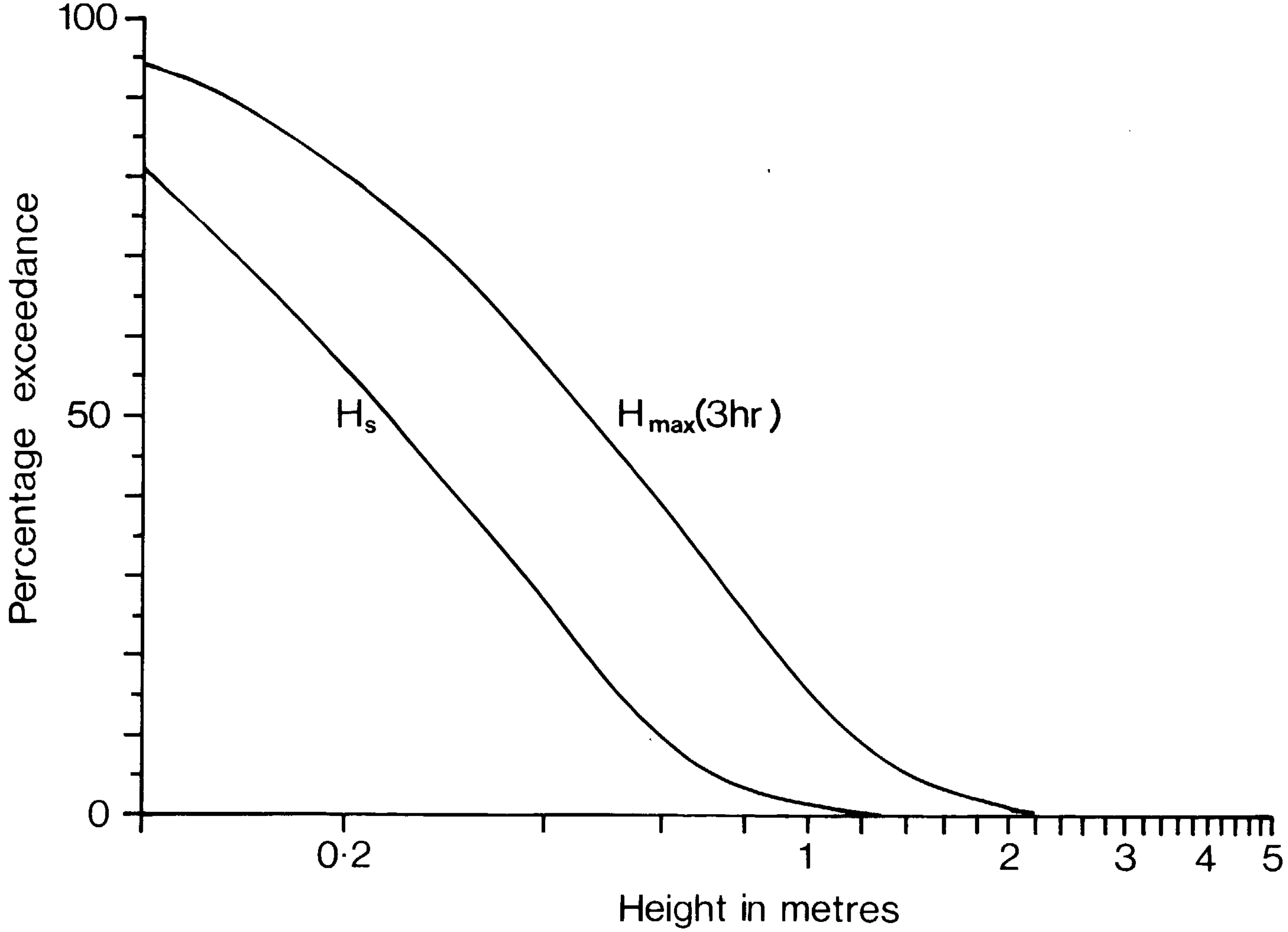
EC



Percentage exceedance of H_s and H_{max}(3hr) – Annual'76-7 **Dunwich**

Fig. 20

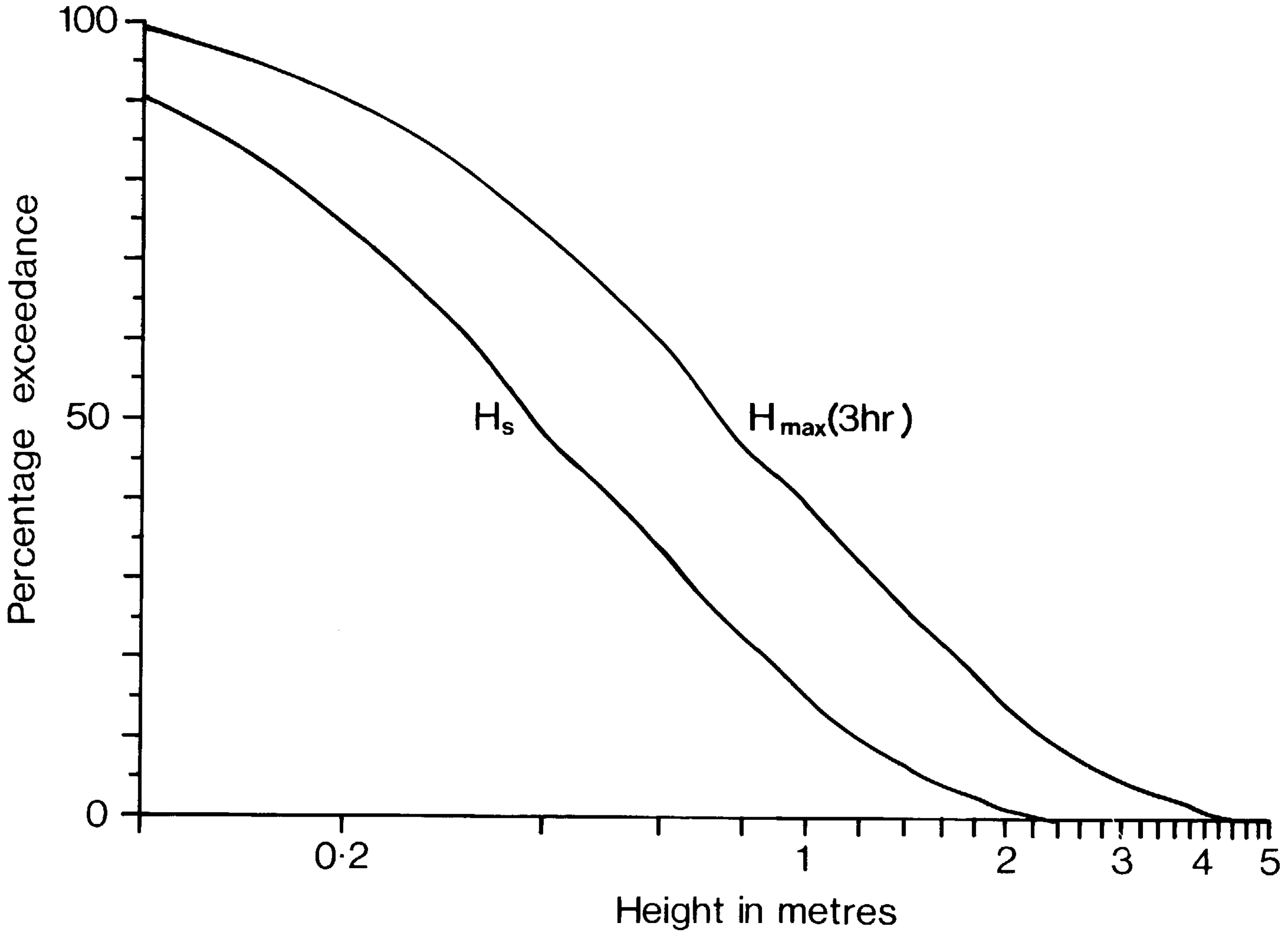
EC



Percentage exceedance of H_s and H_{max} (3hr) – Summer '75 Southwold

Fig. 21

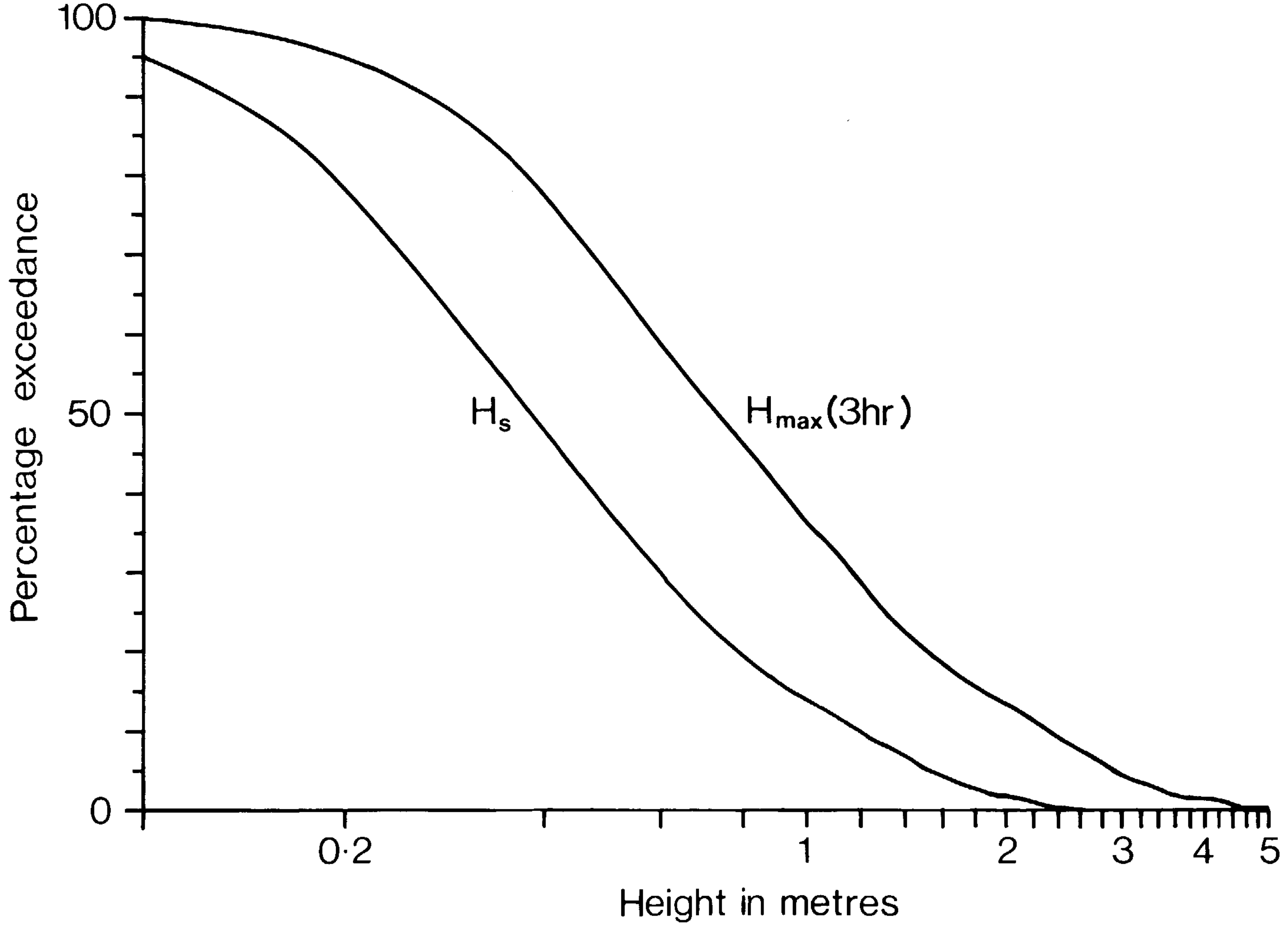
EC



Percentage exceedance of H_s and H_{max} (3hr) – Autumn'75 Southwold

Fig. 22

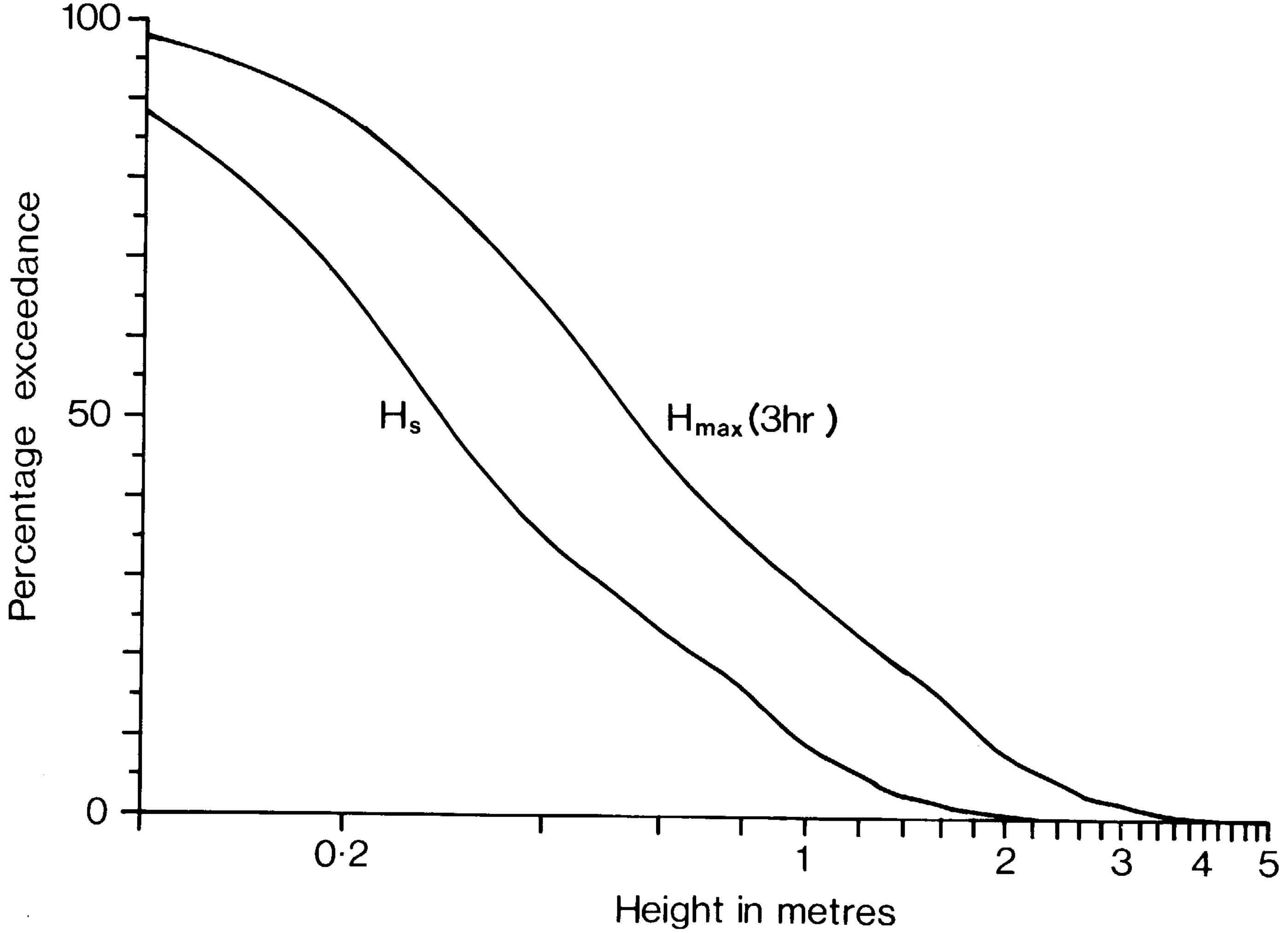
EC



Percentage exceedance of H_s and H_{max}(3hr) – Winter '75-6 Southwold

Fig. 23

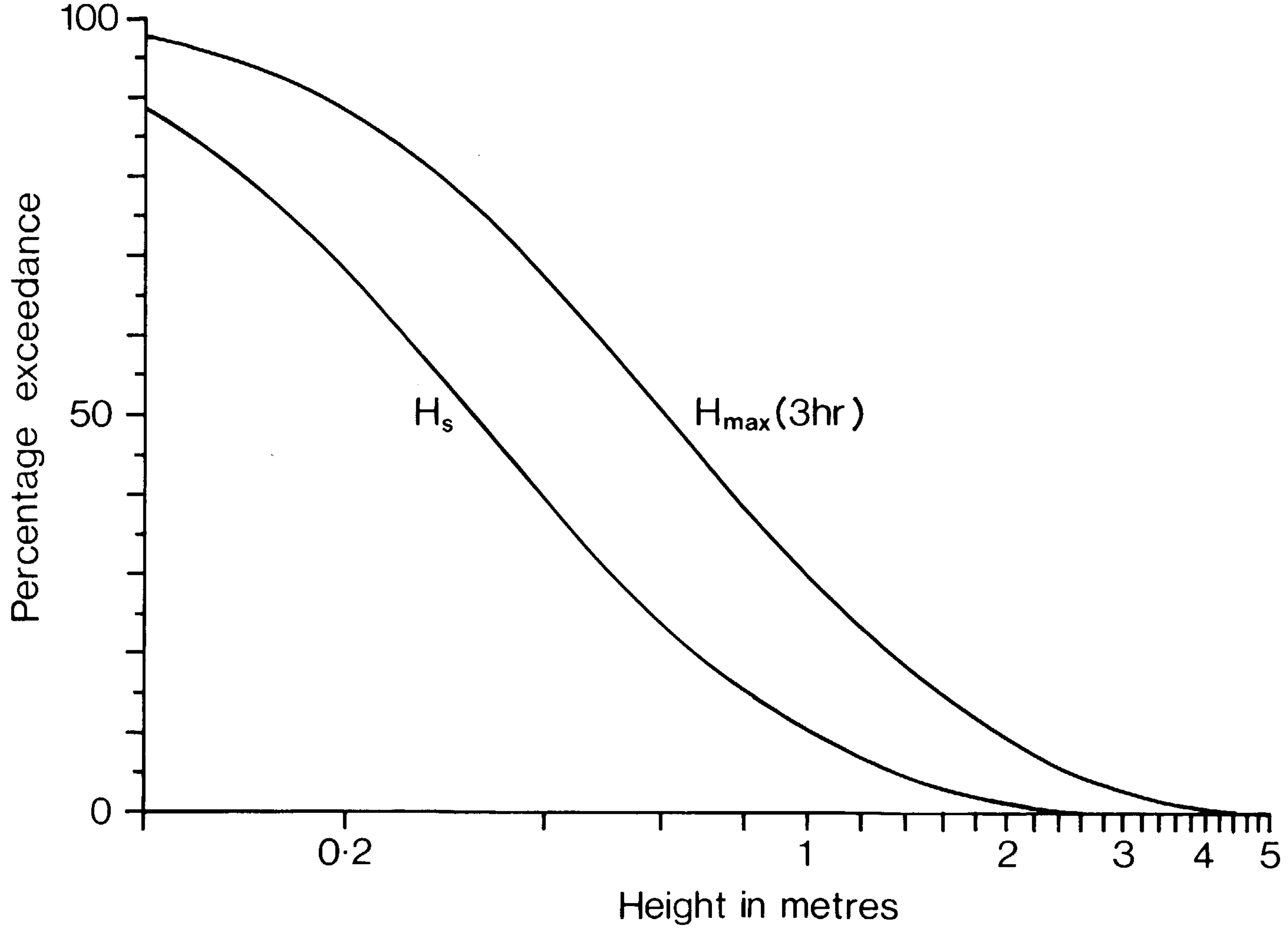
EC



Percentage exceedance of H_s and H_{max}(3hr) – Spring '76 Southwold

Fig. 24

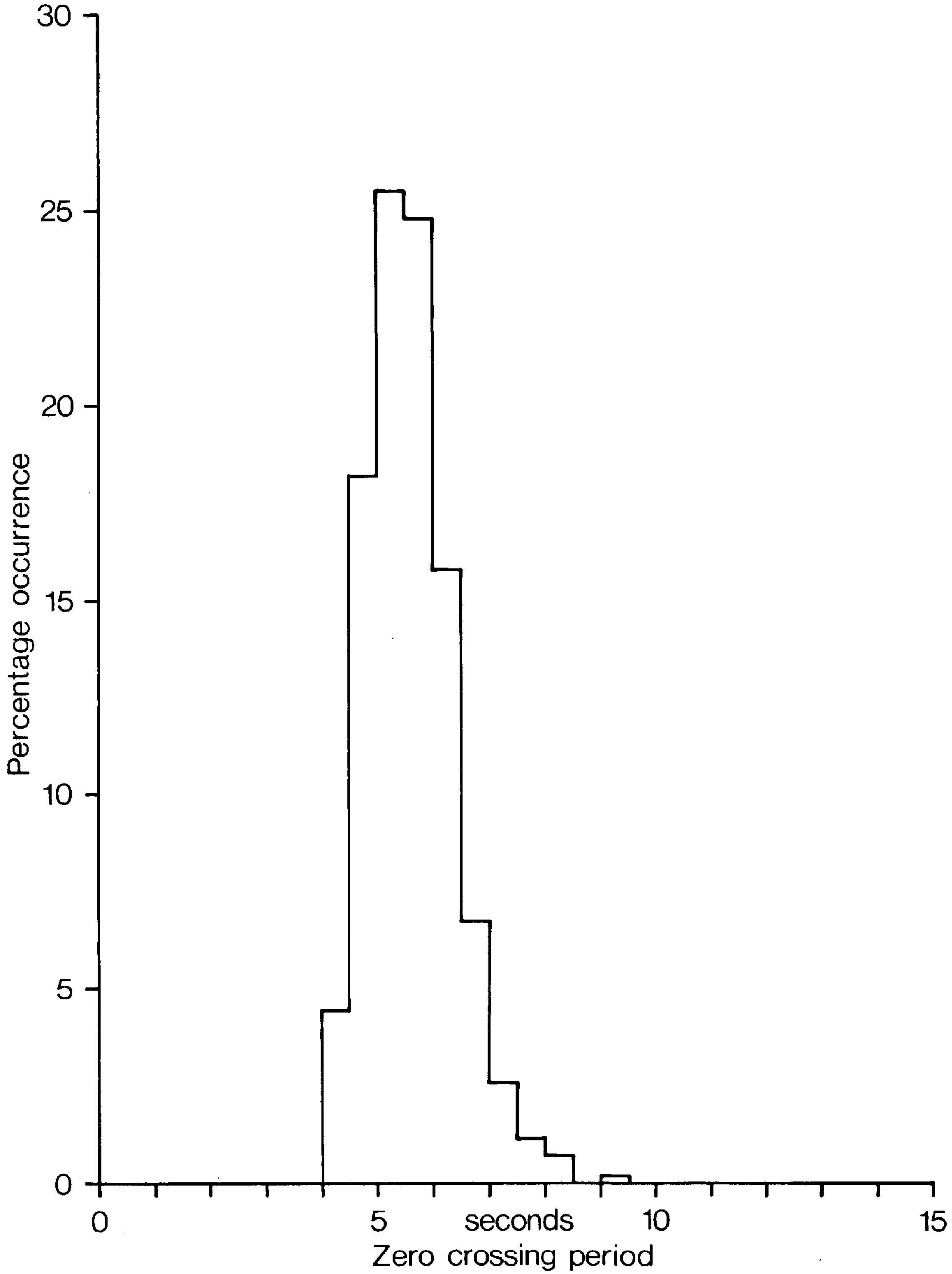
EC



Percentage exceedance of H_s and H_{max}(3hr) – Annual '75-6 Southwold

Fig. 25

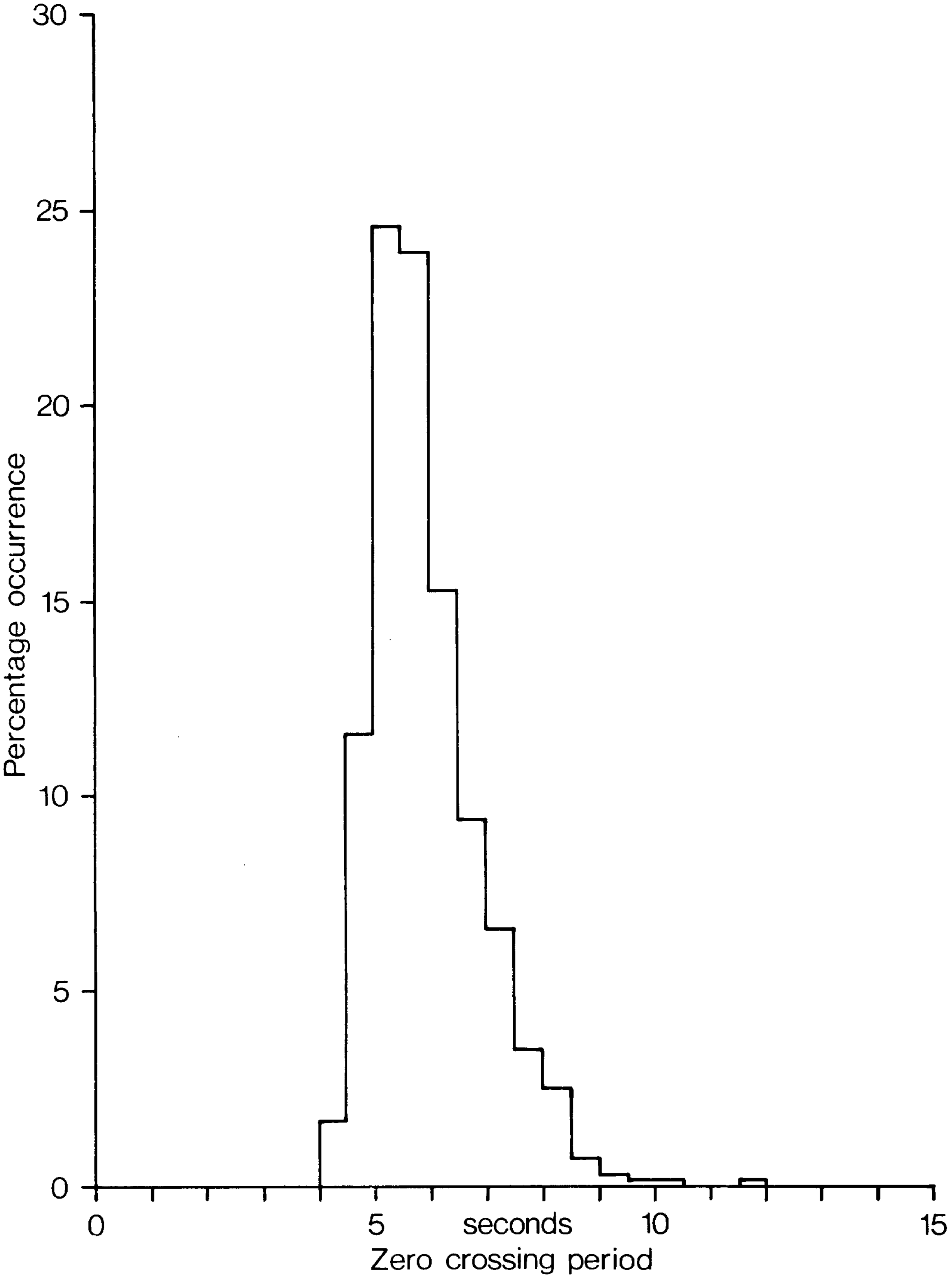
EC



Frequency histogram for zero crossing period - Summer '75

Fig. 26 Aldeburgh

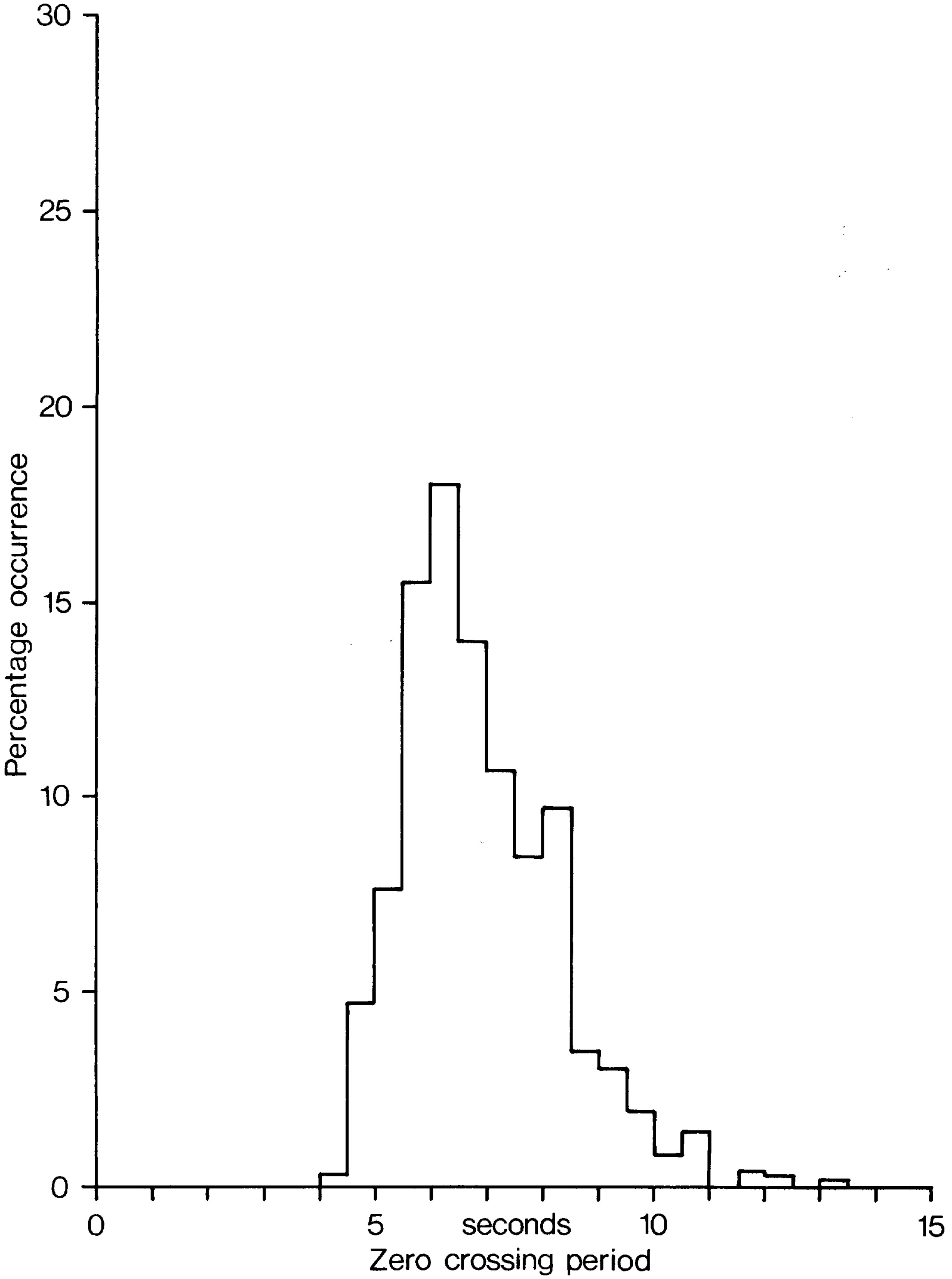
EC



Frequency histogram for zero crossing period - Autumn '75

Fig. 27 **Aldeburgh**

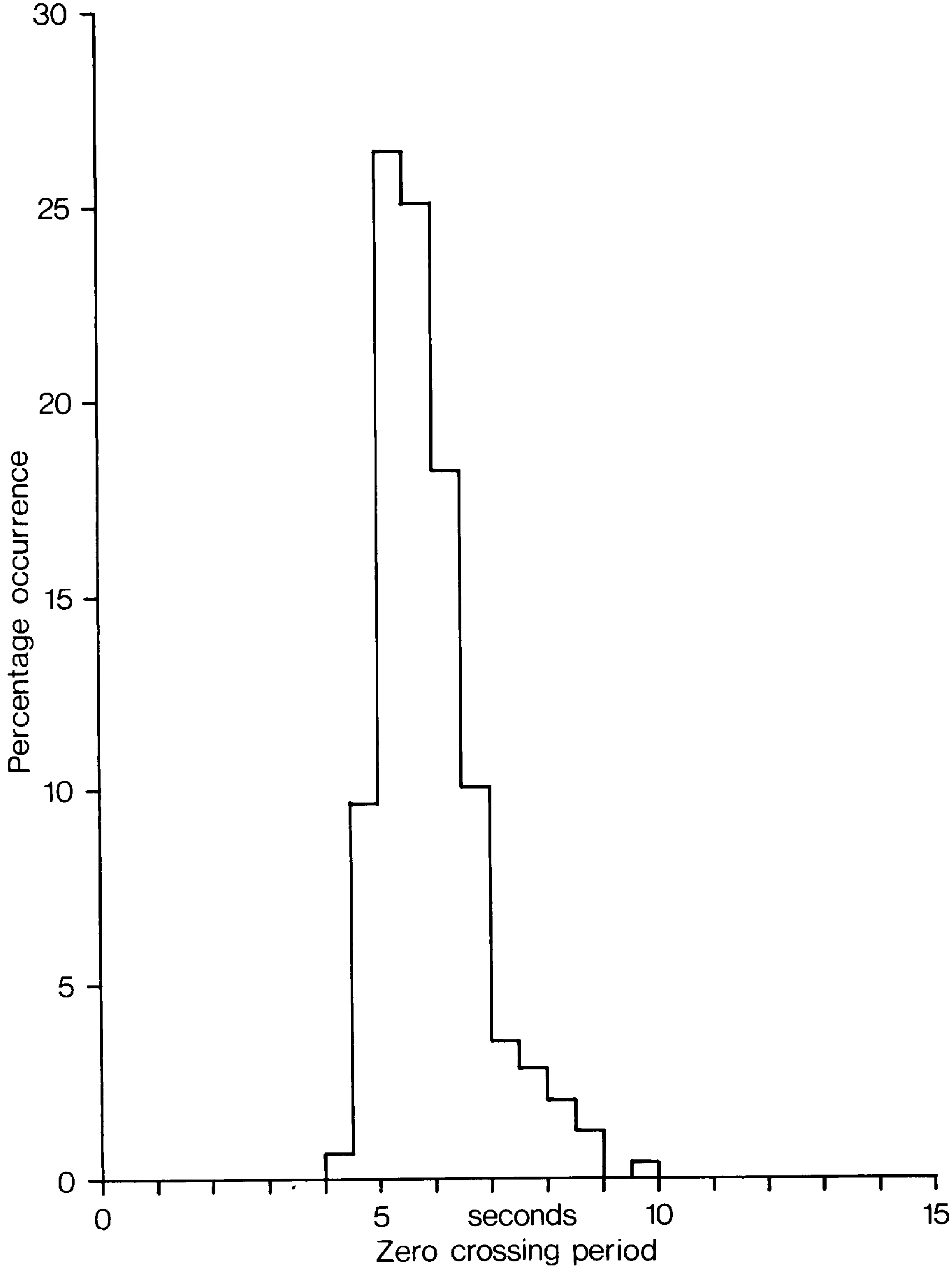
EC



Frequency histogram for zero crossing period - Winter '75-6

Fig. 28 **Aldeburgh**

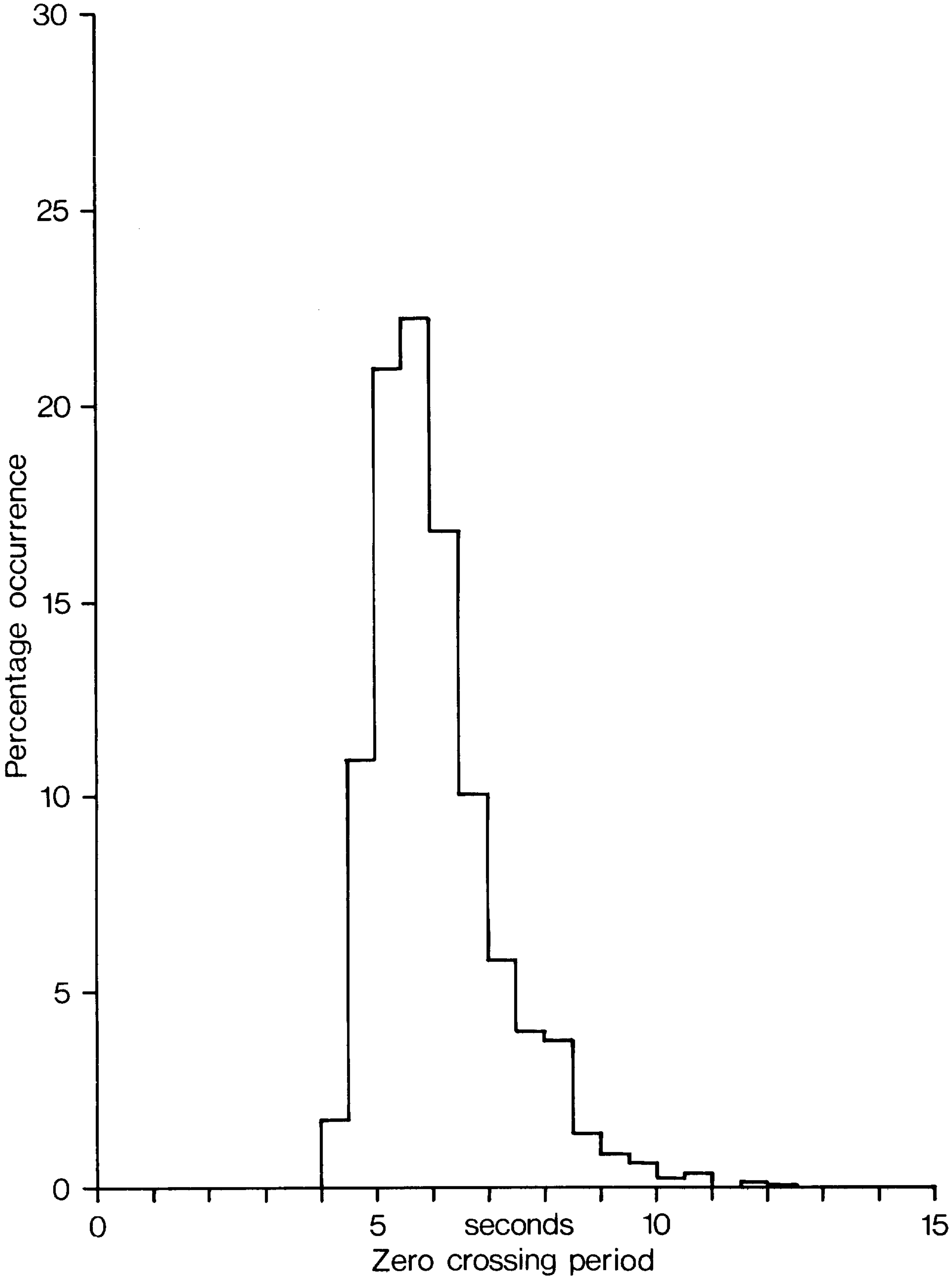
EC



Frequency histogram for zero crossing period - Spring'76

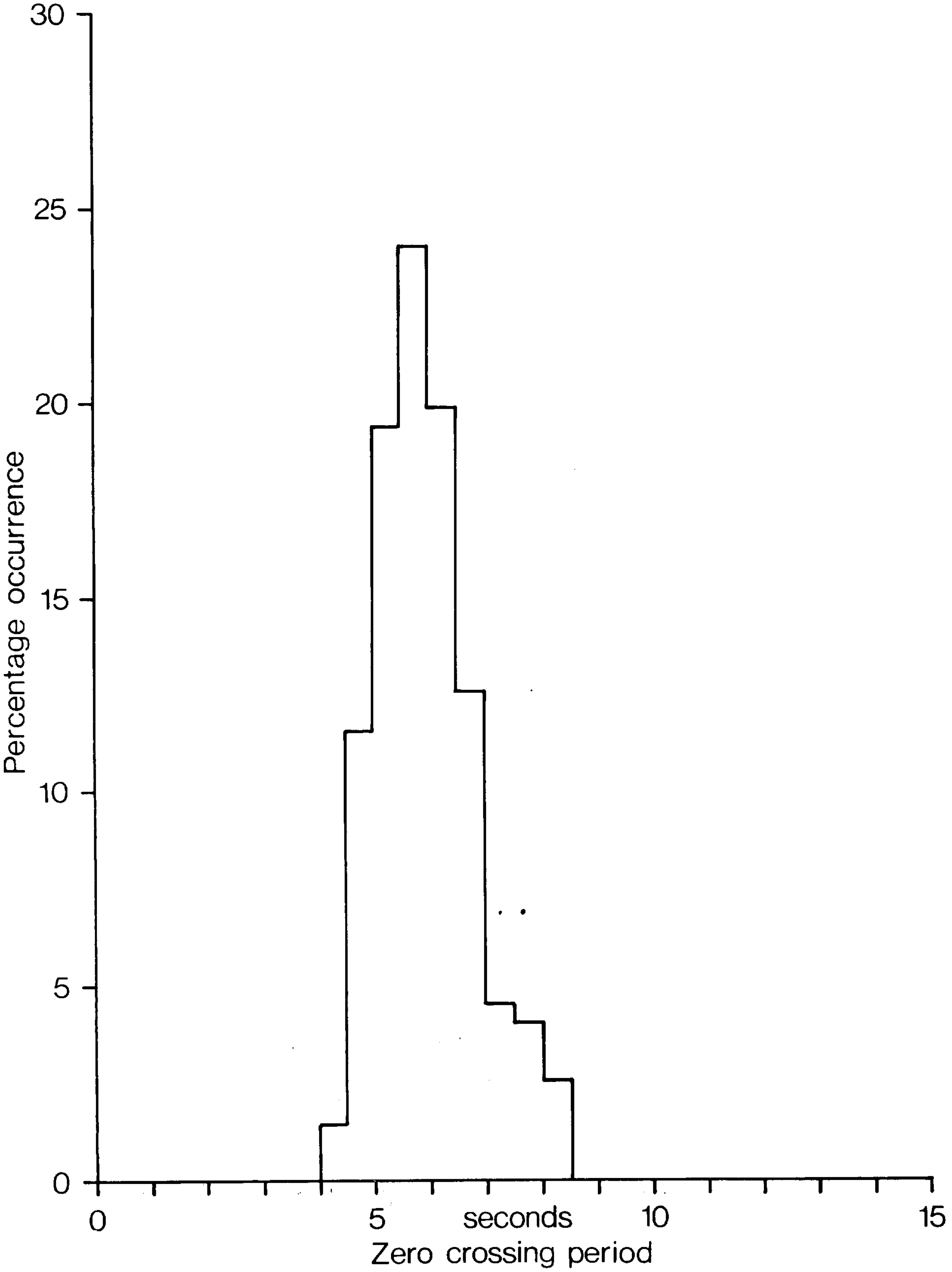
Fig. 29 **Aldeburgh**

EC



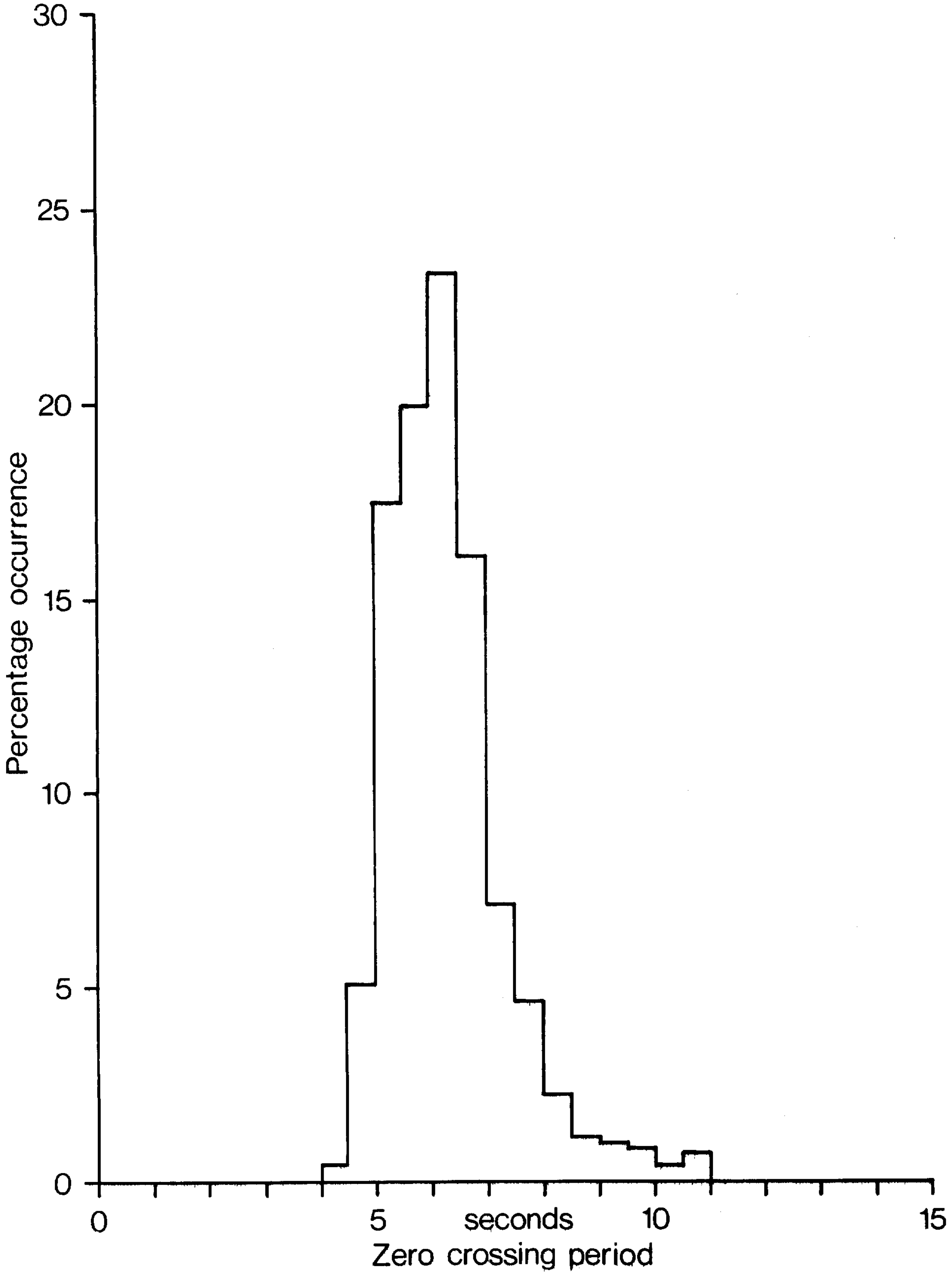
Frequency histogram for zero crossing period -Annual'75-6
Fig. 30 **Aldeburgh**

EC



Frequency histogram for zero crossing period - Summer'76
Fig. 31 **Aldeburgh**

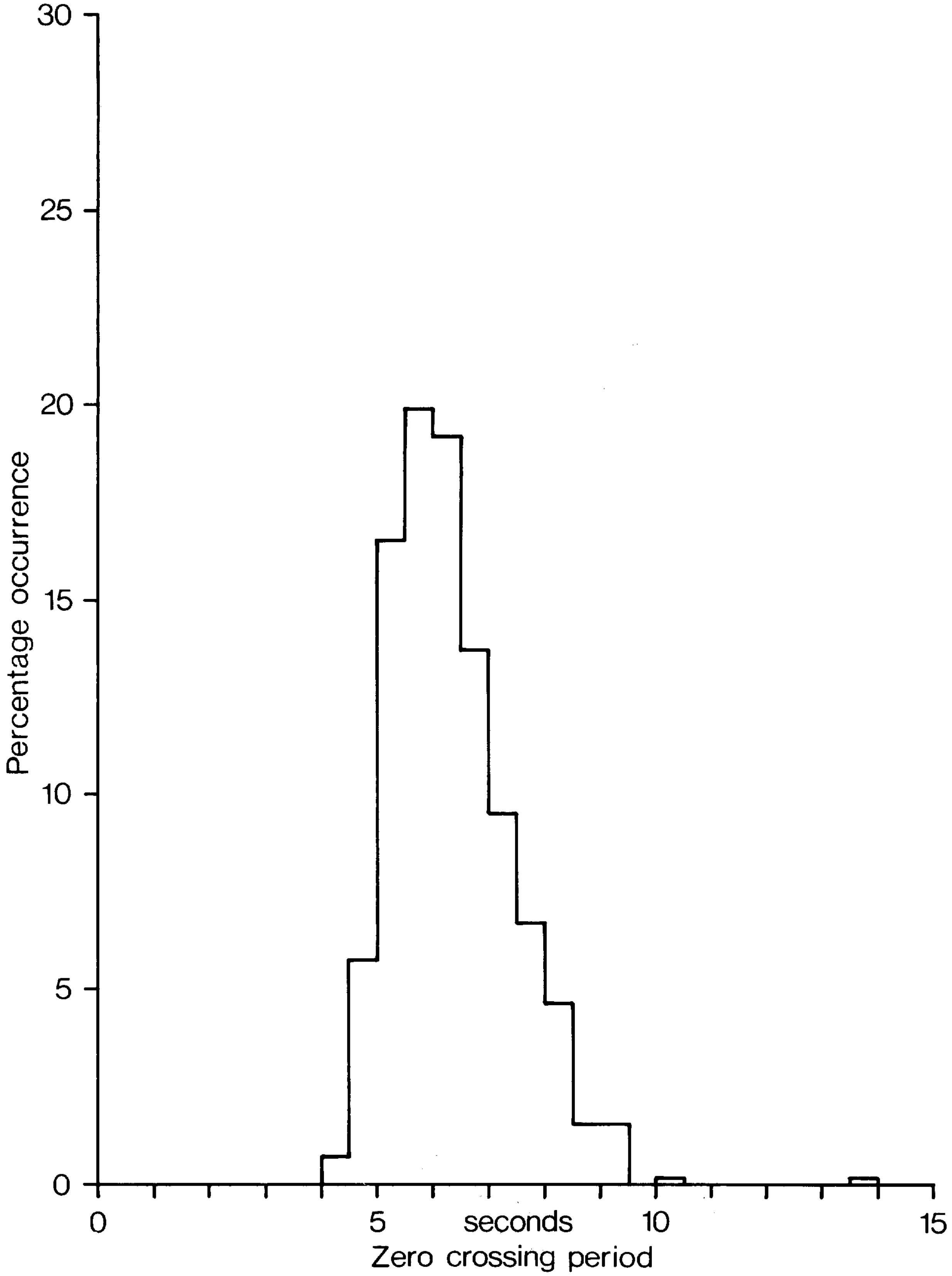
EC



Frequency histogram for zero crossing period - Autumn'76

Fig. 32 **Aldeburgh**

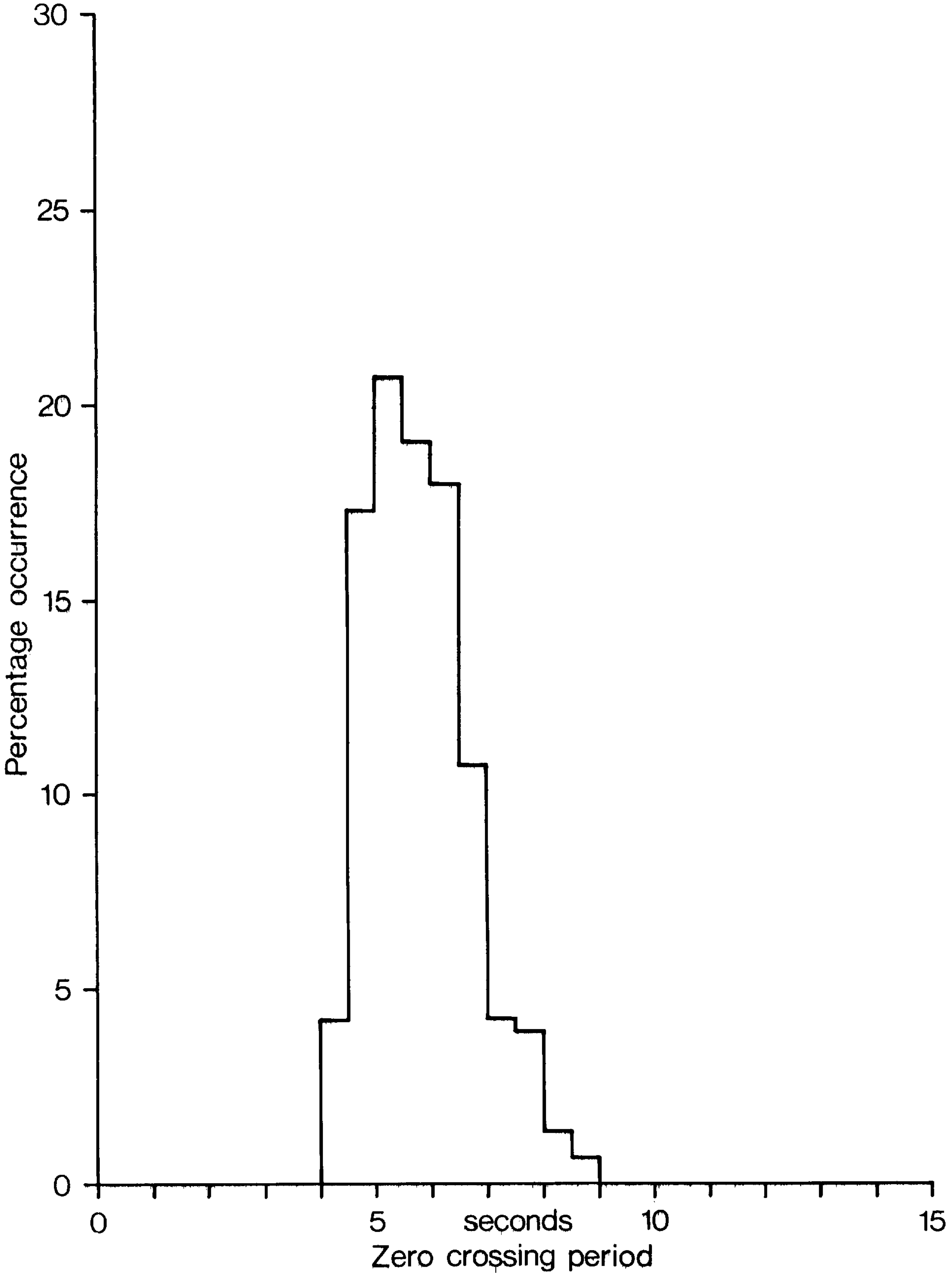
EC



Frequency histogram for zero crossing period - Winter '76-7

Fig. 33 **Aldeburgh**

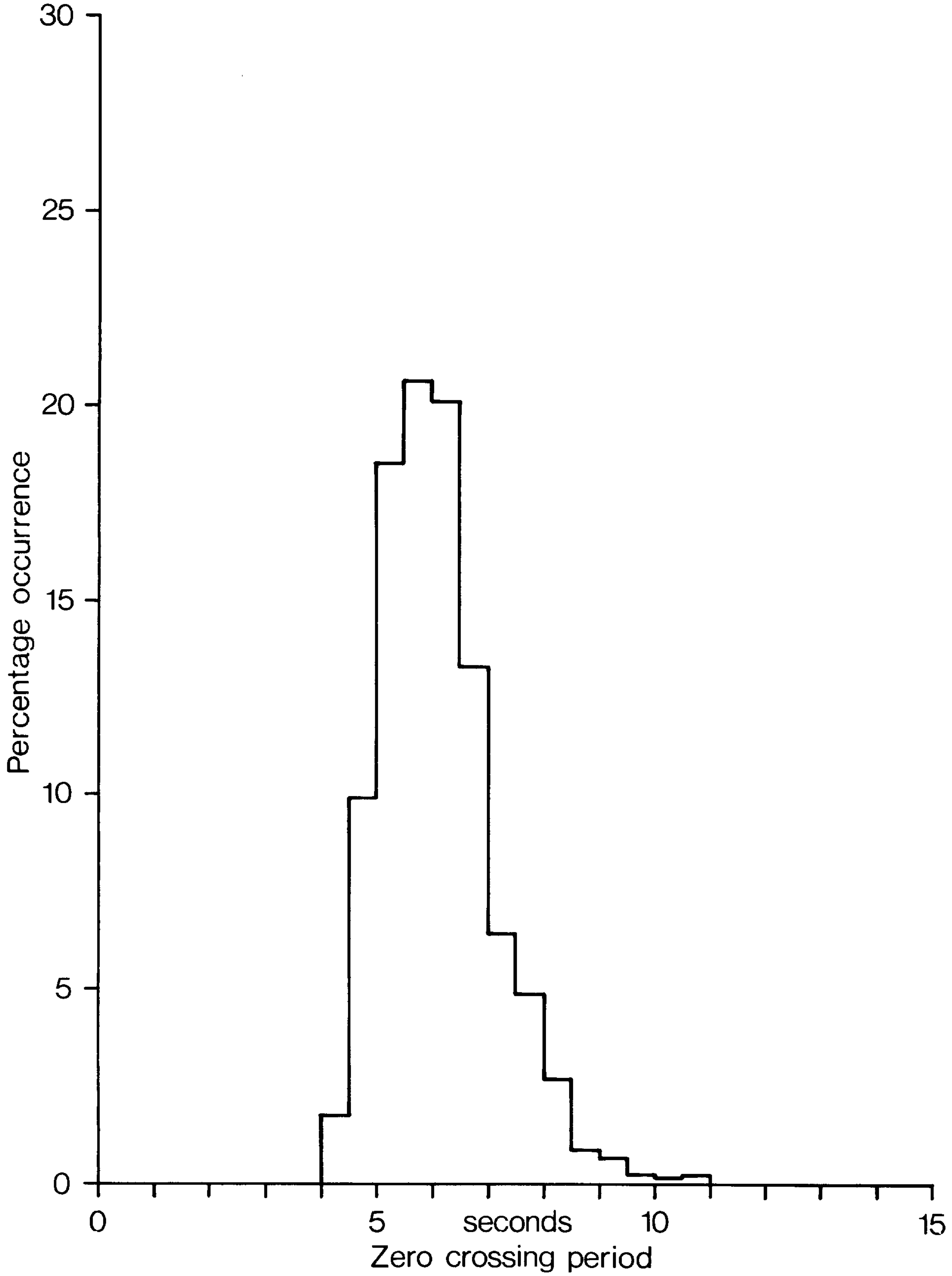
EC



Frequency histogram for zero crossing period - Spring'77

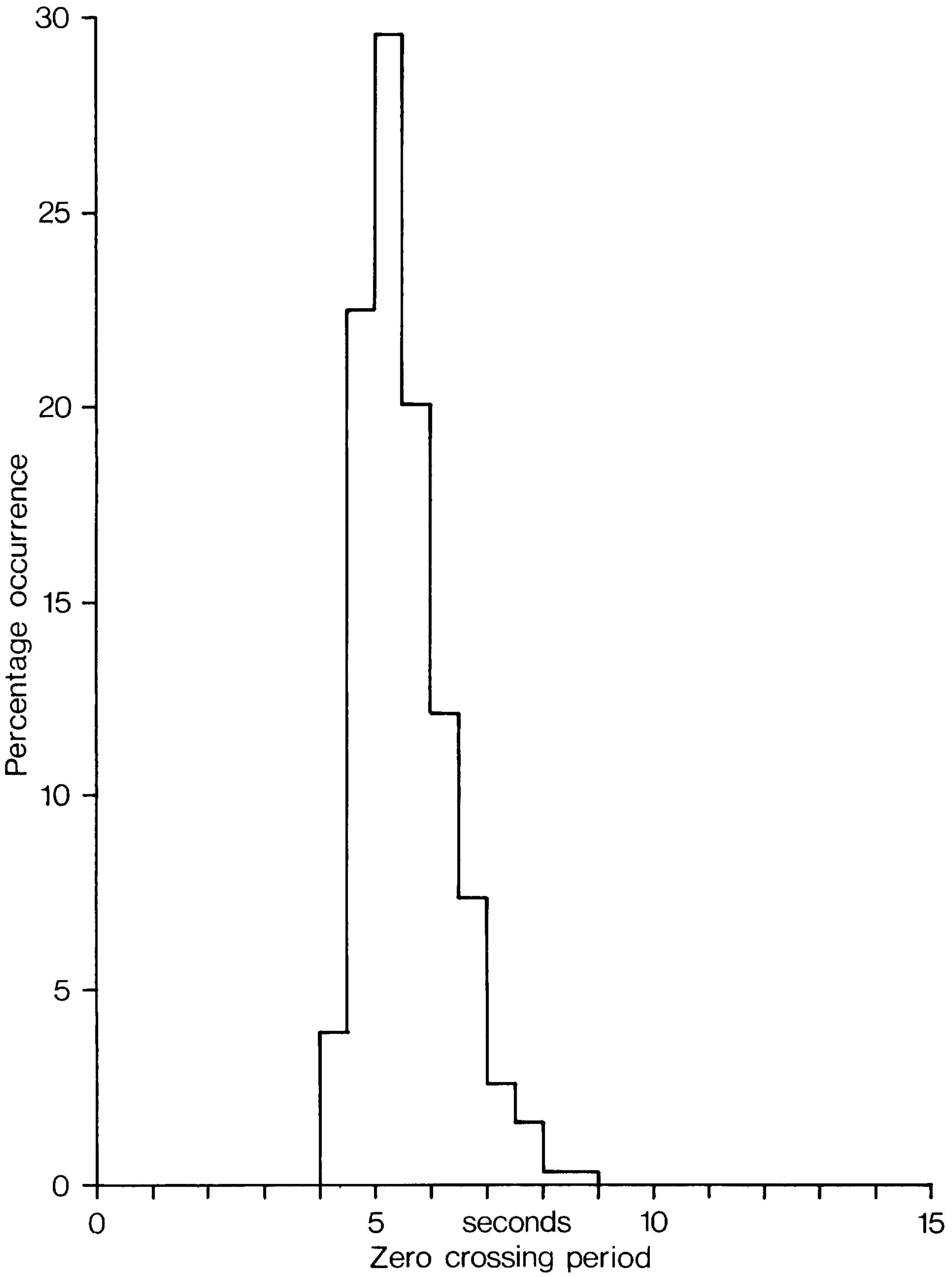
Fig. 34 **Aldeburgh**

EC



Frequency histogram for zero crossing period - Annual '76-7
Fig. 35 **Aldeburgh**

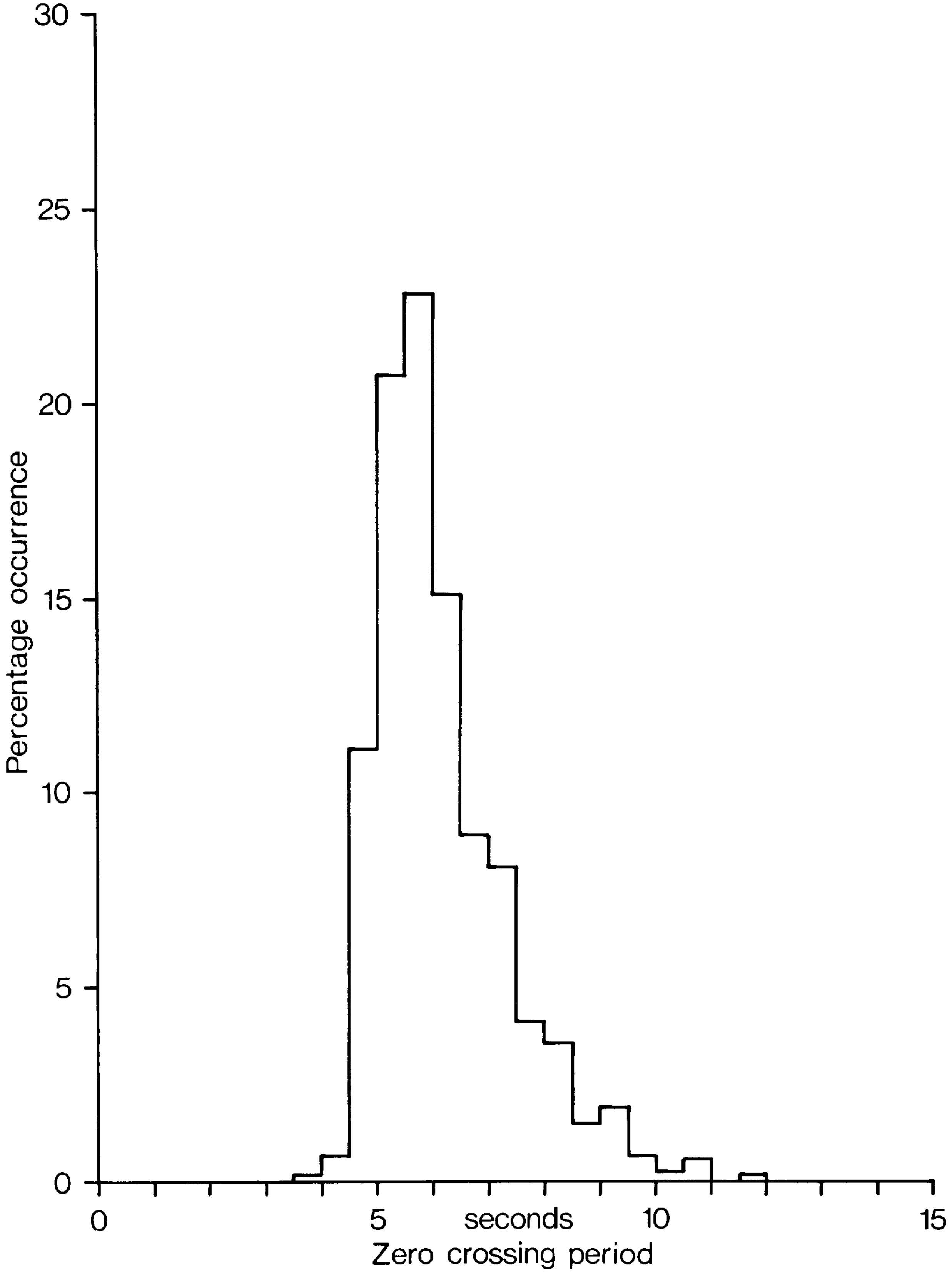
EC



Frequency histogram for zero crossing period - Summer'75

Fig. 36 **Dunwich**

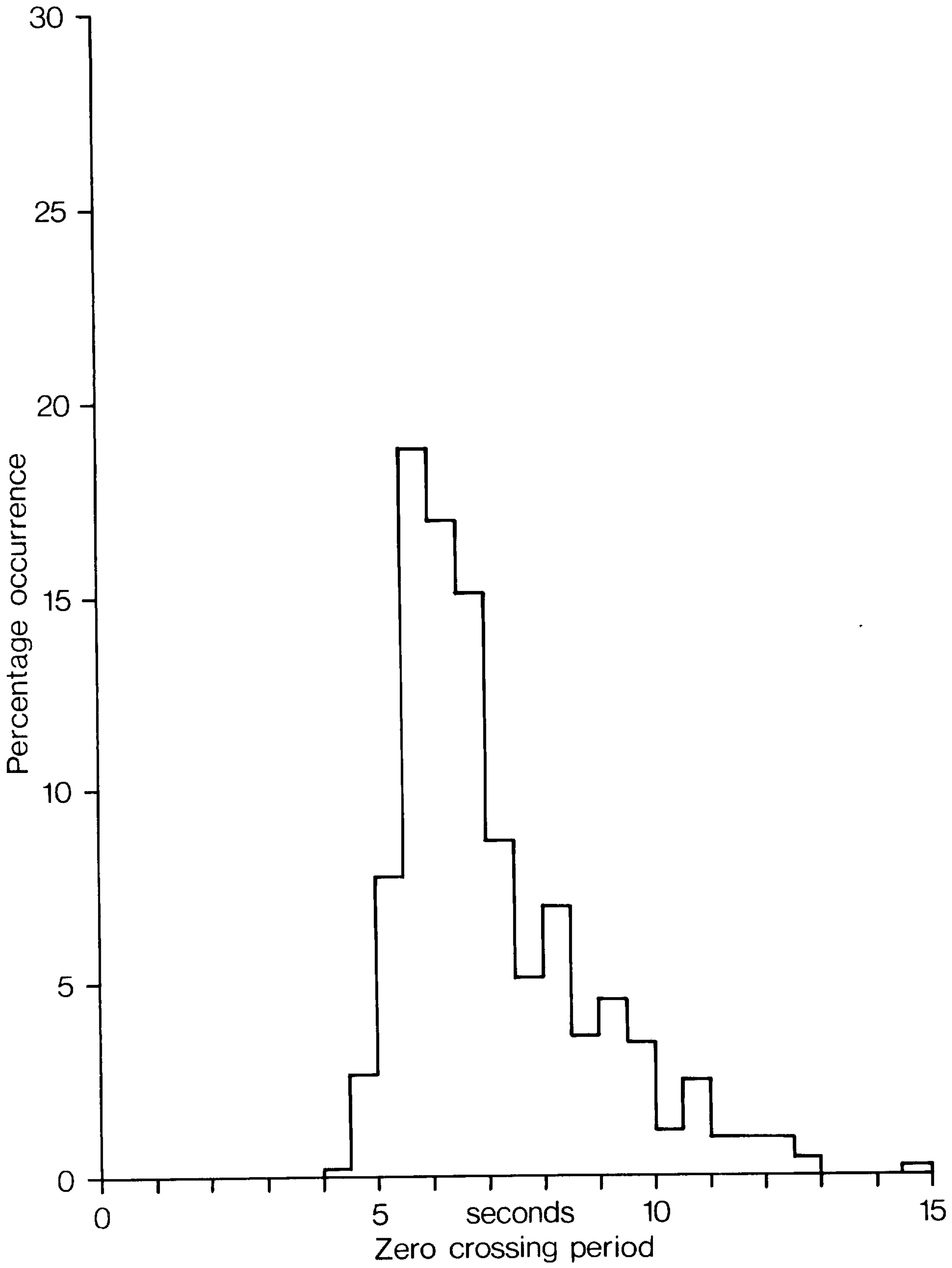
EC



Frequency histogram for zero crossing period - Autumn '75

Fig. 37 **Dunwich**

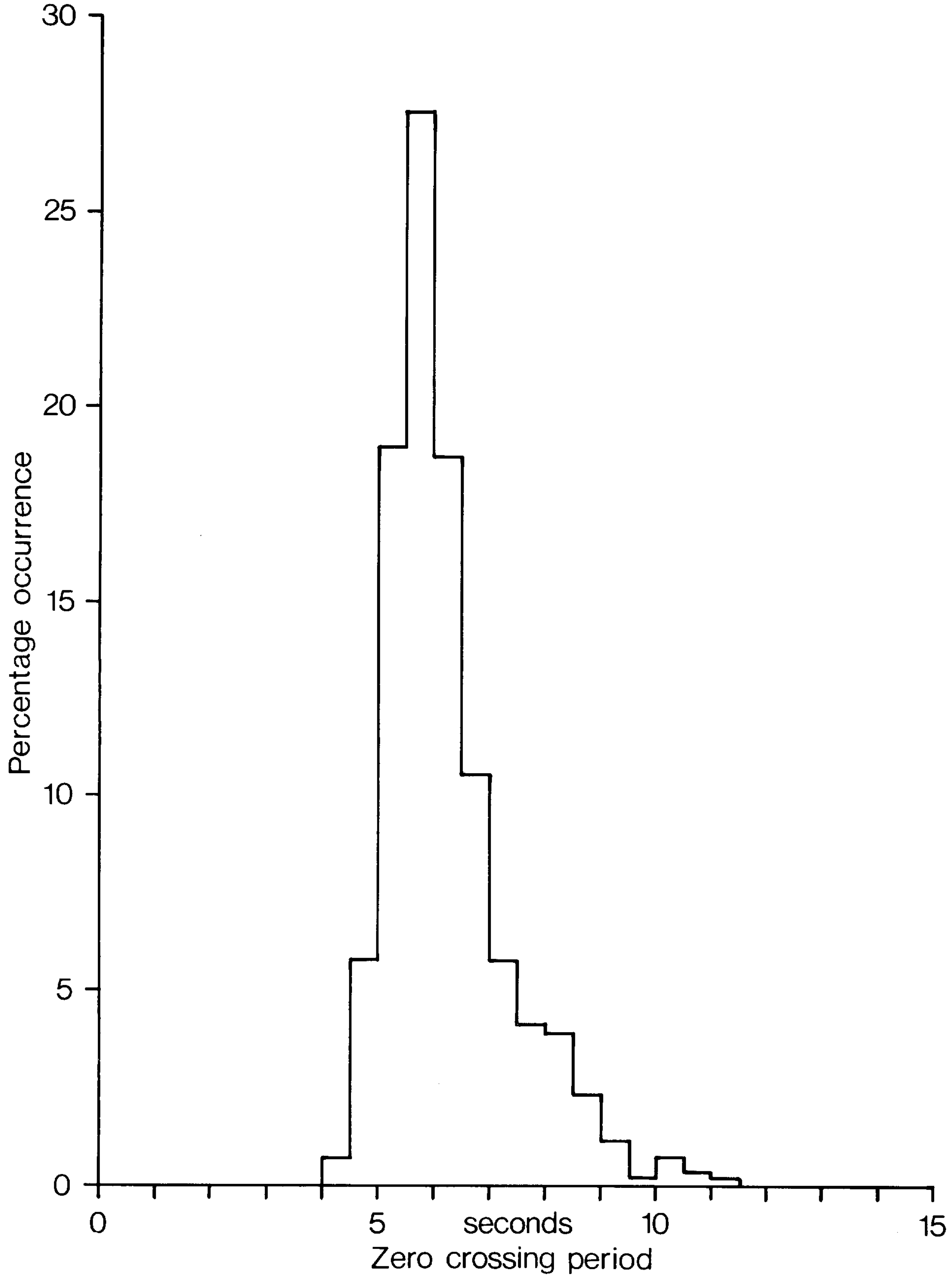
EC



Frequency histogram for zero crossing period - Winter '75-6

Fig. 38 **Dunwich**

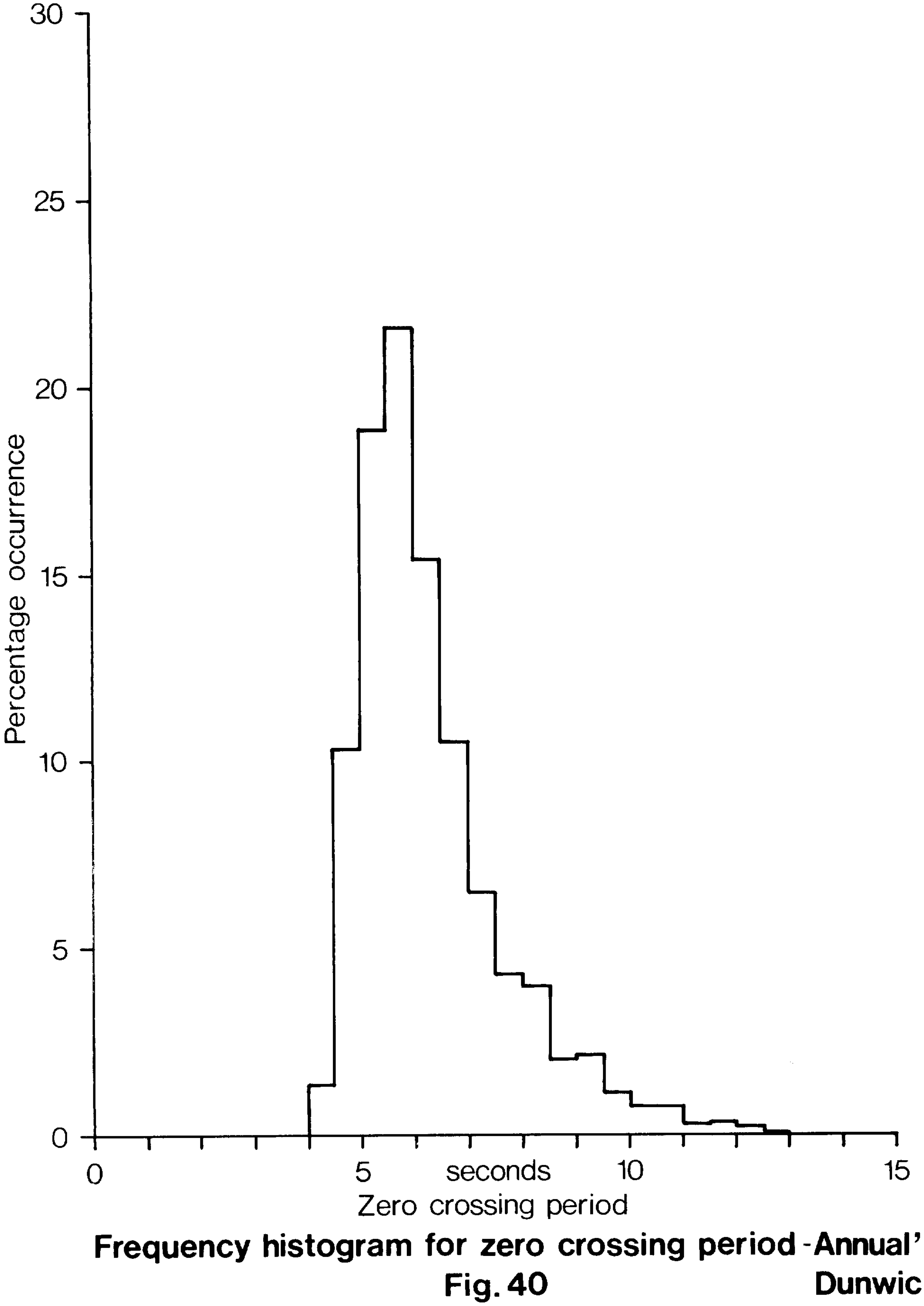
EC



Frequency histogram for zero crossing period - Spring '76

Fig. 39 **Dunwich**

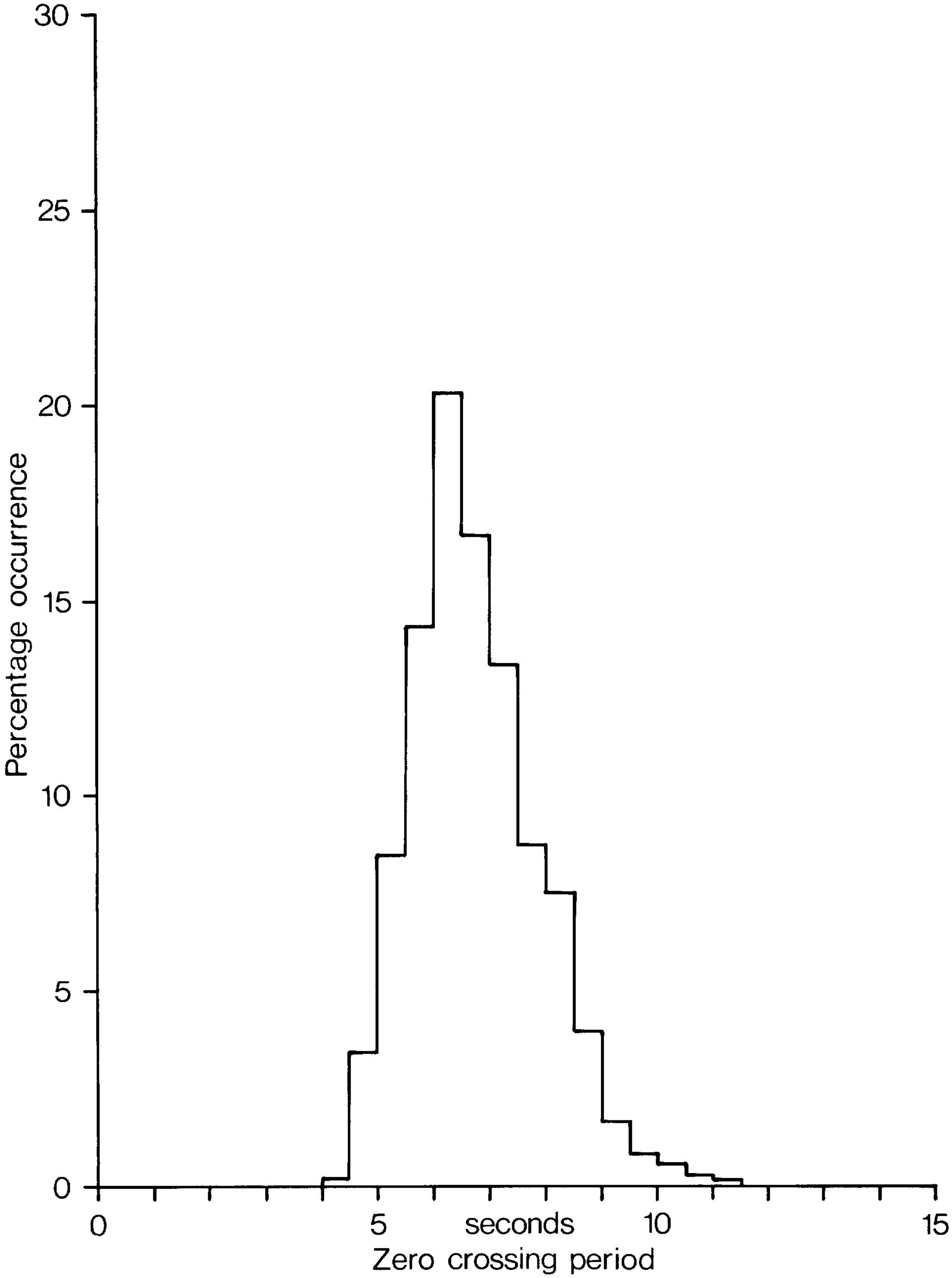
EC



Frequency histogram for zero crossing period - Annual '75-6

Fig. 40 **Dunwich**

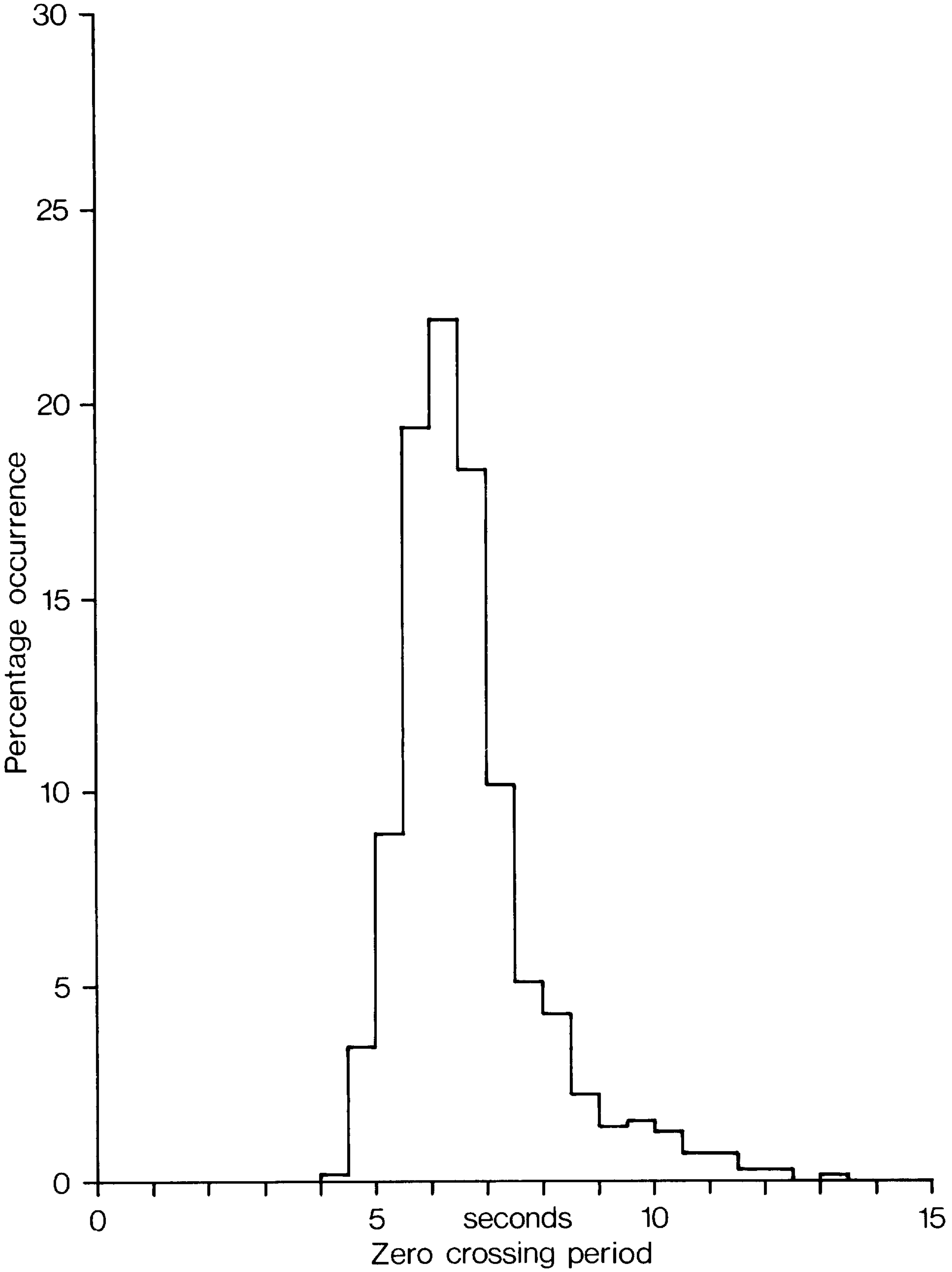
EC



Frequency histogram for zero crossing period - Summer '76

Fig. 41 **Dunwich**

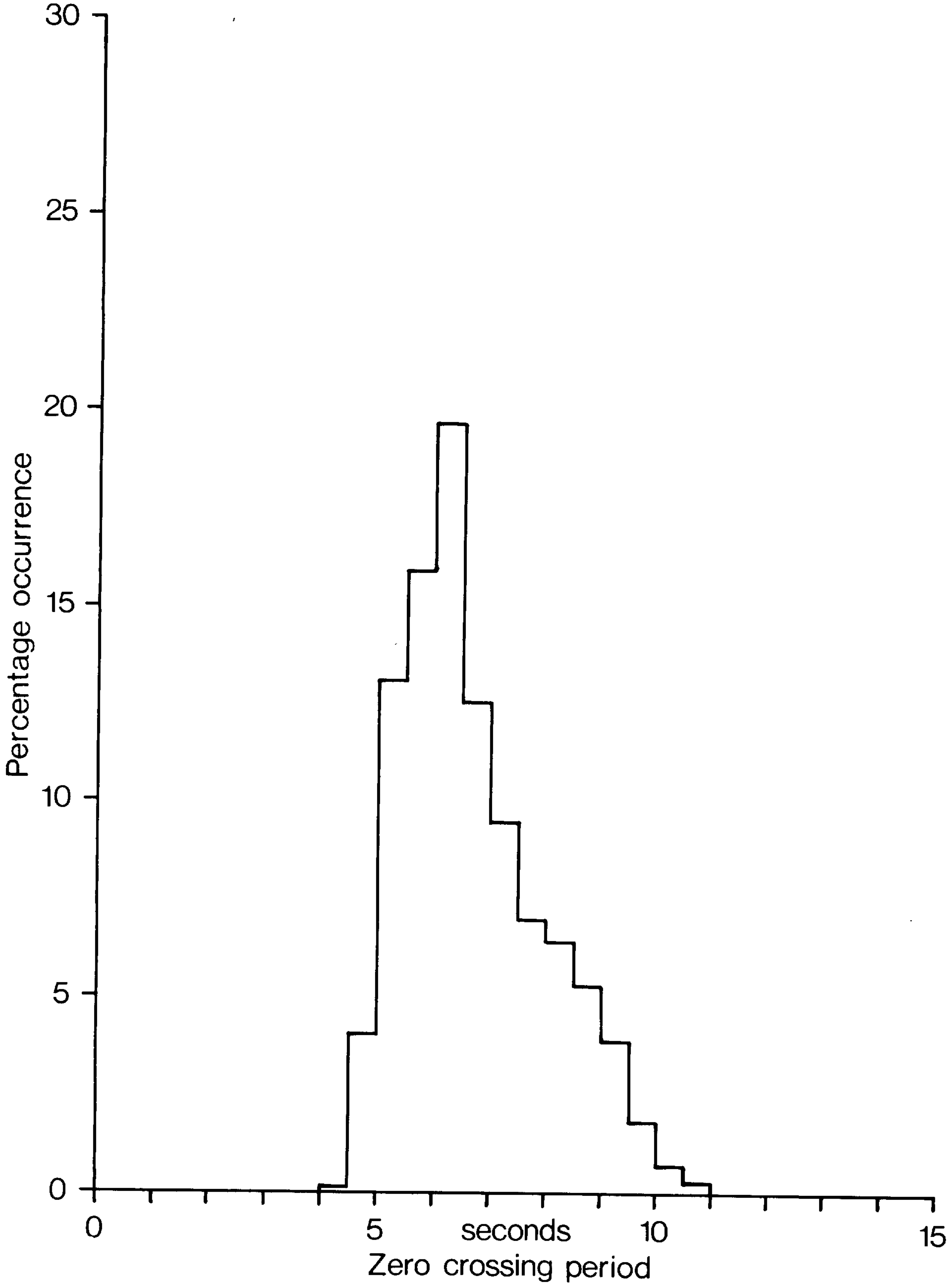
EC



Frequency histogram for zero crossing period - Autumn'76

Fig. 42 **Dunwich**

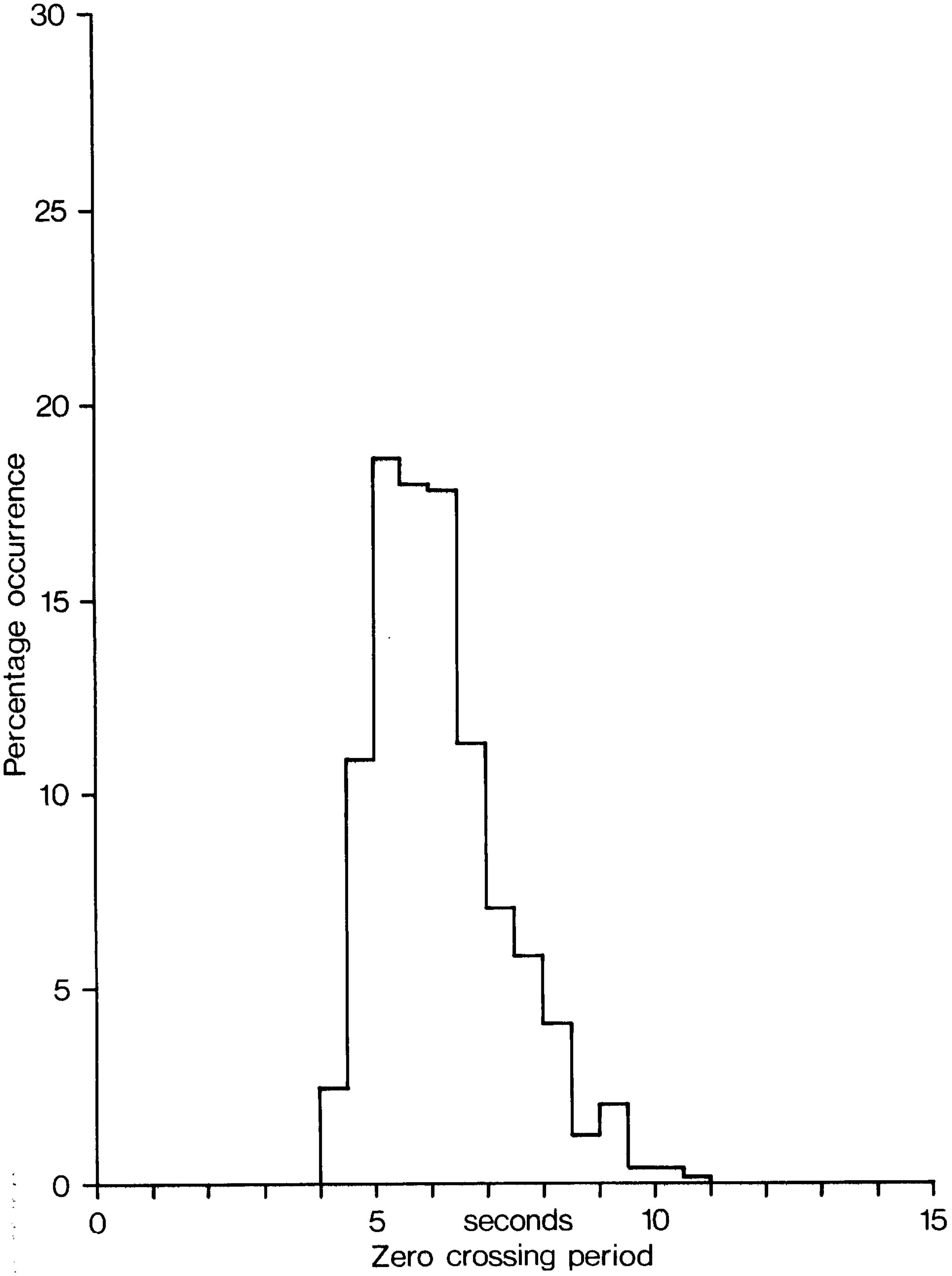
EC



Frequency histogram for zero crossing period - Winter '76-7

Fig. 43 **Dunwich**

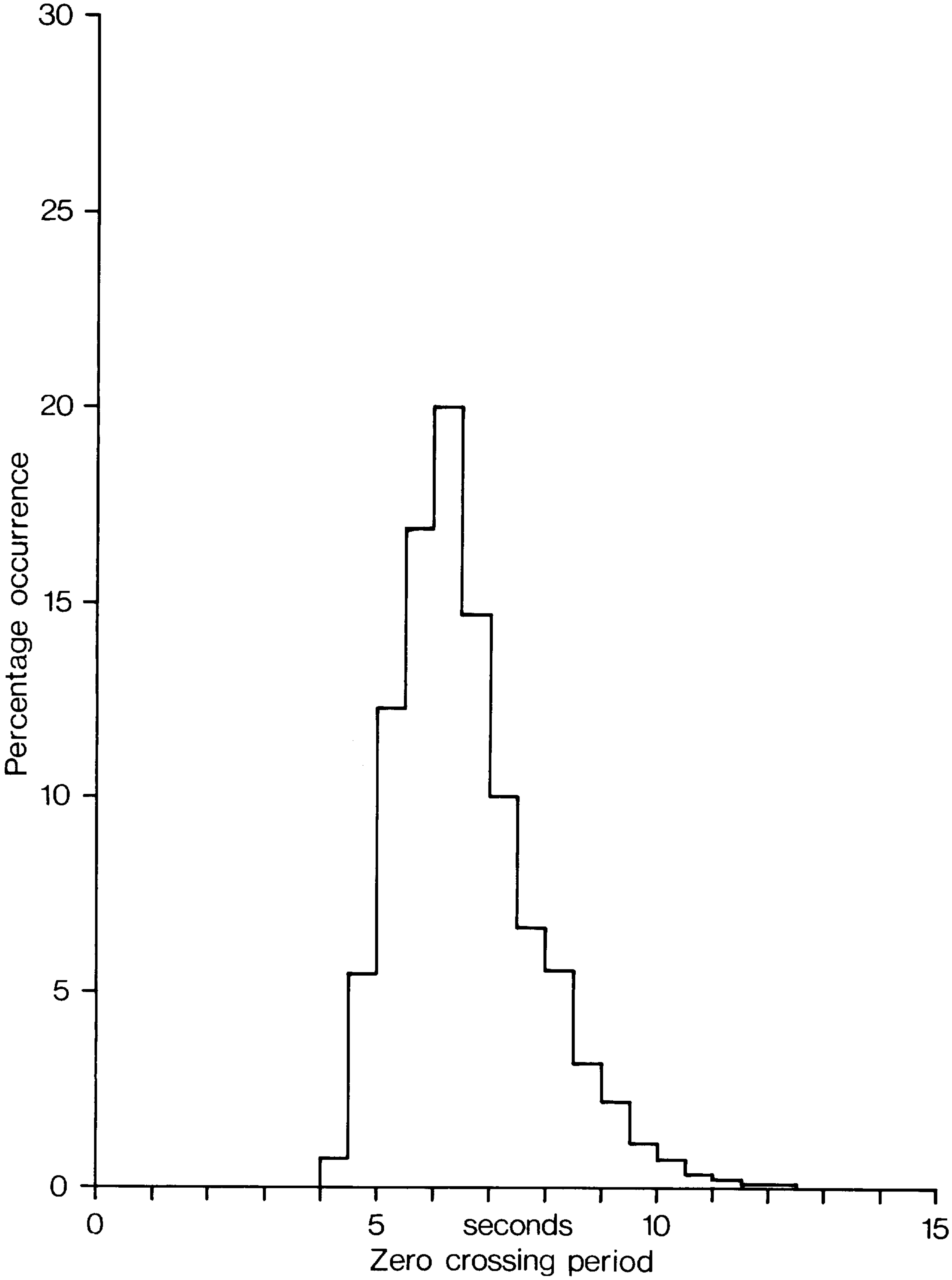
EC



Frequency histogram for zero crossing period - Spring'77

Fig. 44 **Dunwich**

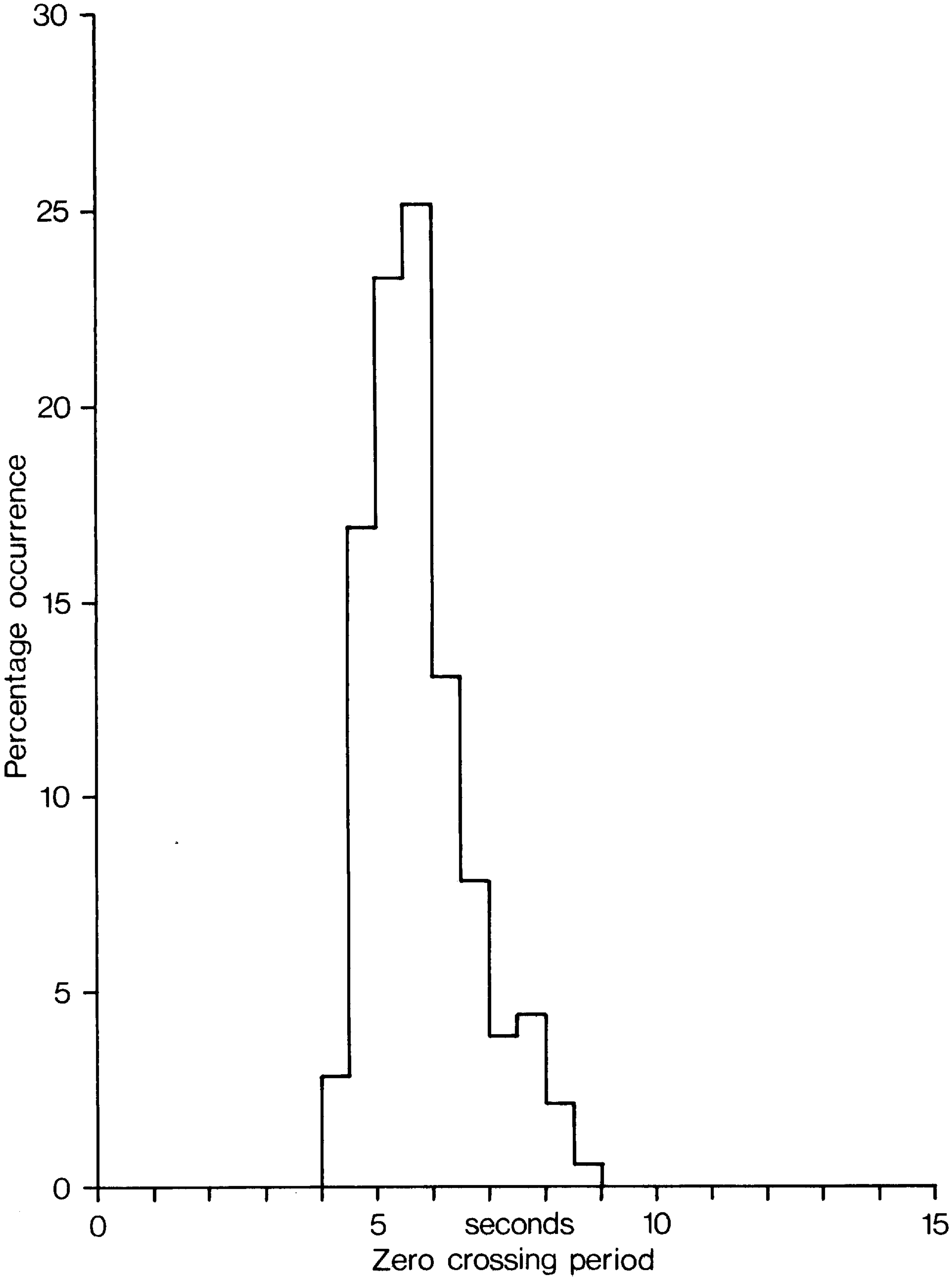
EC



Frequency histogram for zero crossing period -Annual'76-7

Fig. 45 **Dunwich**

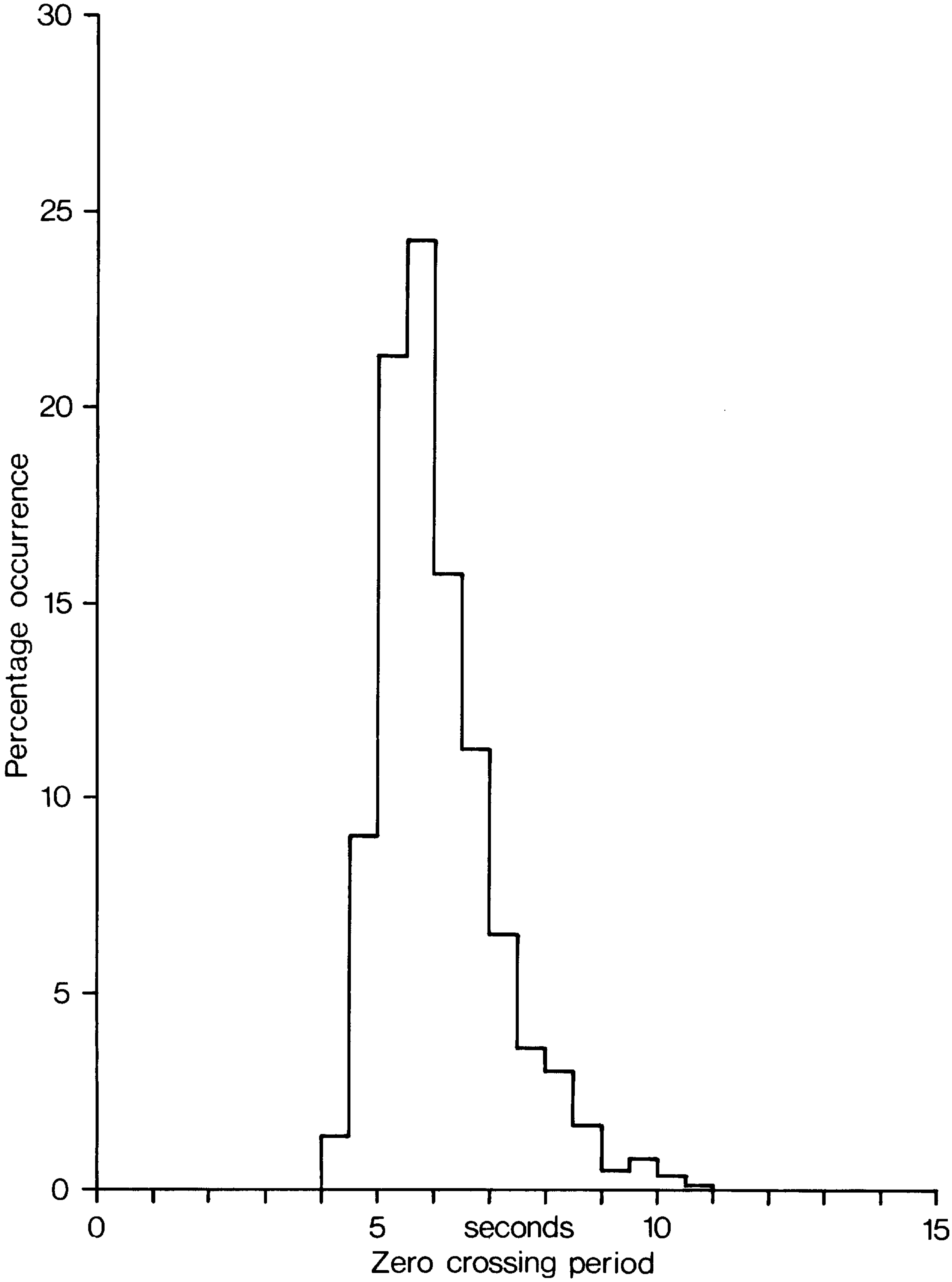
EC



Frequency histogram for zero crossing period - Summer'75

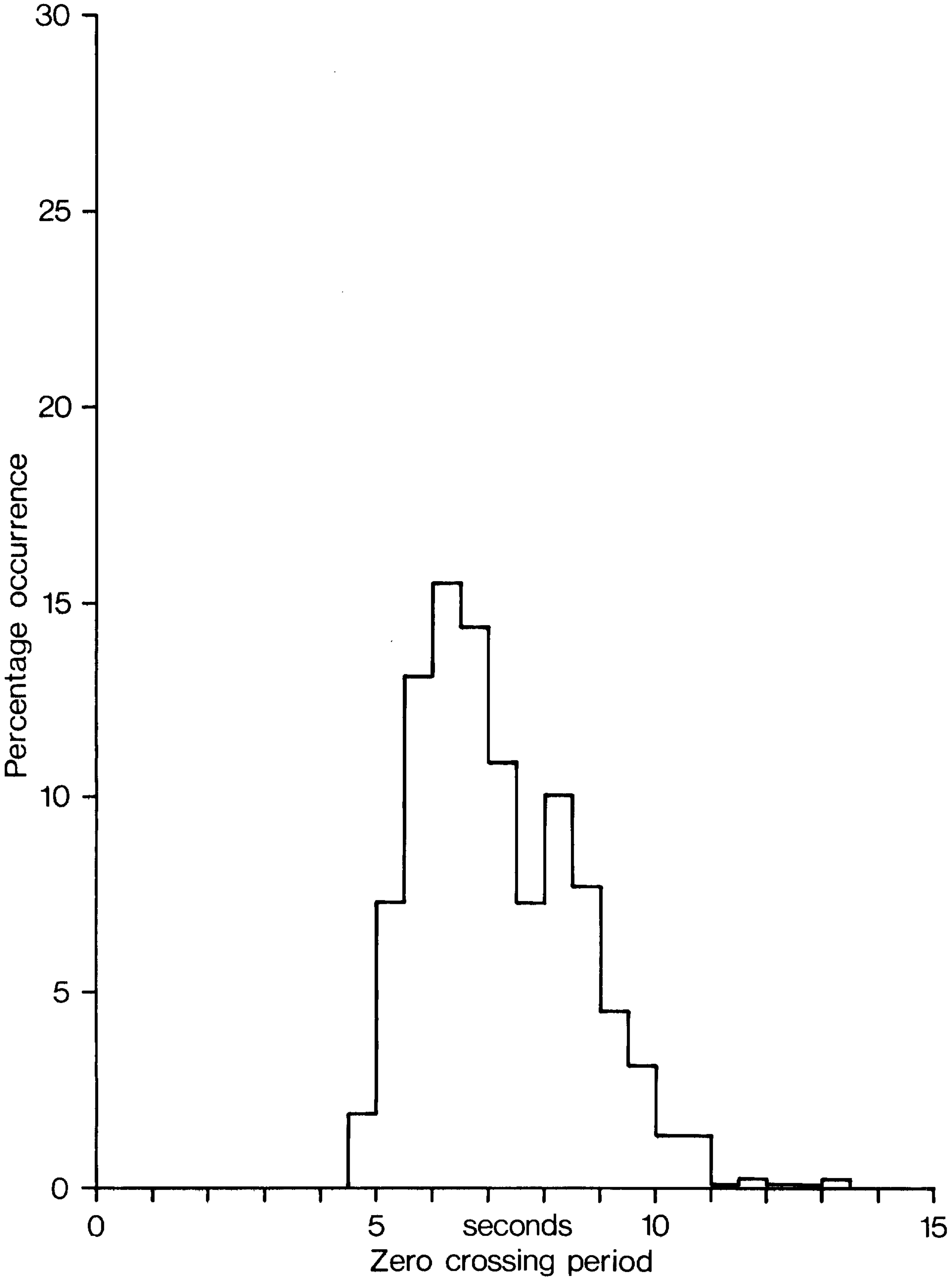
Fig. 46 **Southwold**

EC



Frequency histogram for zero crossing period - Autumn'75
Fig. 47 **Southwold**

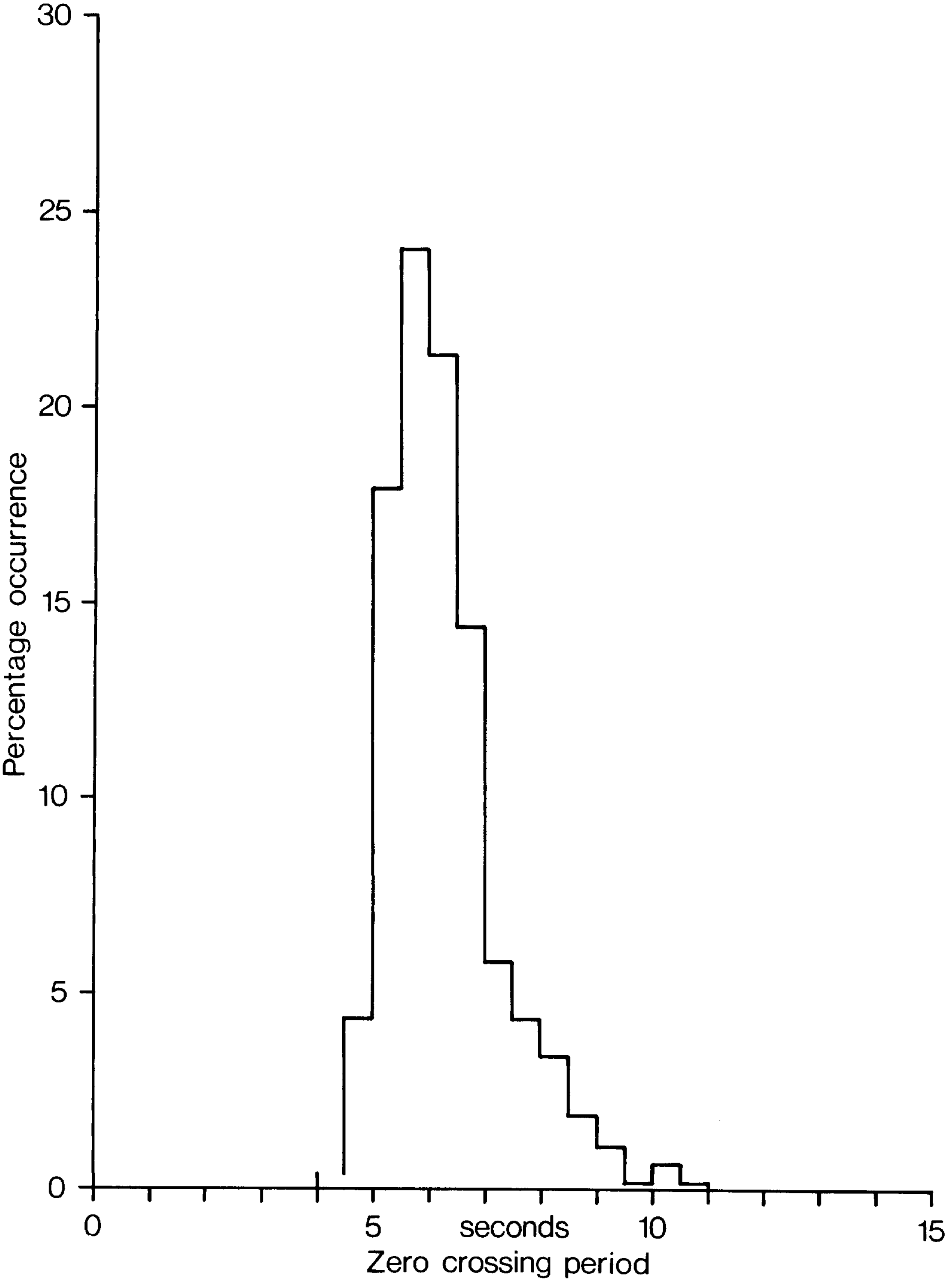
EC



Frequency histogram for zero crossing period - Winter'75-6

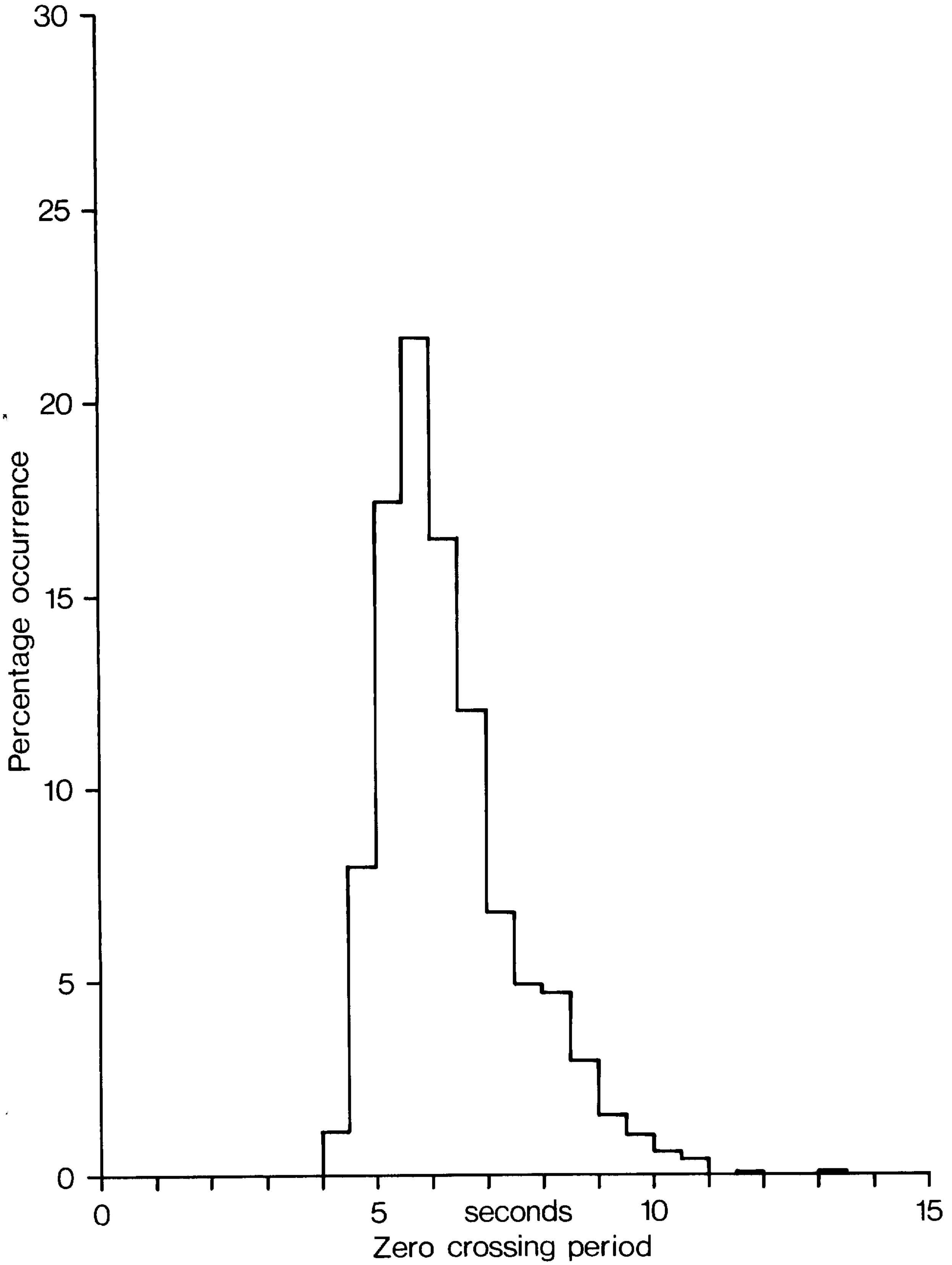
Fig. 48 **Southwold**

EC



Frequency histogram for zero crossing period - Spring'76
Fig. 49 **Southwold**

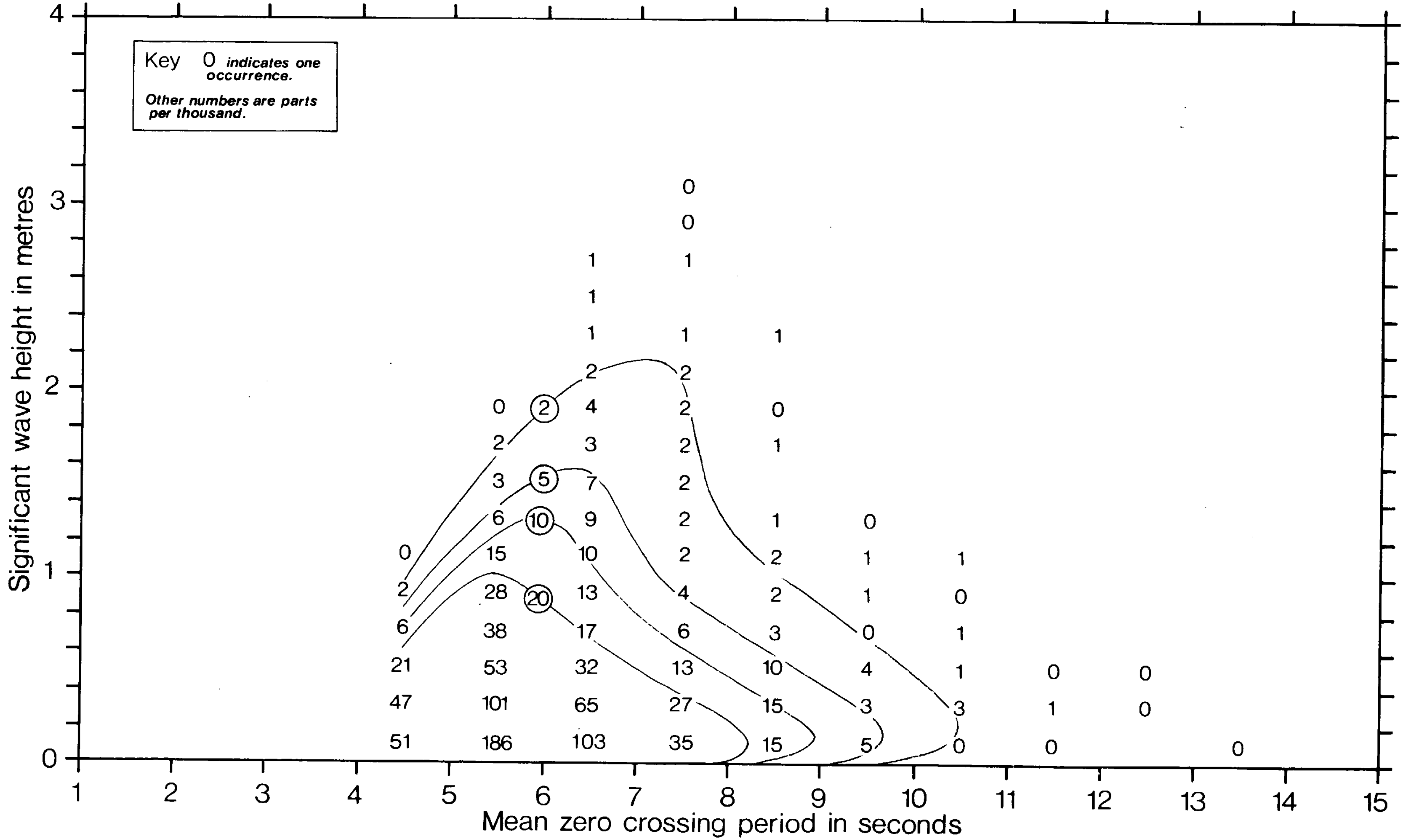
EC



Frequency histogram for zero crossing period - Annual '75-6

Fig. 50 **Southwold**

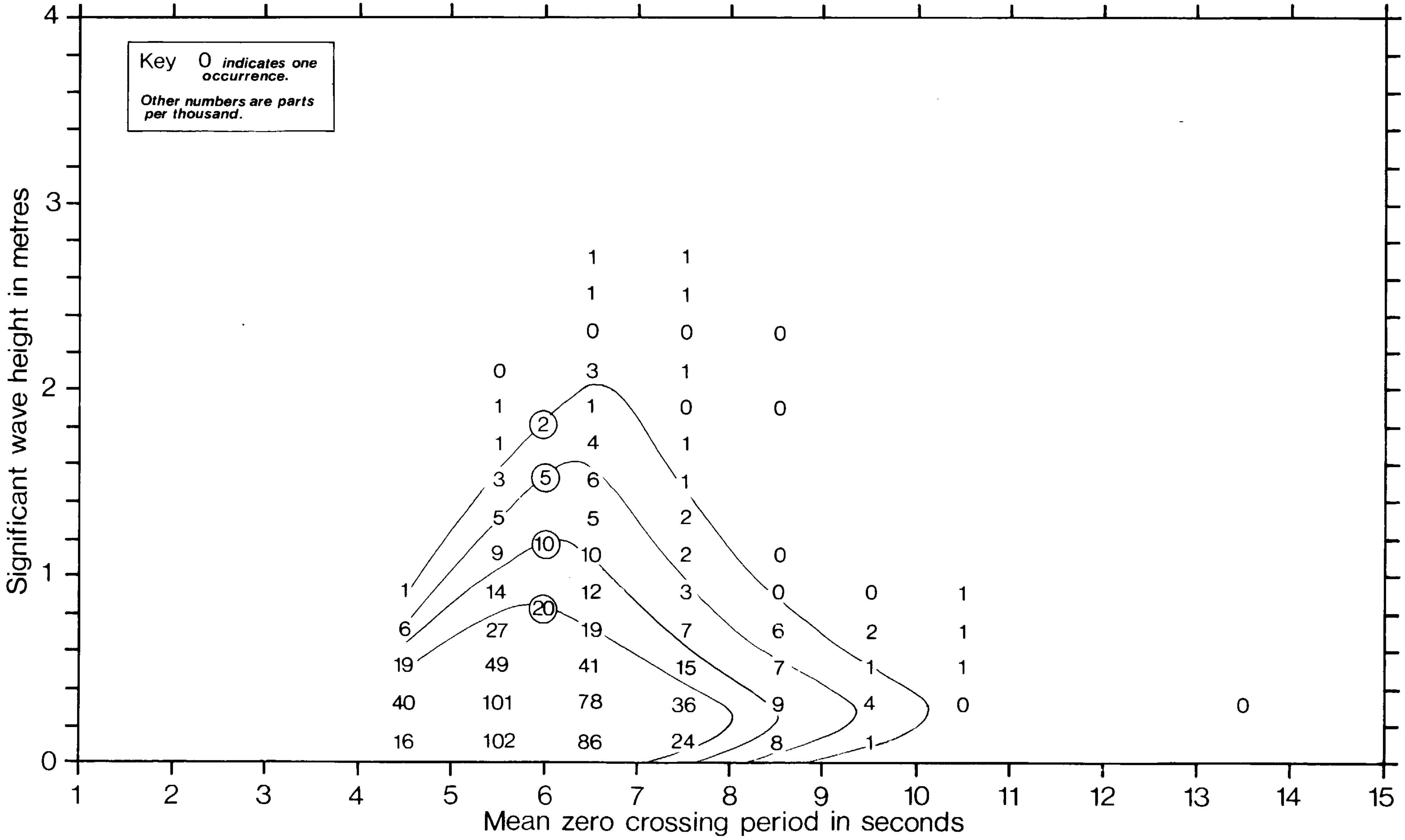
EC



Scatter diagram in parts per thousand - Annual '75-6 **Aldeburgh**

Fig. 51

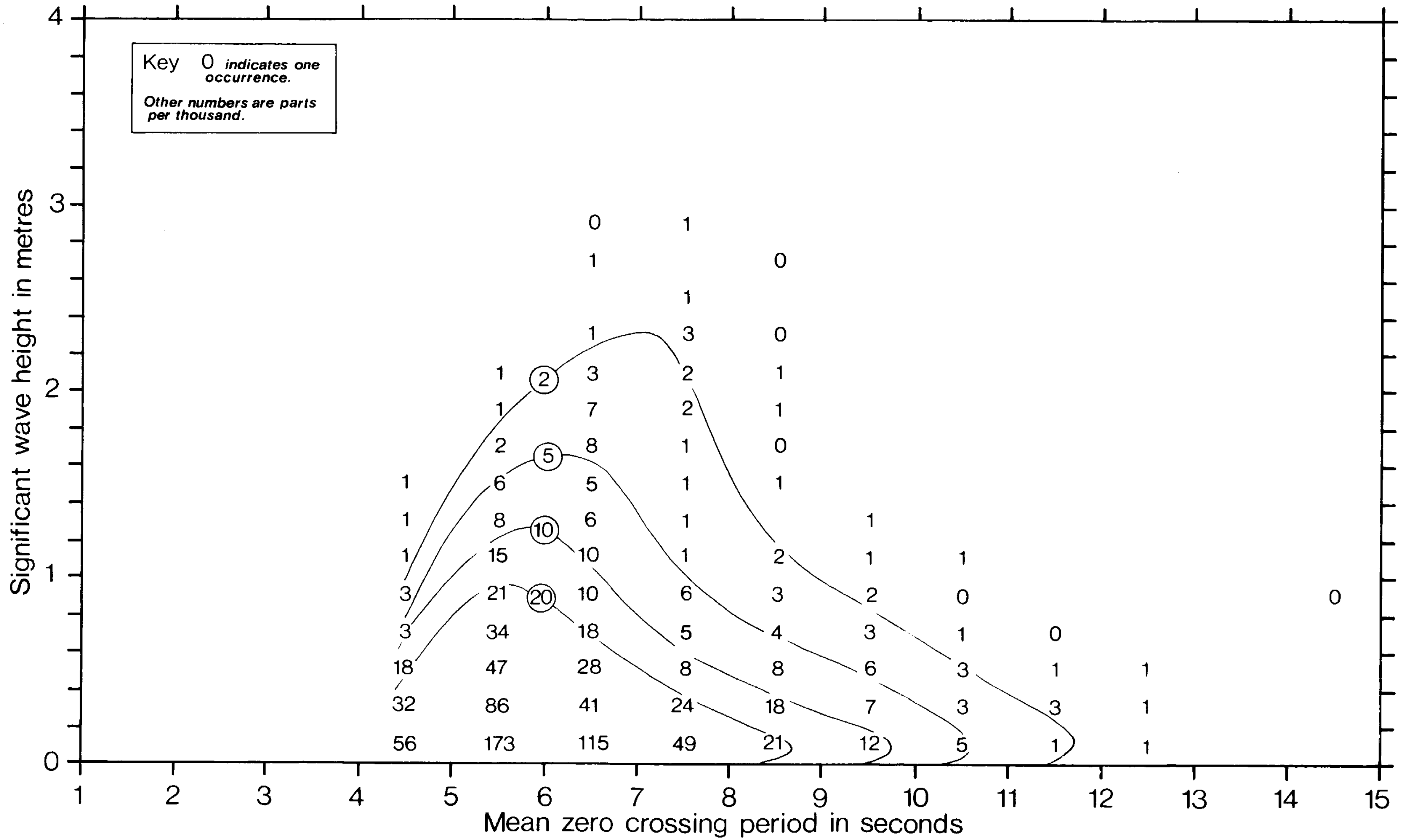
EC



Scatter diagram in parts per thousand - Annual'76-7 **Aldeburgh**

Fig. 52

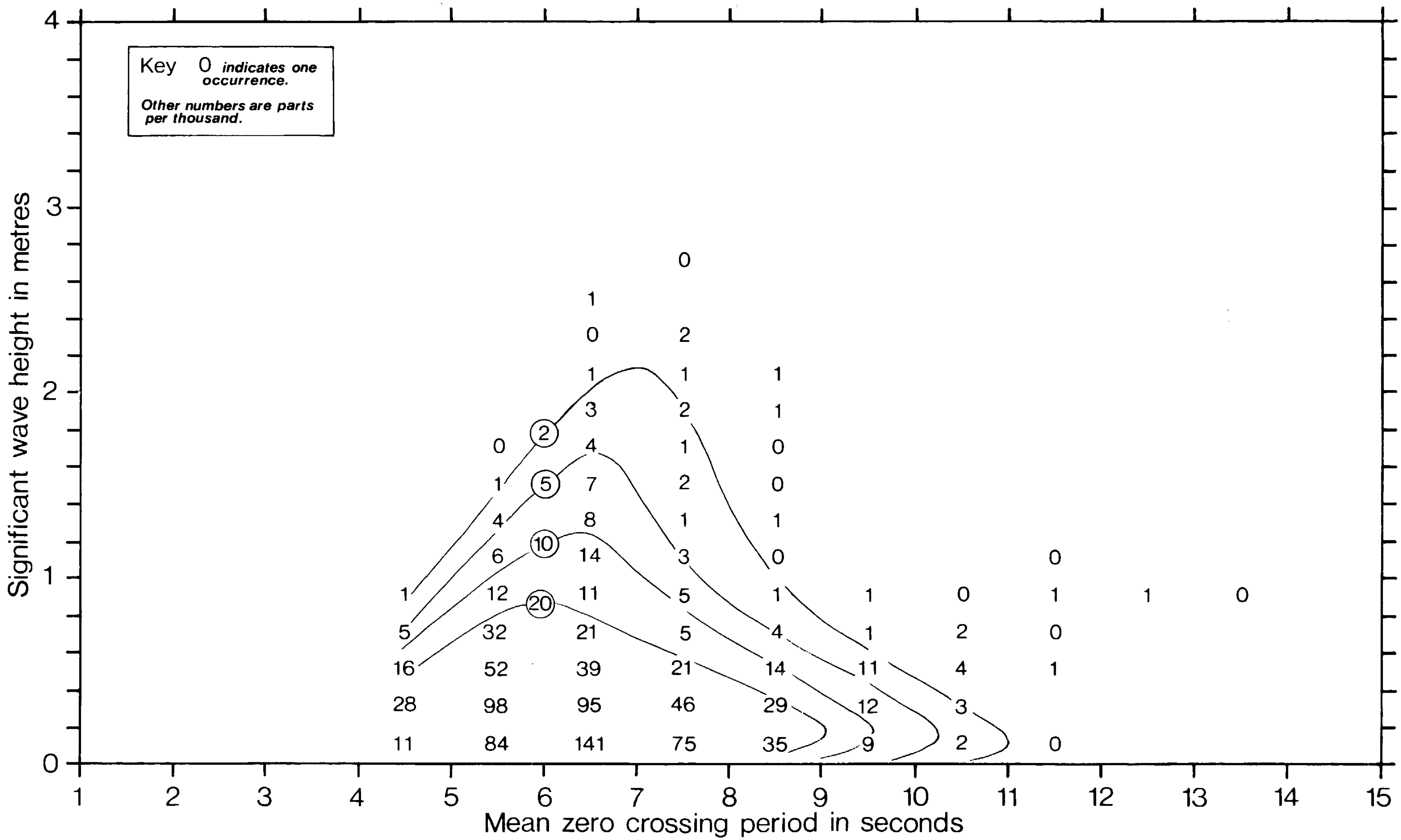
EC



Scatter diagram in parts per thousand - Annual '75-6 Dunwich

Fig.53

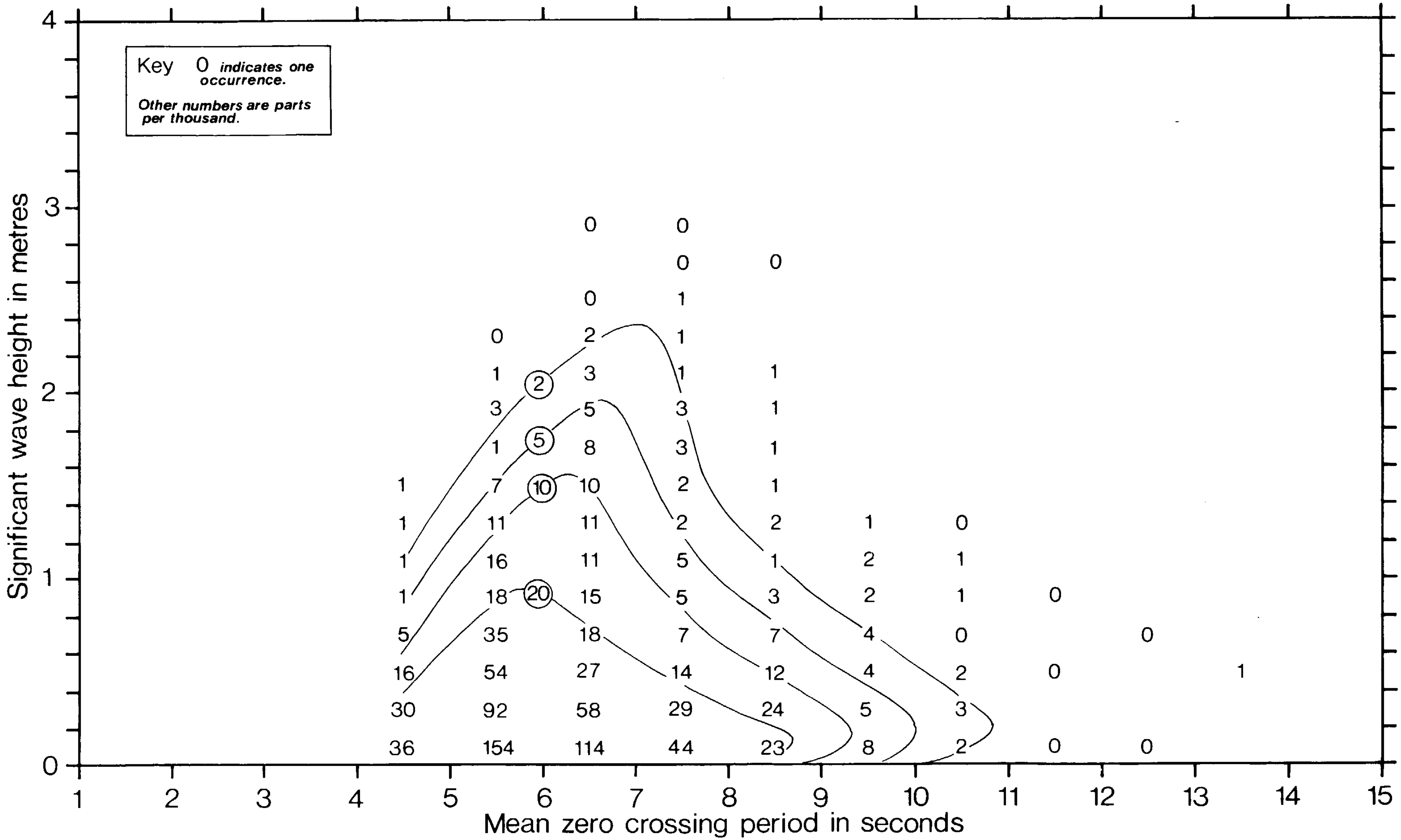
EC



Scatter diagram in parts per thousand - Annual '76-7 Dunwich

Fig. 54

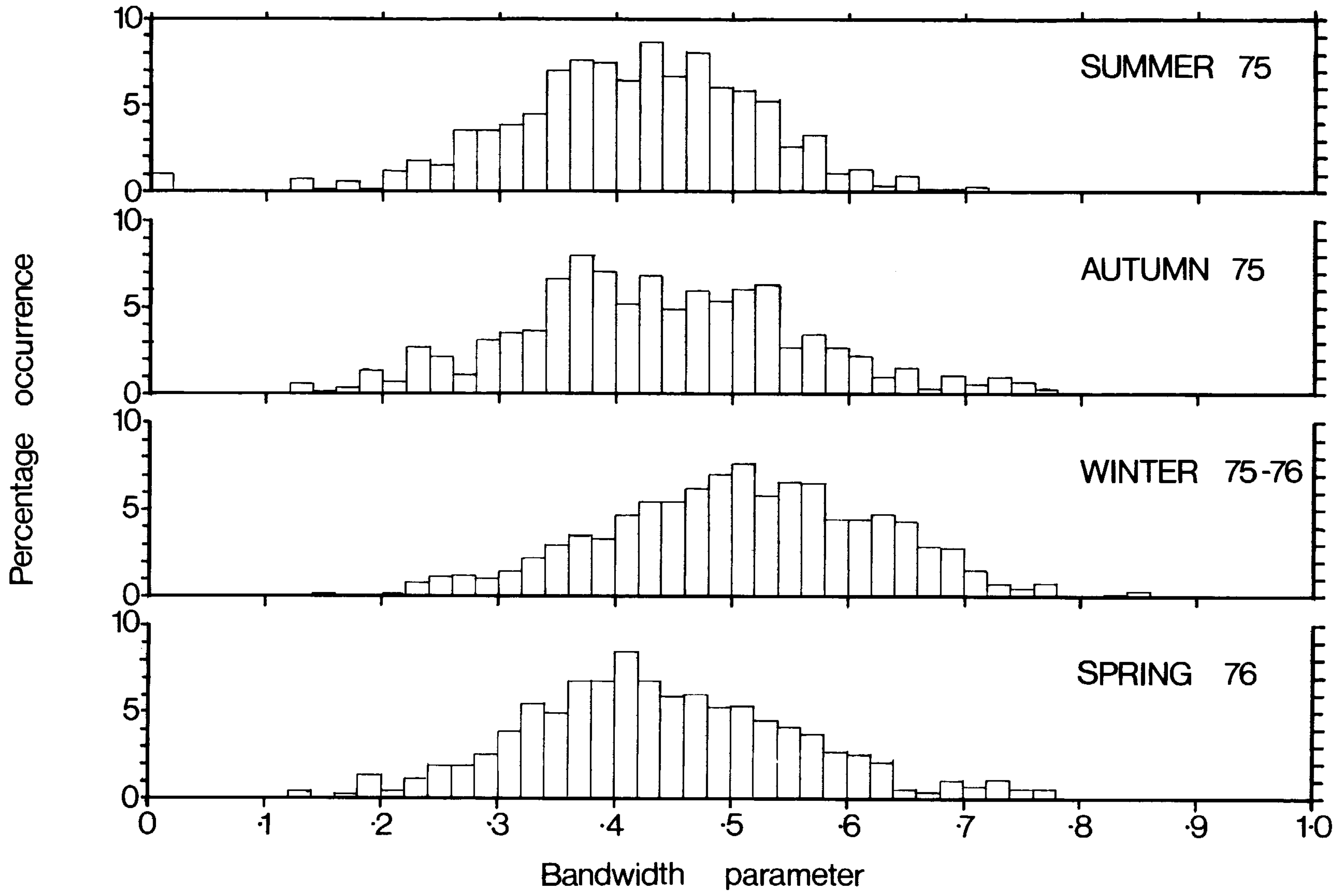
EC



Scatter diagram in parts per thousand - Annual'75-6 Southwold

Fig. 55

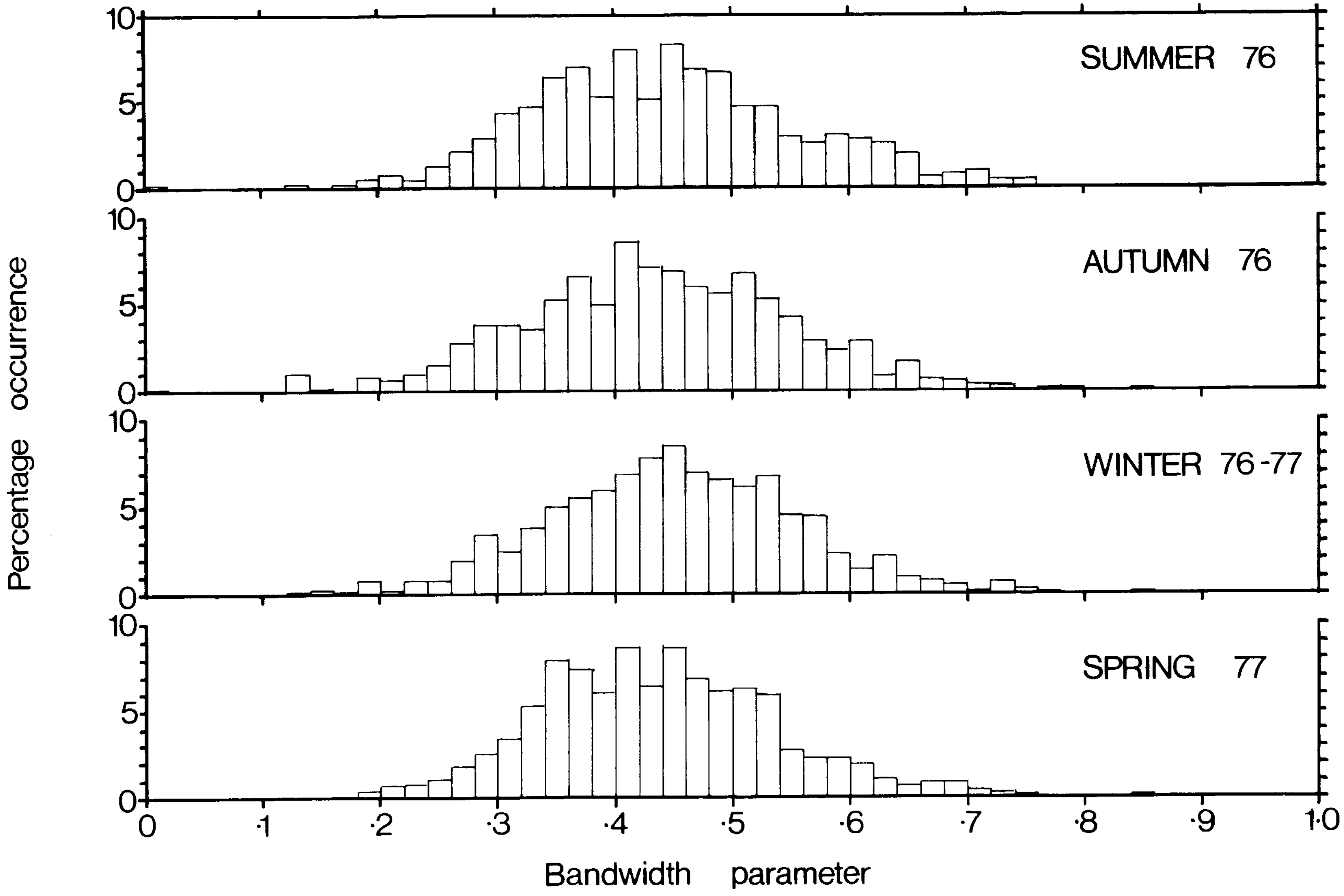
EC



Frequency histograms for Bandwidth parameter Annual' 75-6 Aldeburgh

Fig. 56

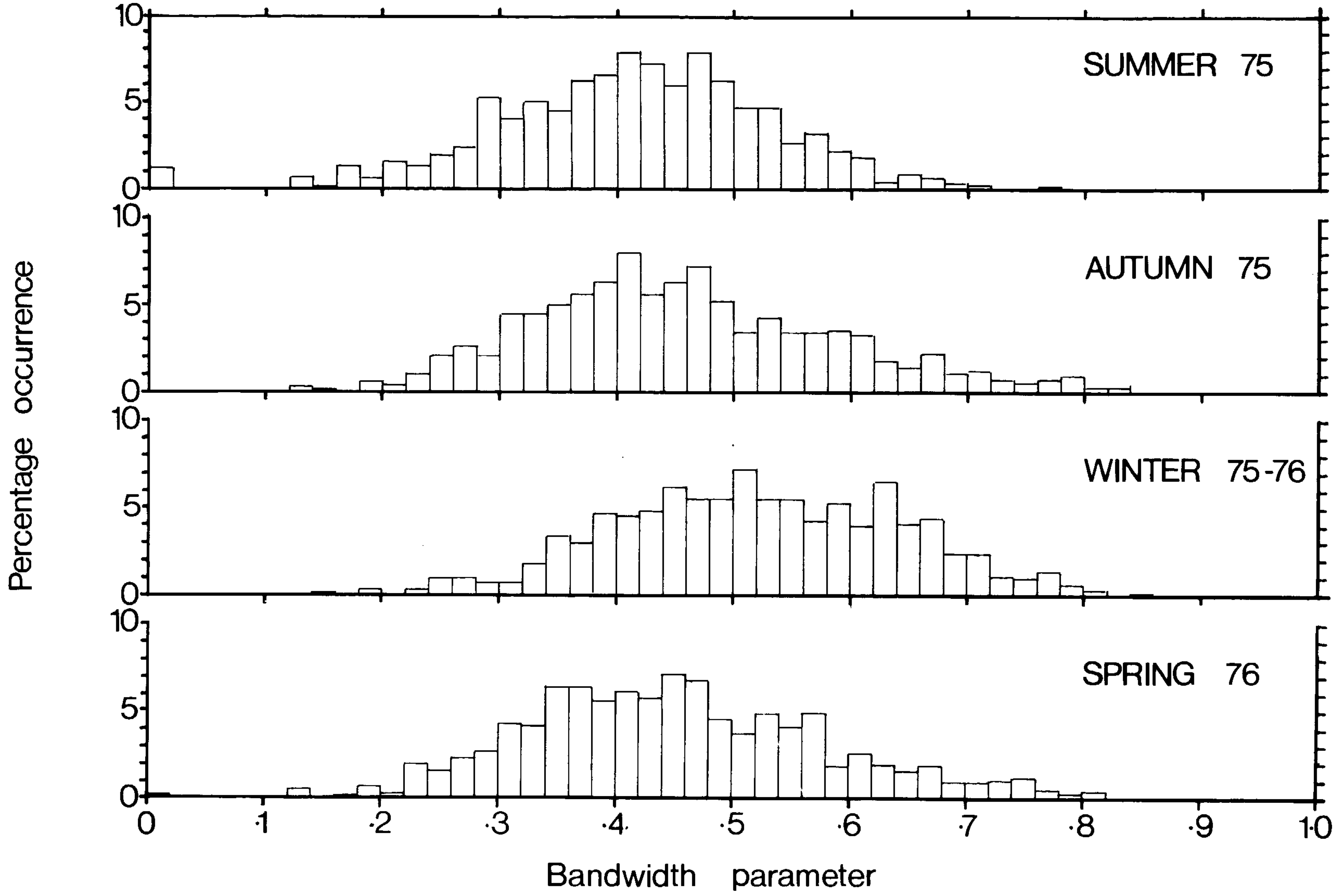
EC



Frequency histograms for Bandwidth parameter Annual' 76-7 Aldeburgh

Fig. 57

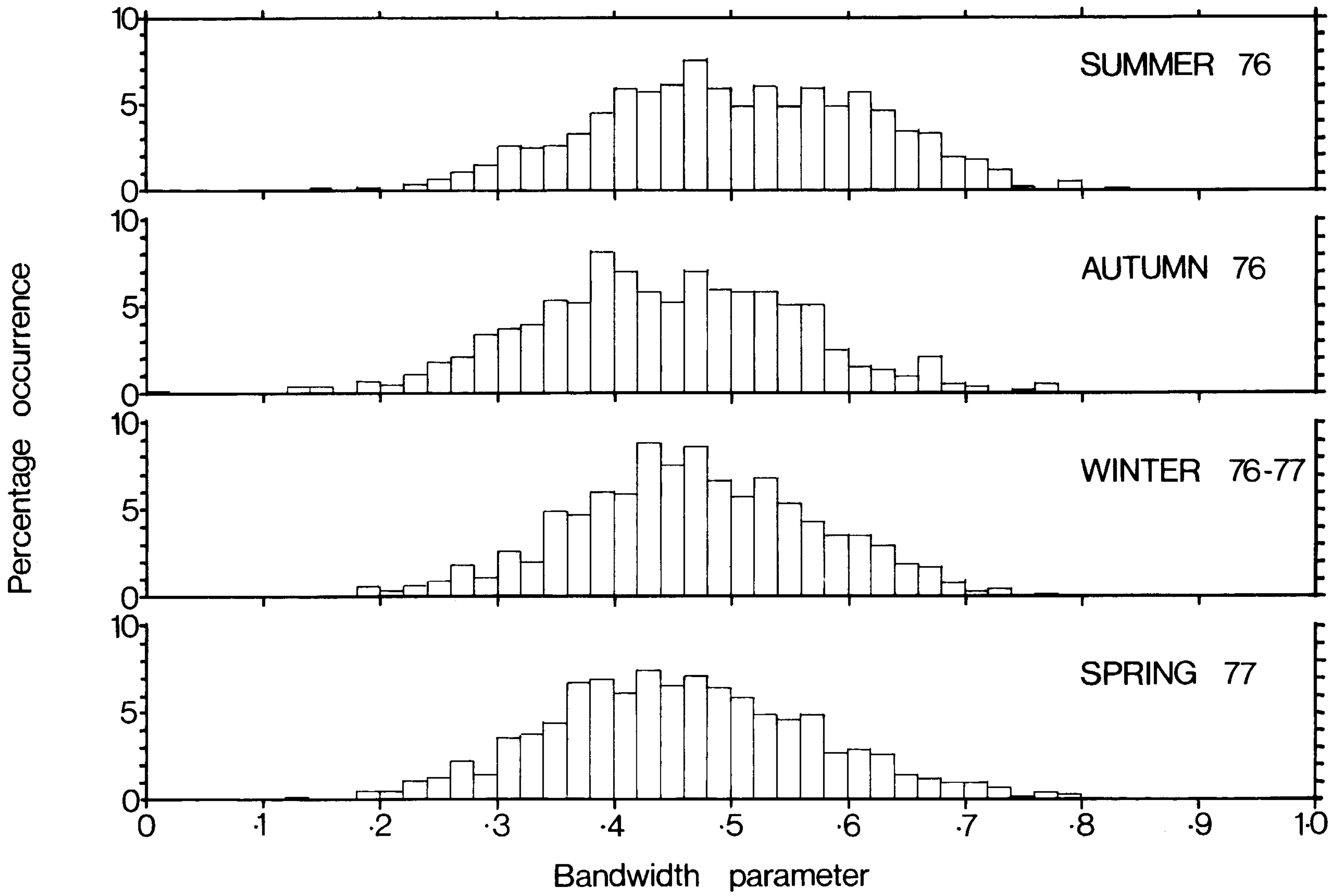
EC



Frequency histograms for Bandwidth parameter Annual' 75-6 Dunwich

Fig. 58

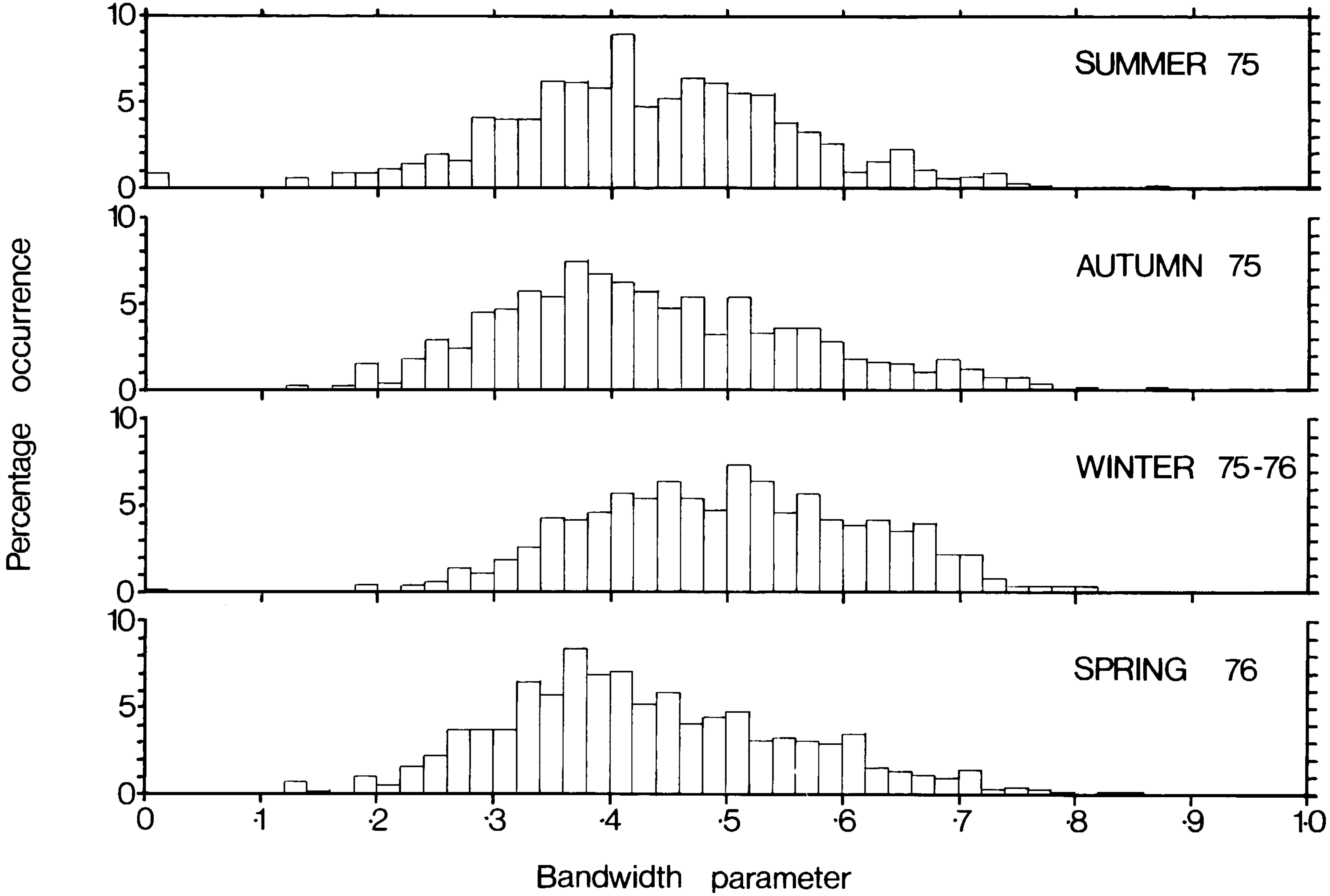
EC



Frequency histograms for Bandwidth parameter Annual' 76-7 Dunwich

Fig. 59

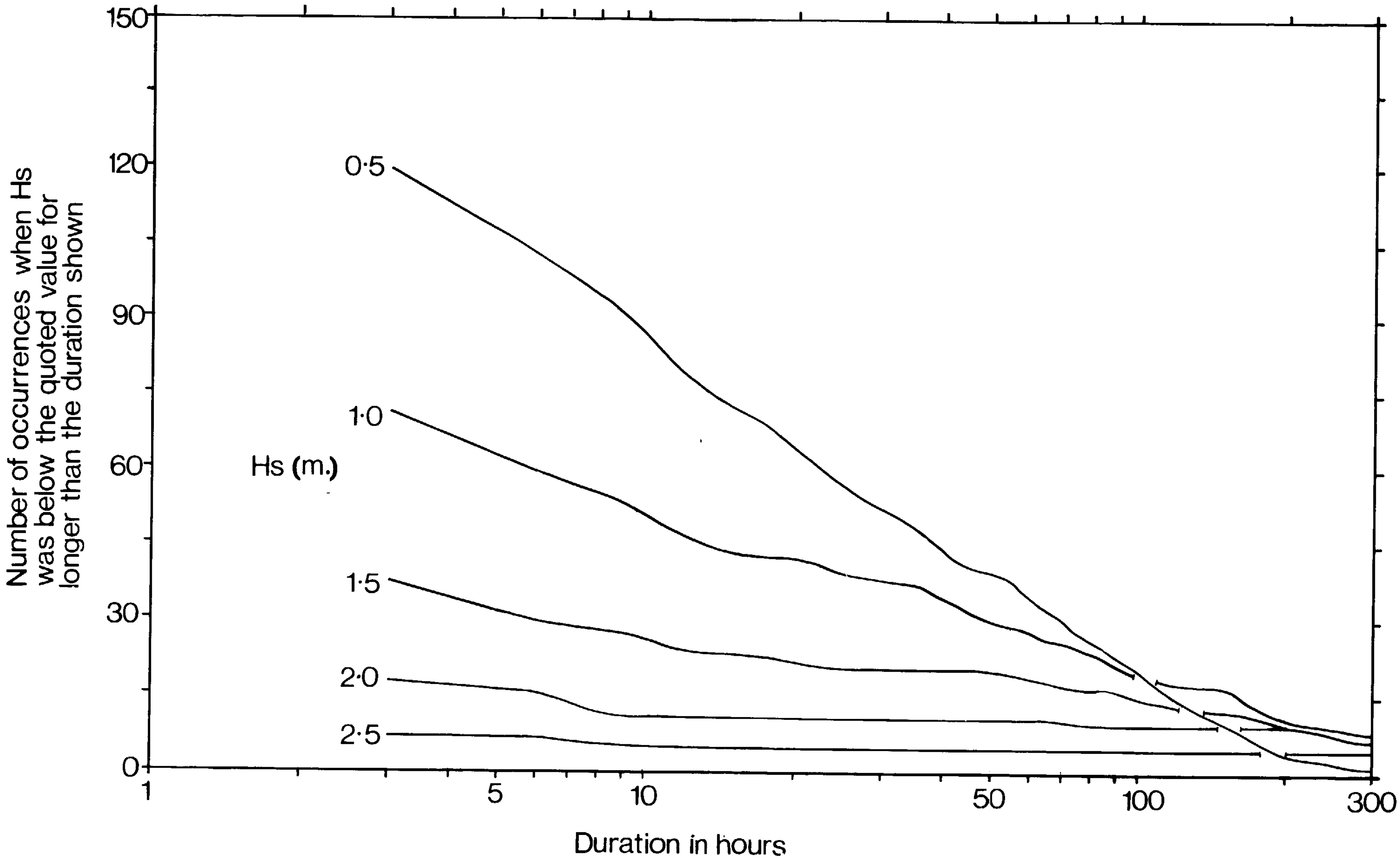
EC



Frequency histograms for Bandwidth parameter Annual'75-6 Southwold

Fig. 60

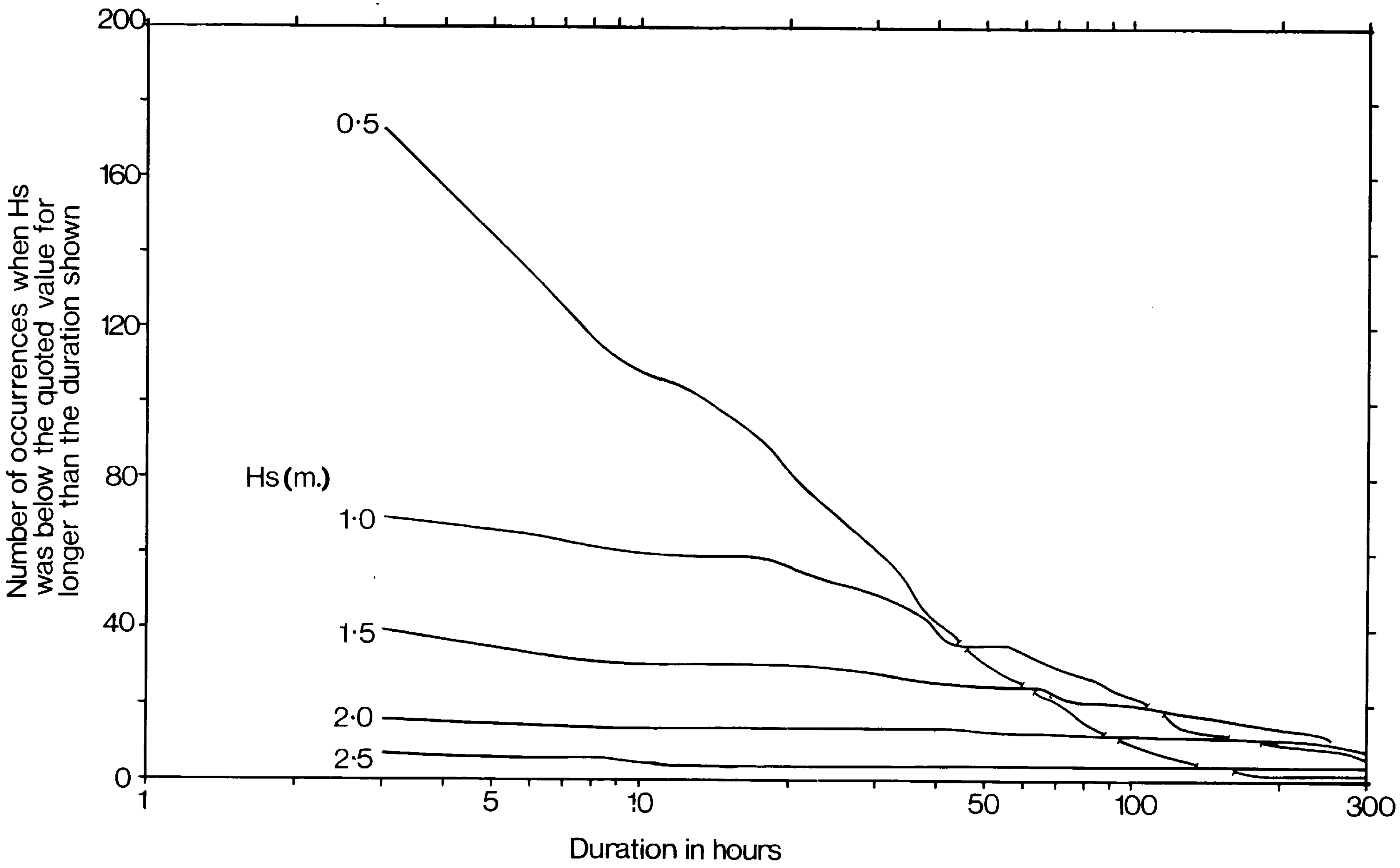
EC



Persistence of Calms - Aldeburgh' 75 - 6

Fig. 61

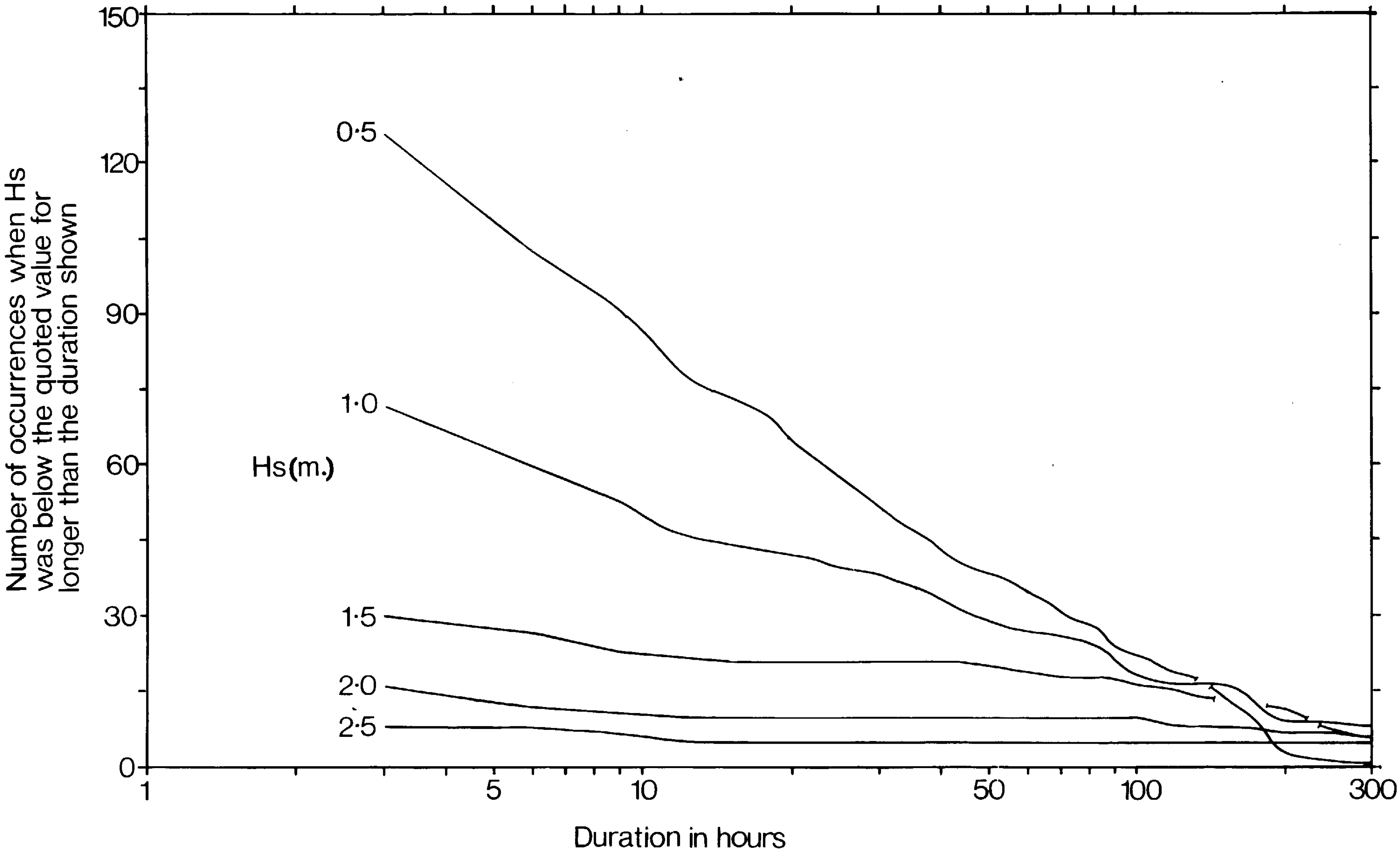
EC



Persistence of Calms - Aldeburgh' 76-7

Fig. 62

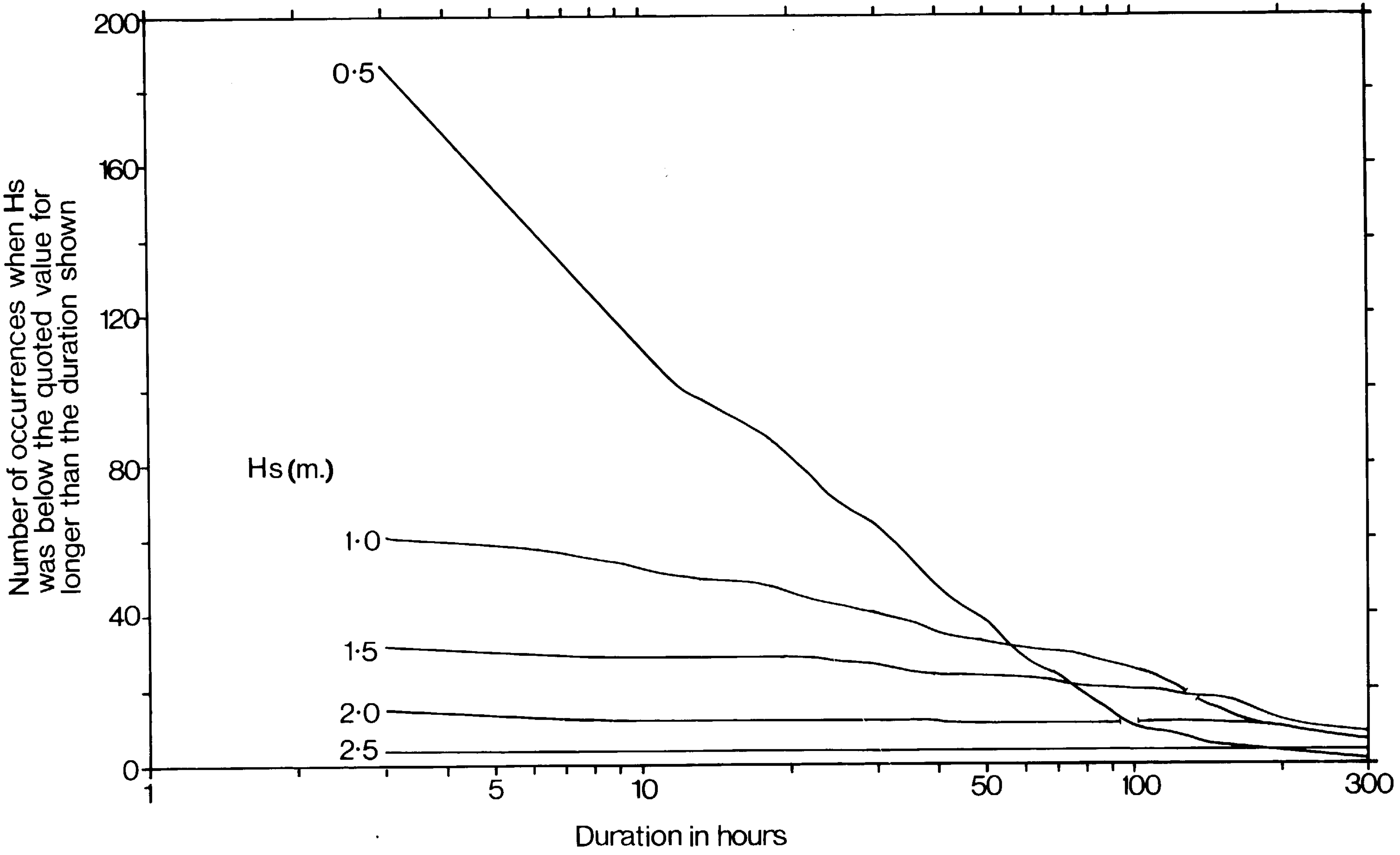
EC



Persistence of Calms - Dunwich' 75-6

Fig. 63

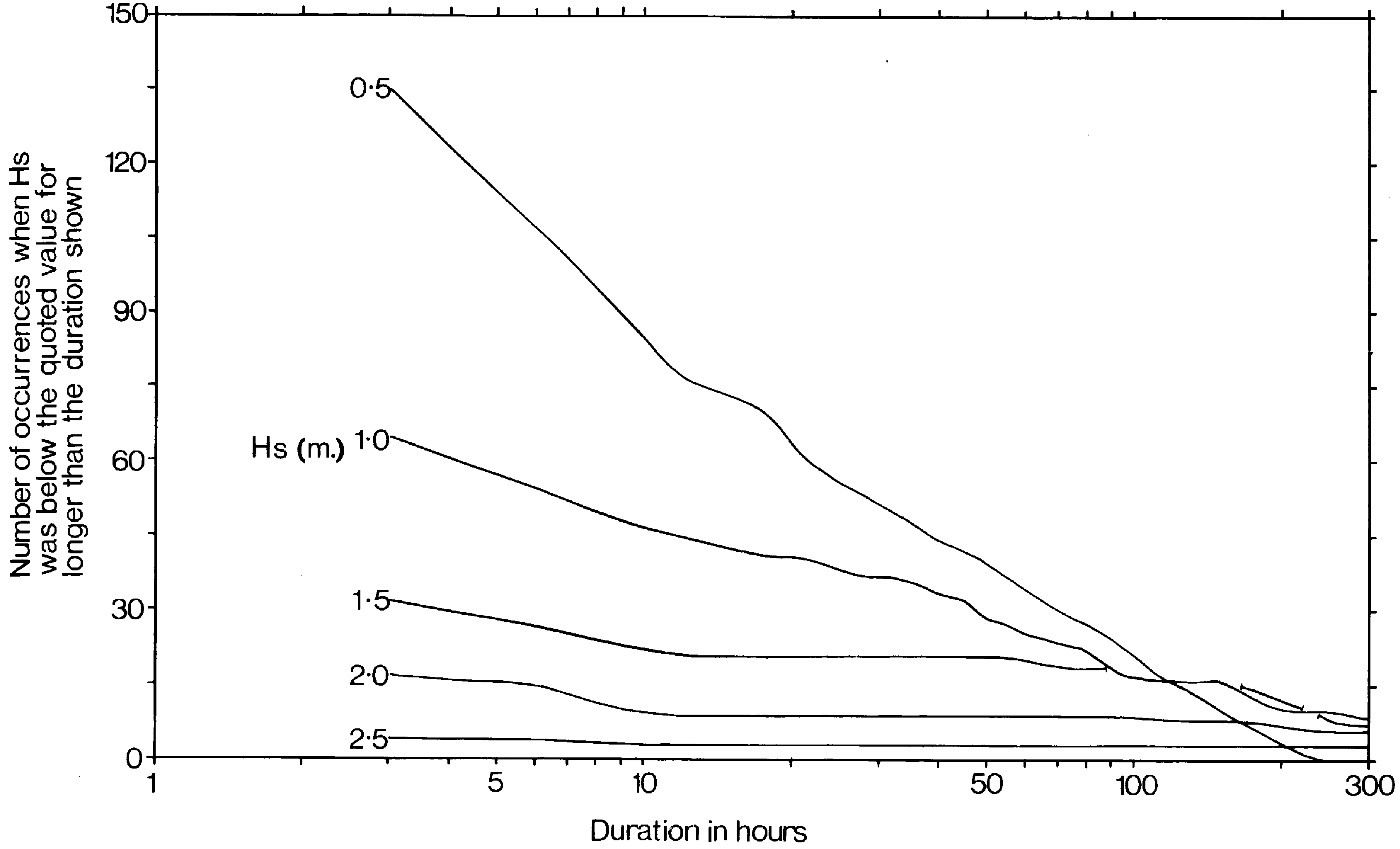
EC



Persistence of Calms - Dunwich' 76-7

Fig. 64

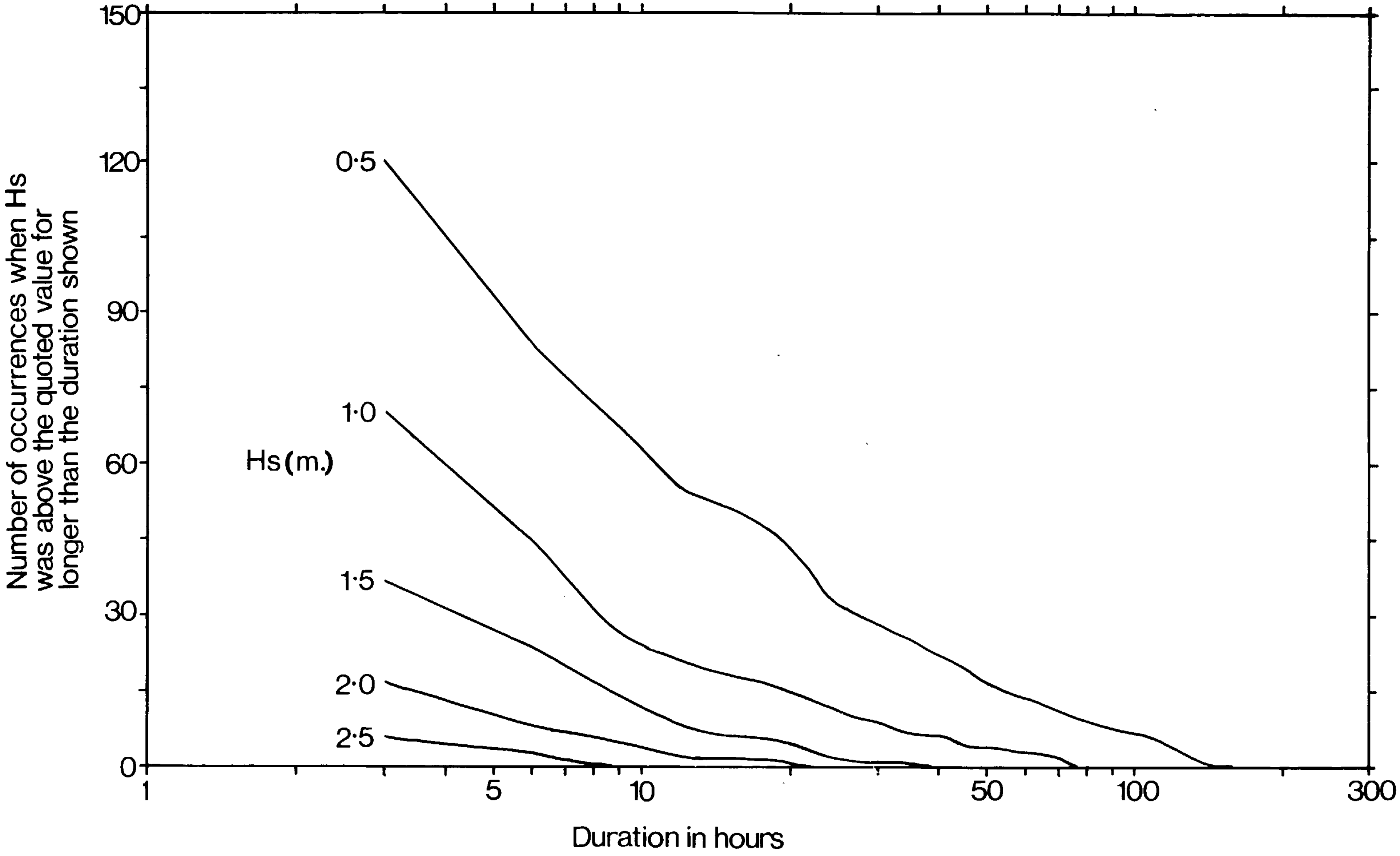
EC



Persistence of Calms - Southwold' 75-6

Fig. 65

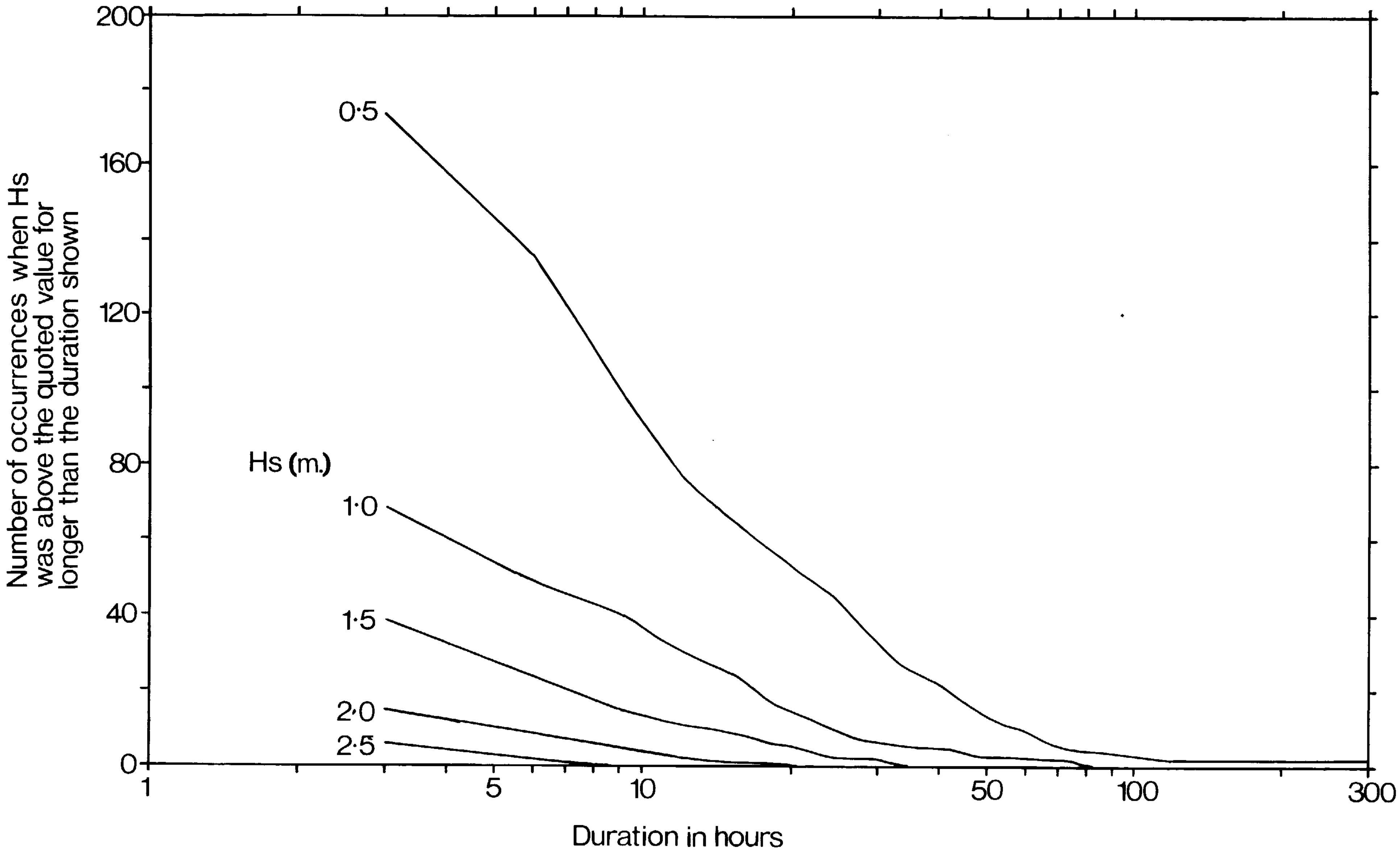
EC



Persistence of Storms - Aldeburgh' 75-6

Fig. 66

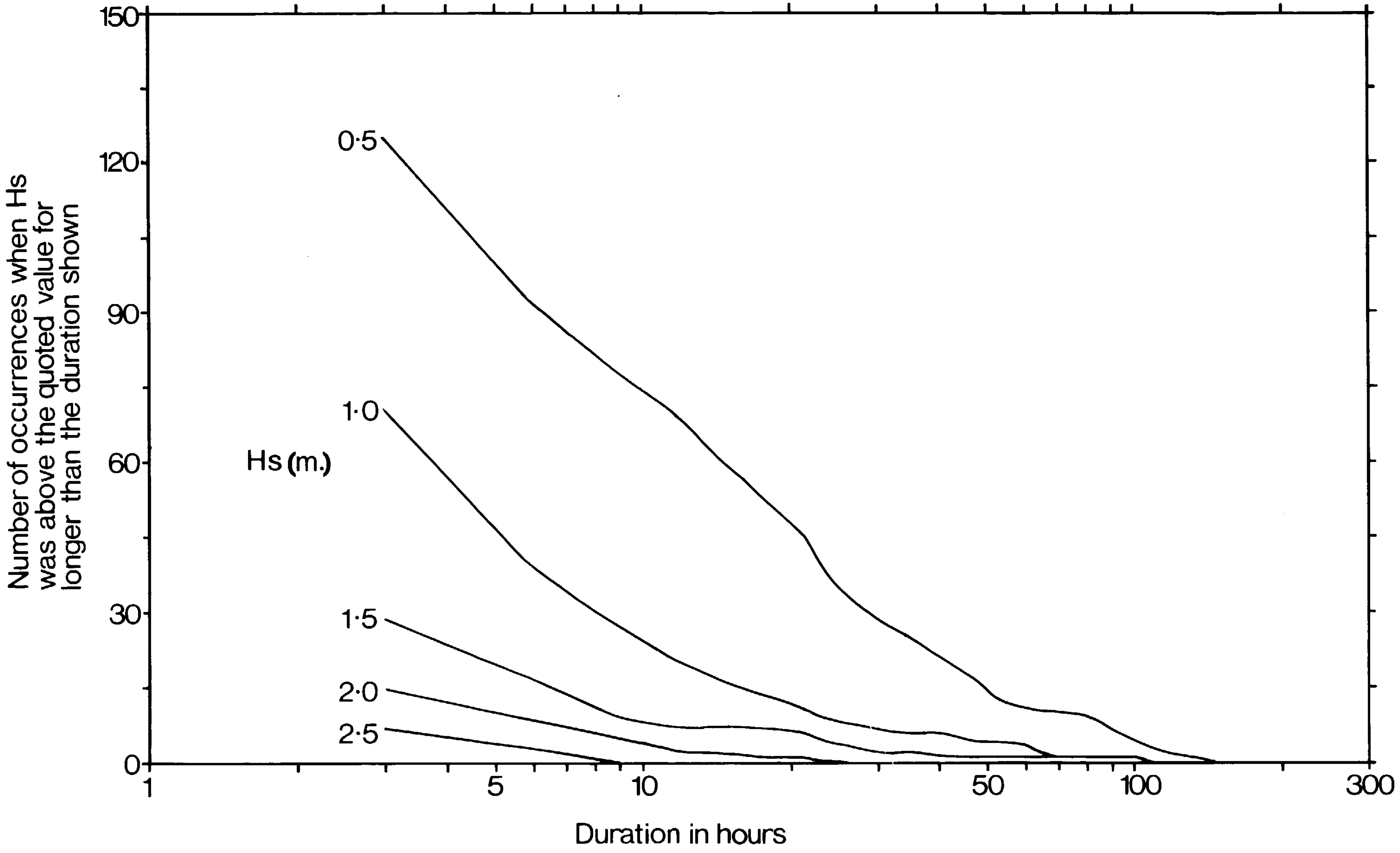
EC



Persistence of Storms - Aldeburgh' 76-7

Fig. 67

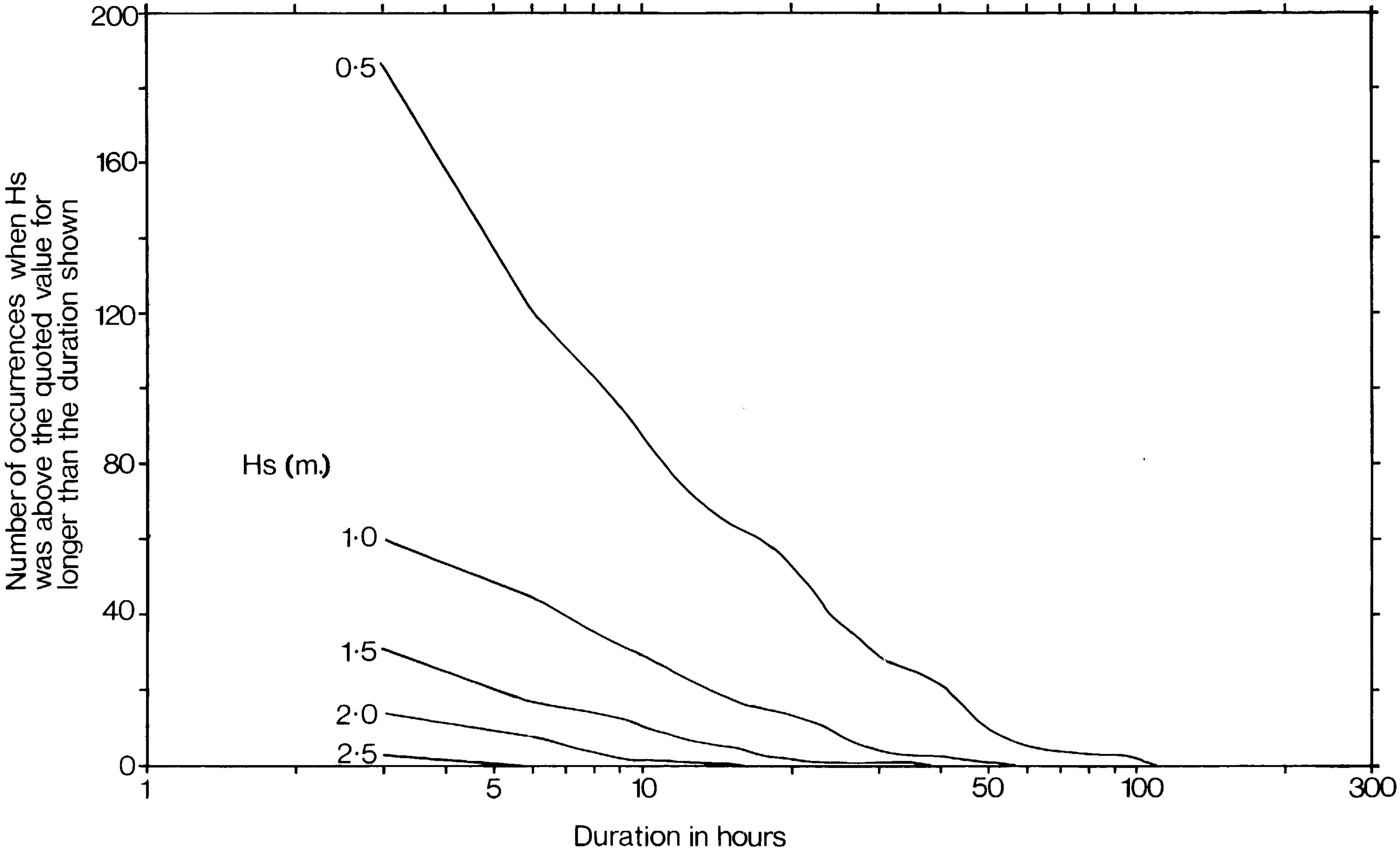
EC



Persistence of Storms - Dunwich' 75-6

Fig. 68

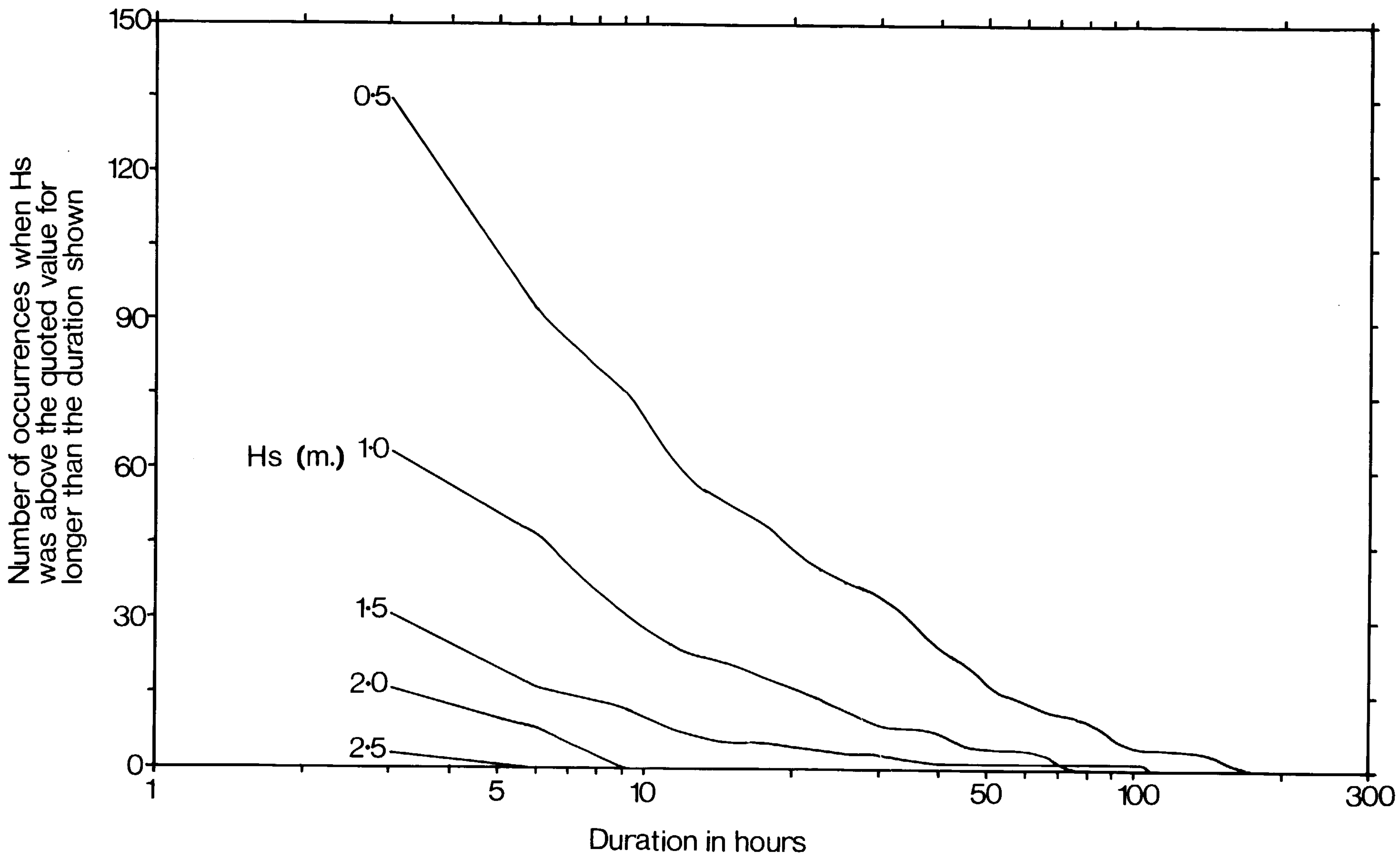
EC



Persistence of Storms - Dunwich' 76-7

Fig. 69

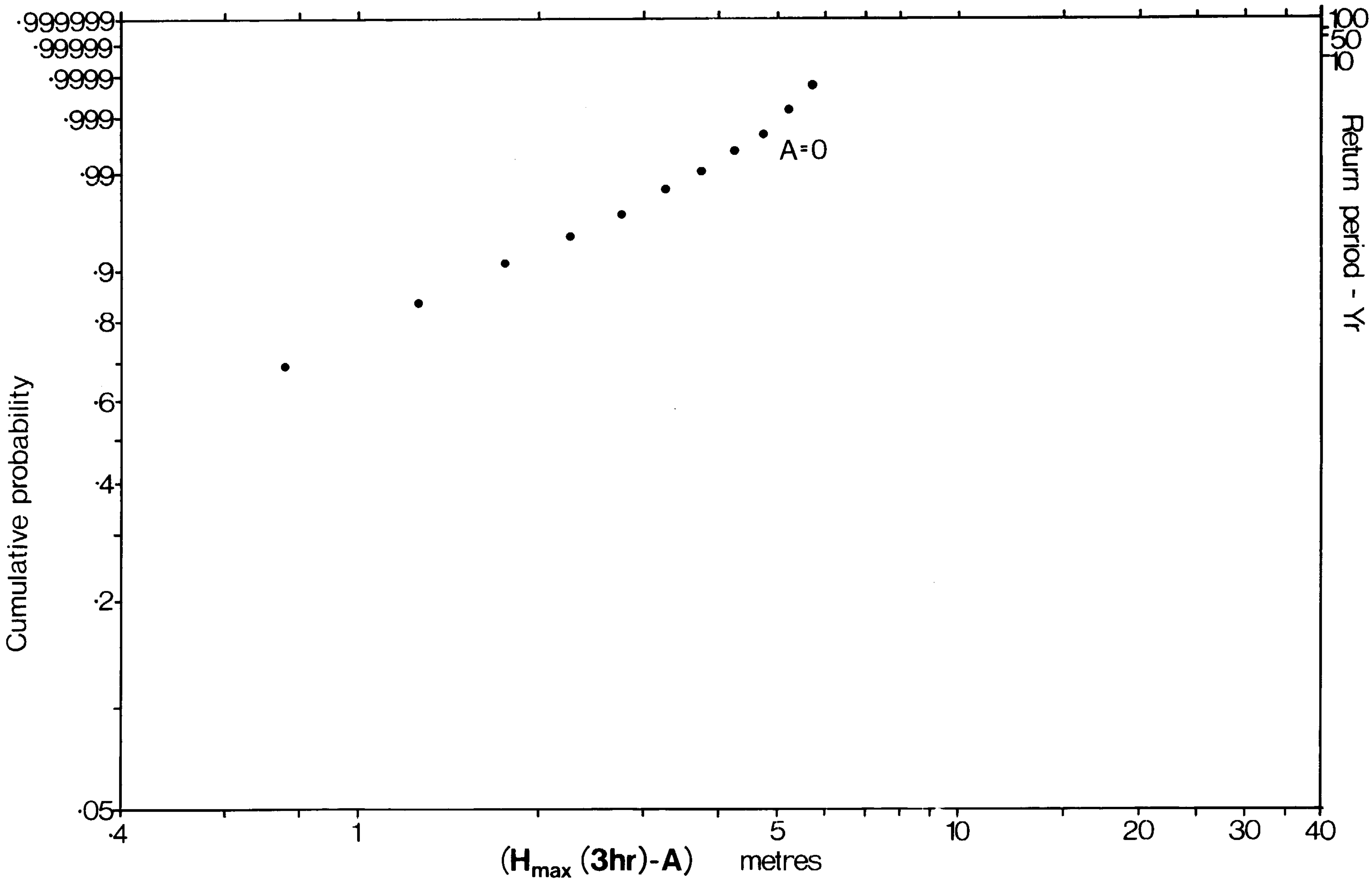
EC



Persistence of Storms - Southwold' 75-6

Fig. 70

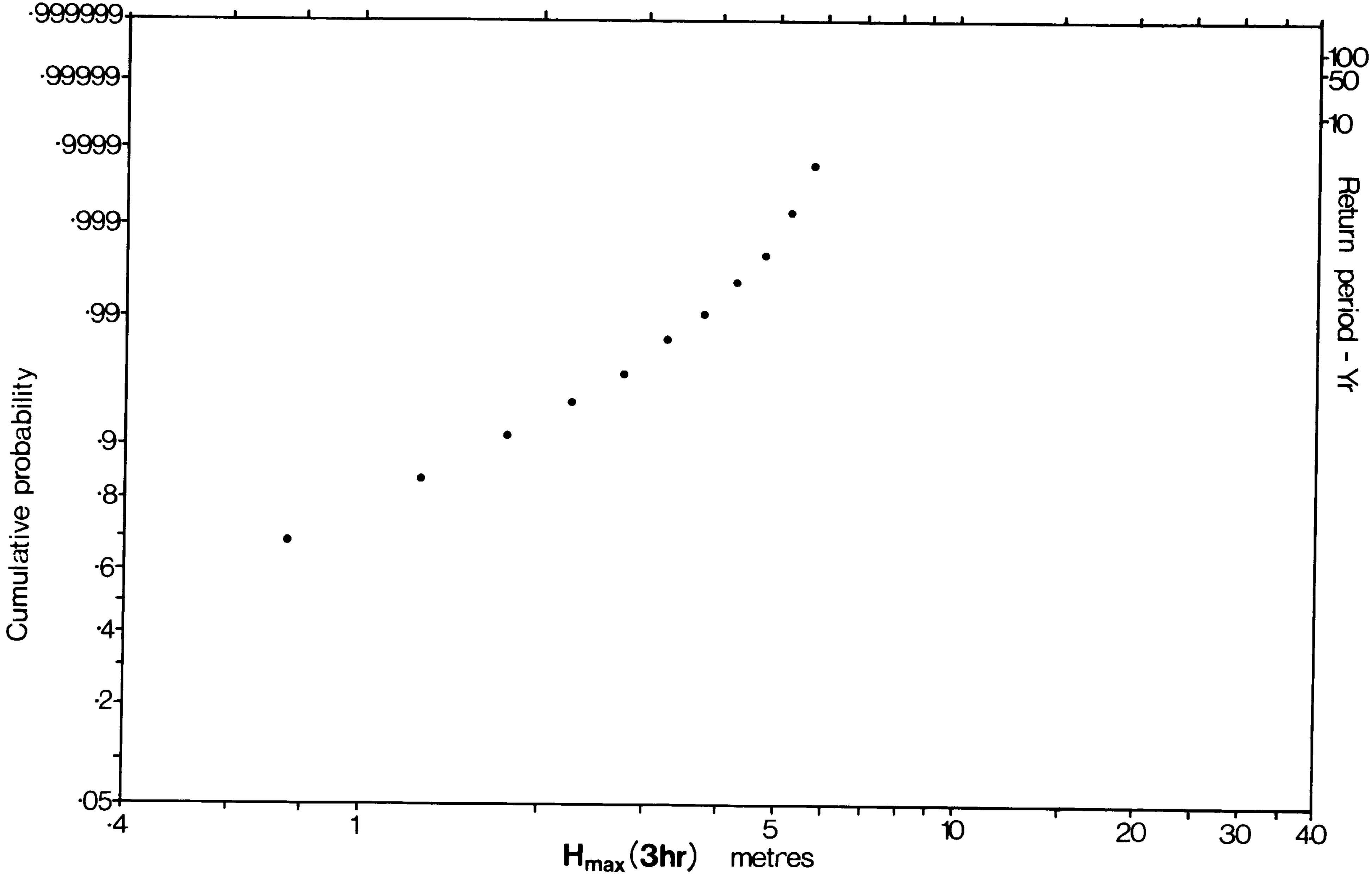
EC



Cumulative distribution of $(H_{max}$(3hr)-A) Weibull scale - Aldeburgh' 75-7

Fig. 71

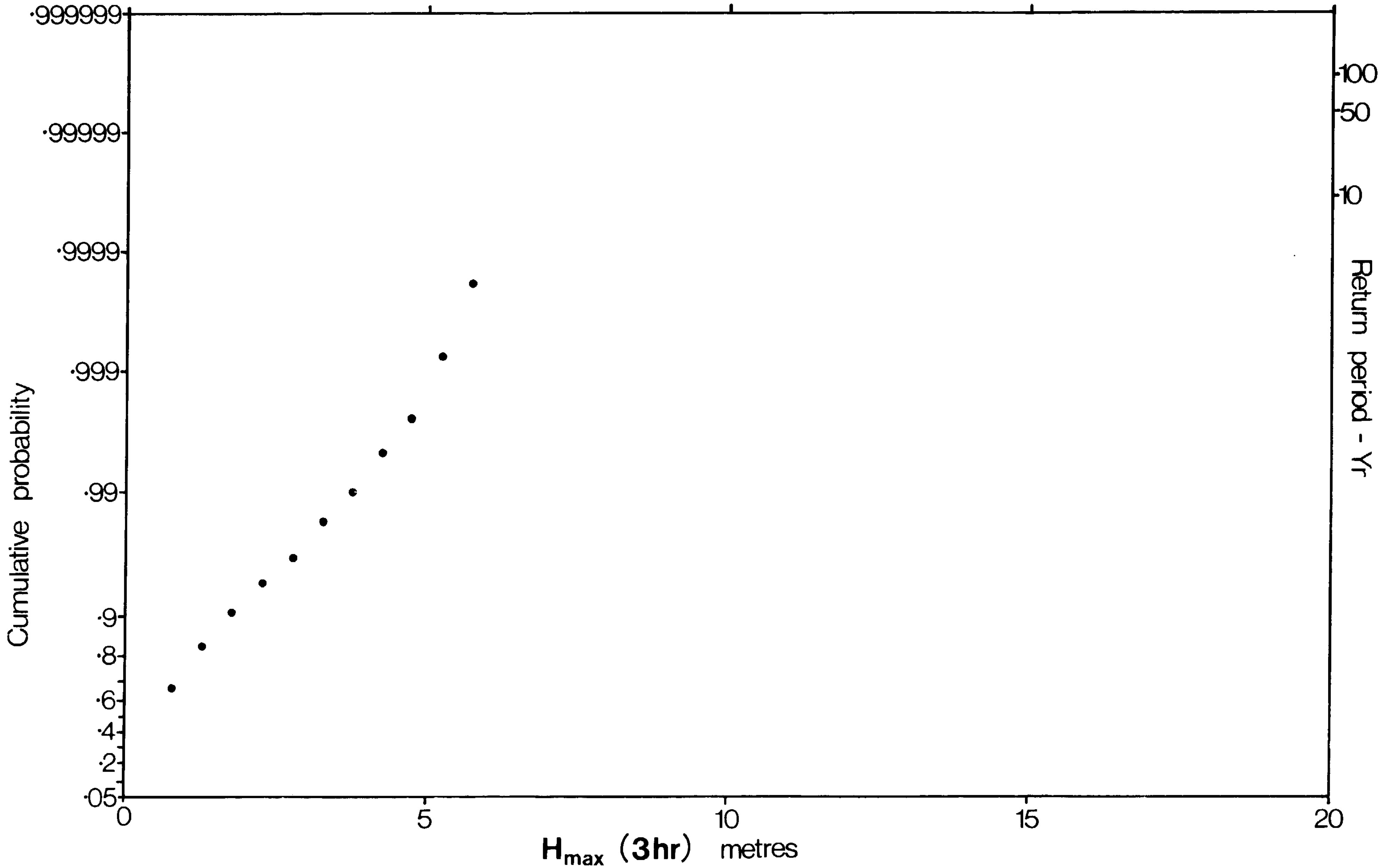
EC



Cumulative distribution of H_{max} (3hr) Log normal scale. Aldeburgh' 75-7

Fig. 72

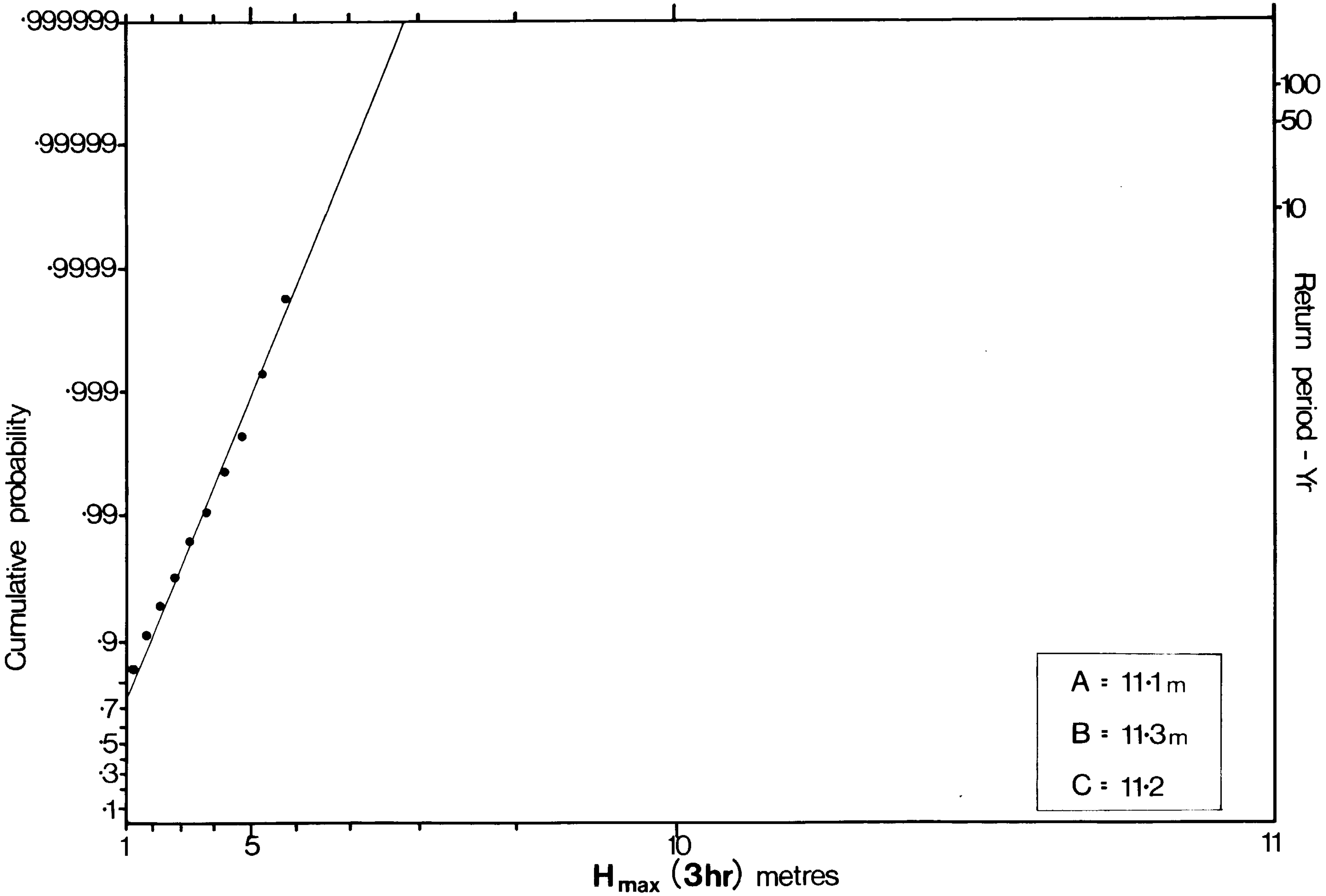
EC



Cumulative distribution of H_{max} (3hr) Gumbel I scale - Aldeburgh' 75-7

Fig. 73

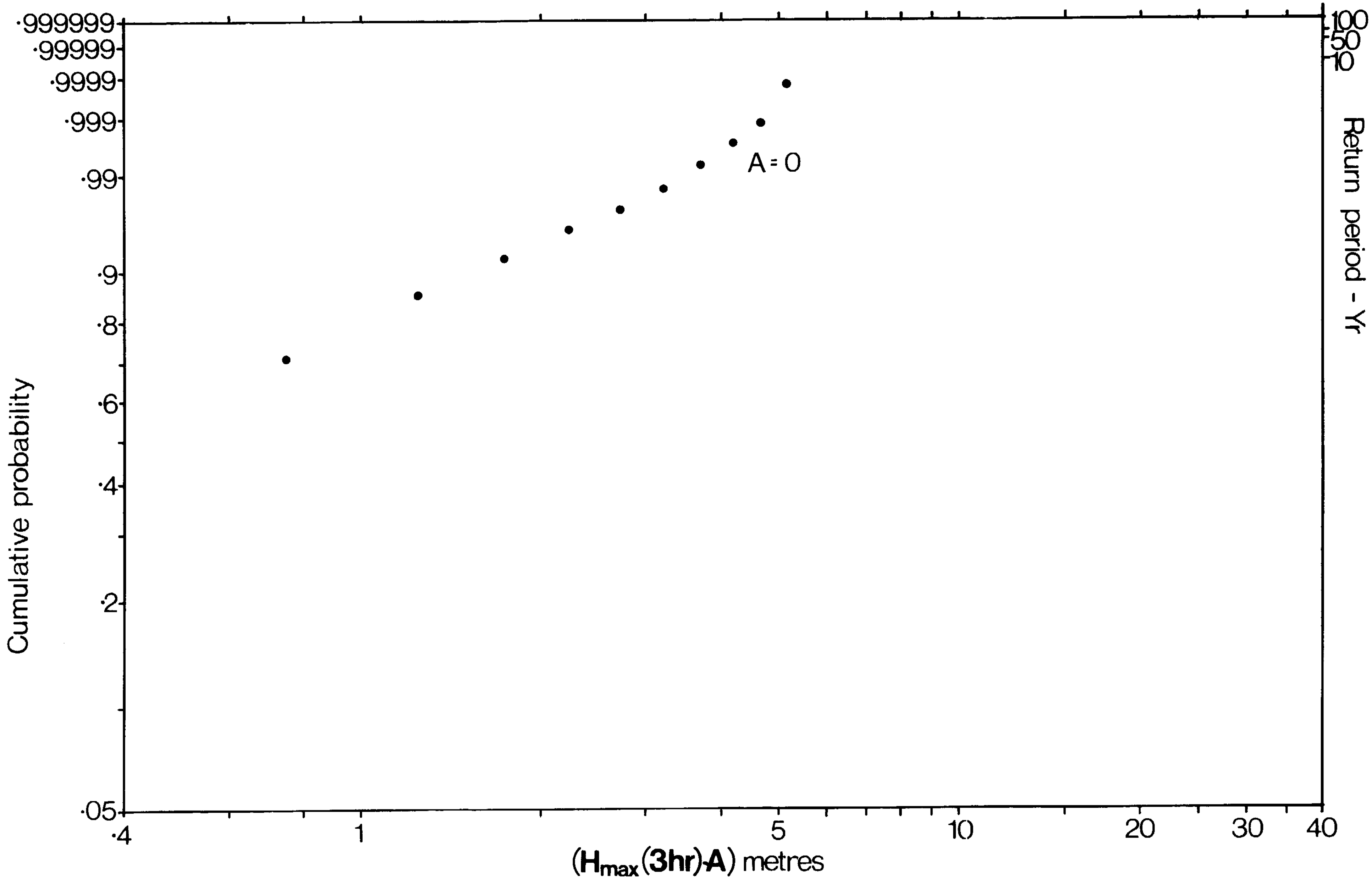
EC



Cumulative distribution of H_{max} (3hr) Gumbel III scale - Aldeburgh' 75-7

Fig. 74

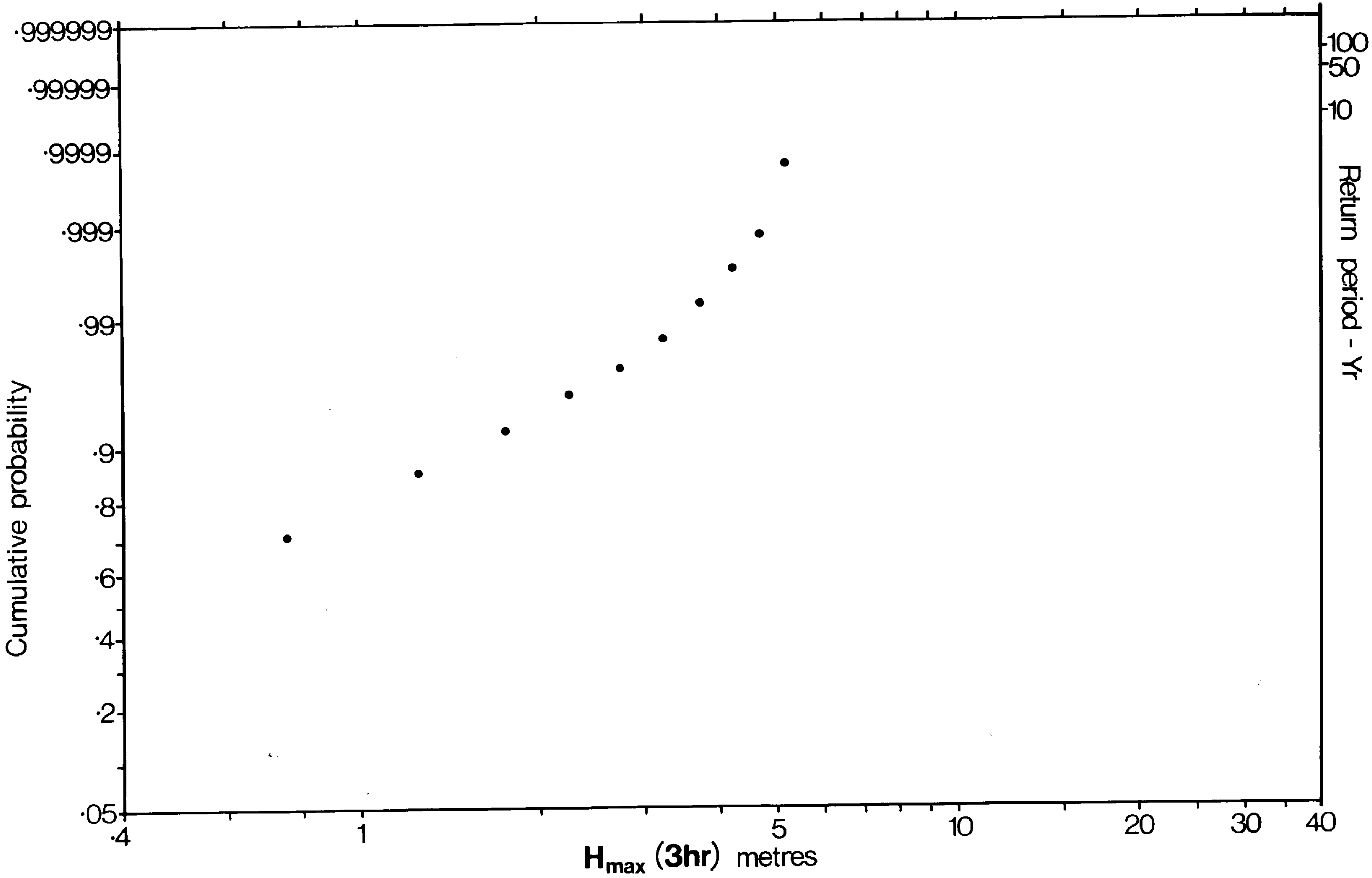
EC



Cumulative distribution of $(H_{max}(3hr)\text{-}A)$ Weibull scale - Dunwich ' 75-7

Fig. 75

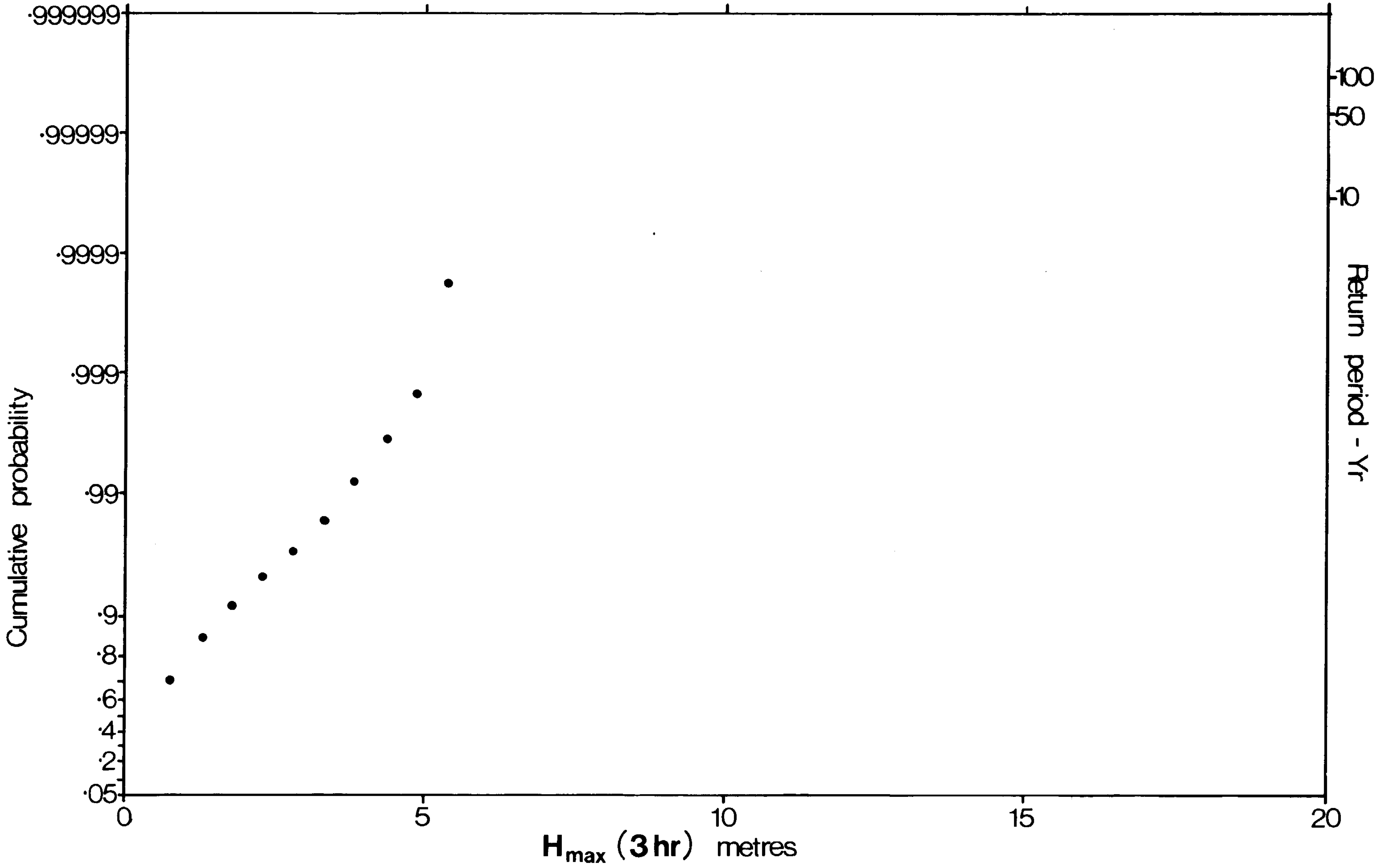
EC



Cumulative distribution of H_{max} (3hr) Log normal scale. Dunwich' 75-7

Fig. 76

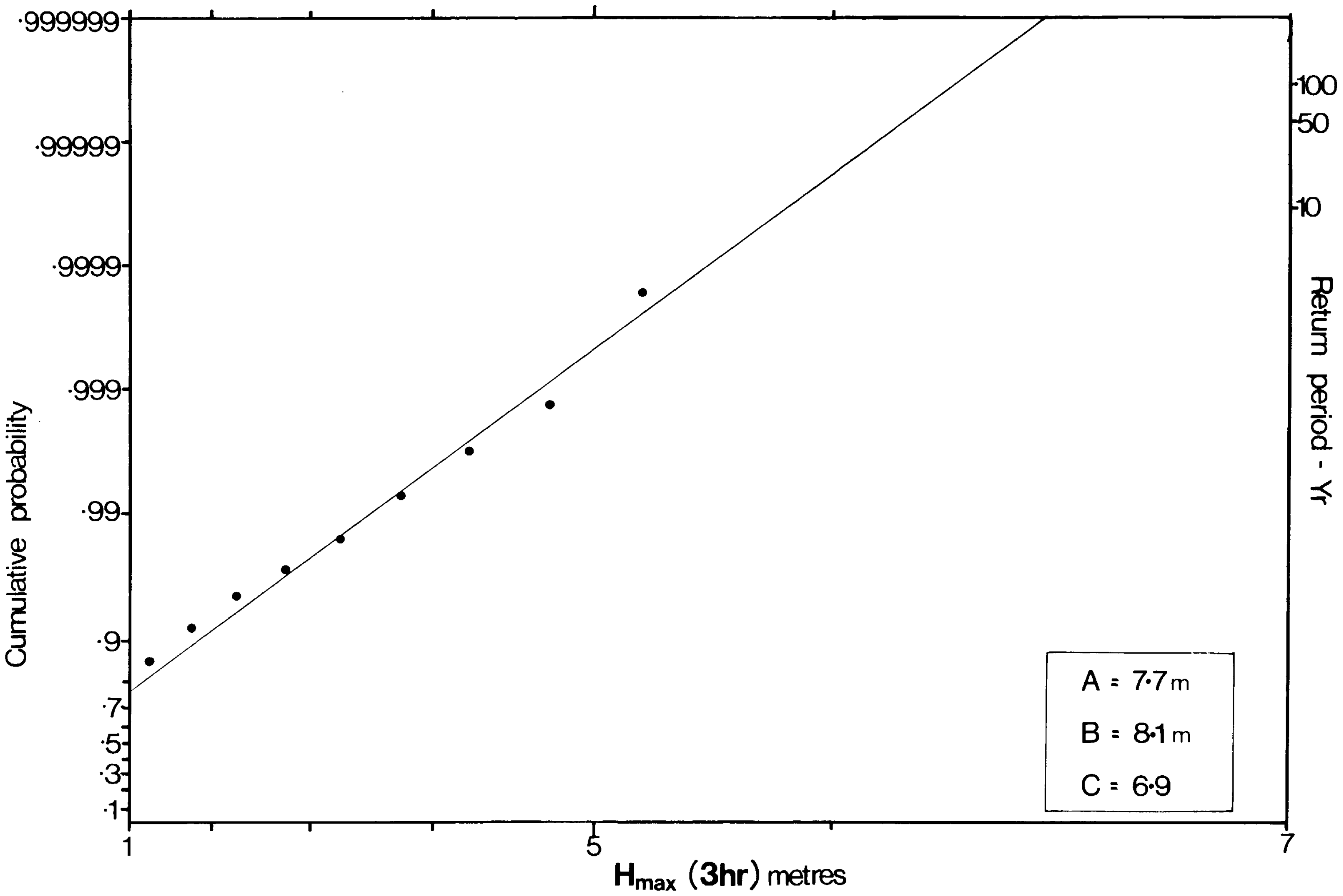
EC



Cumulative distribution of H_{max} (3hr) Gumbel I scale - Dunwich' 75-7

Fig. 77

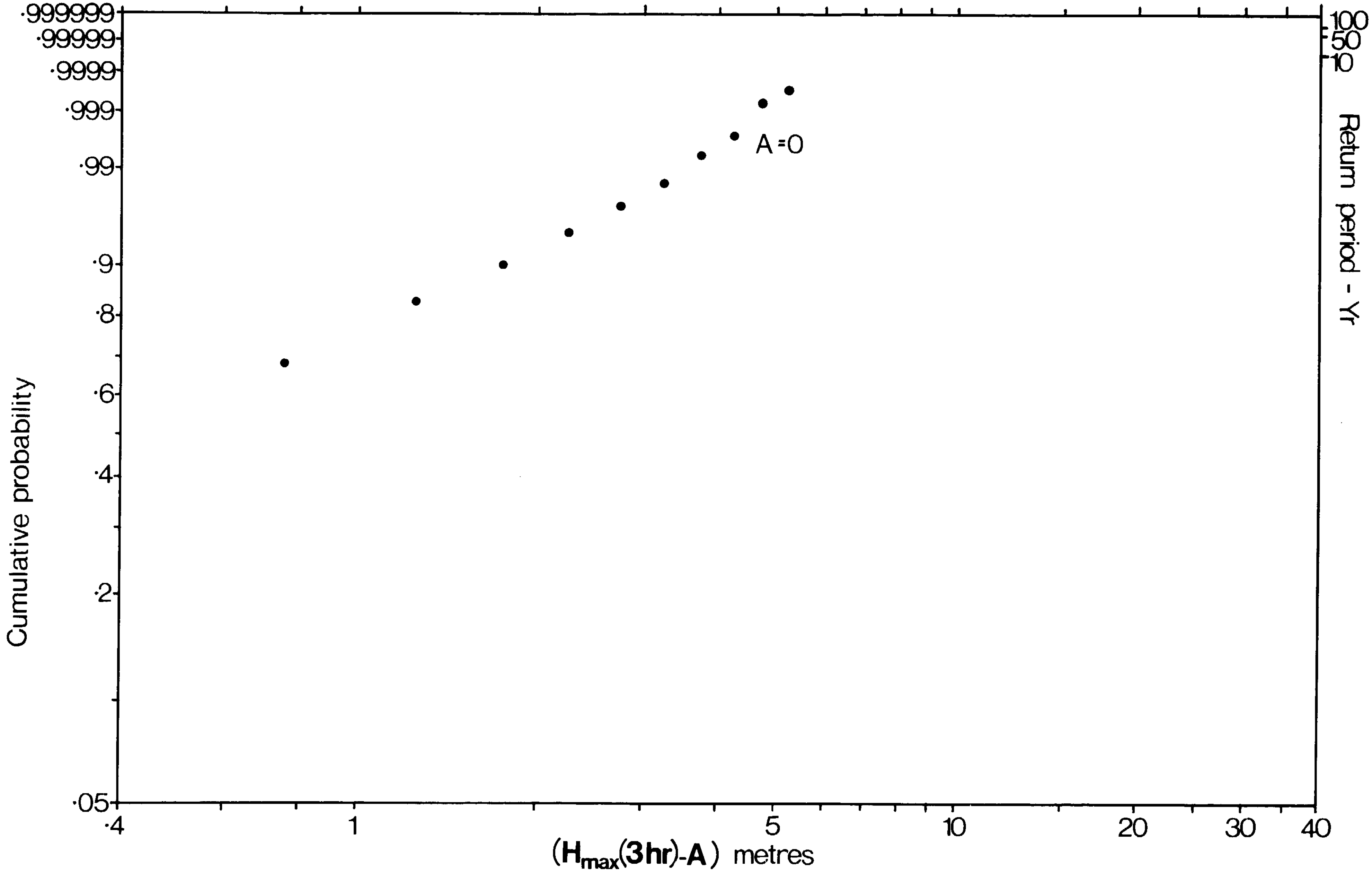
EC



Cumulative distribution of H_{max} (3hr) Gumbel III scale - Dunwich' 75-7

Fig. 78

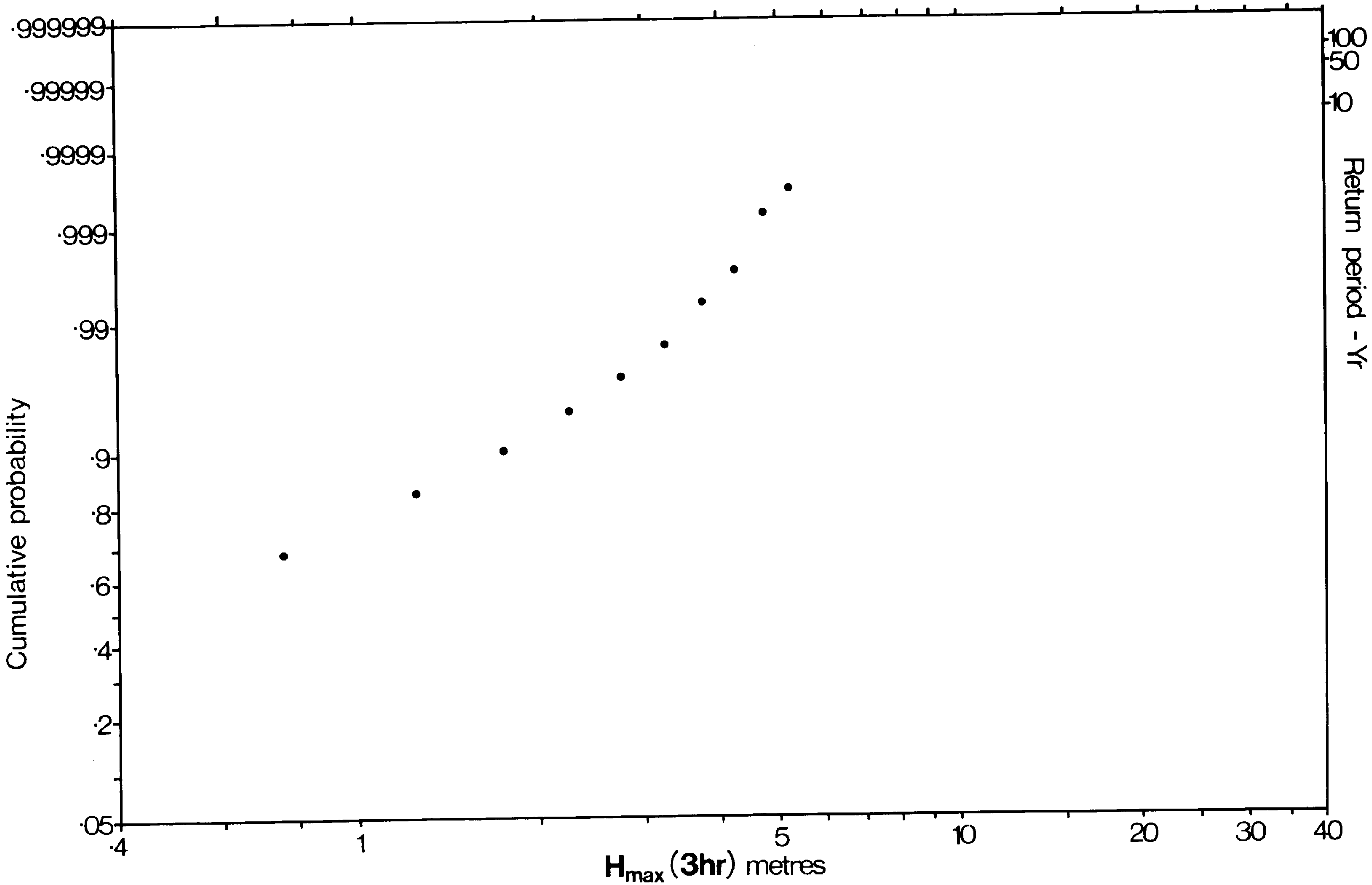
EC



Cumulative distribution of $(H_{max}(3hr)\text{-}A)$ Weibull scale Southwold' 75-6

Fig. 79

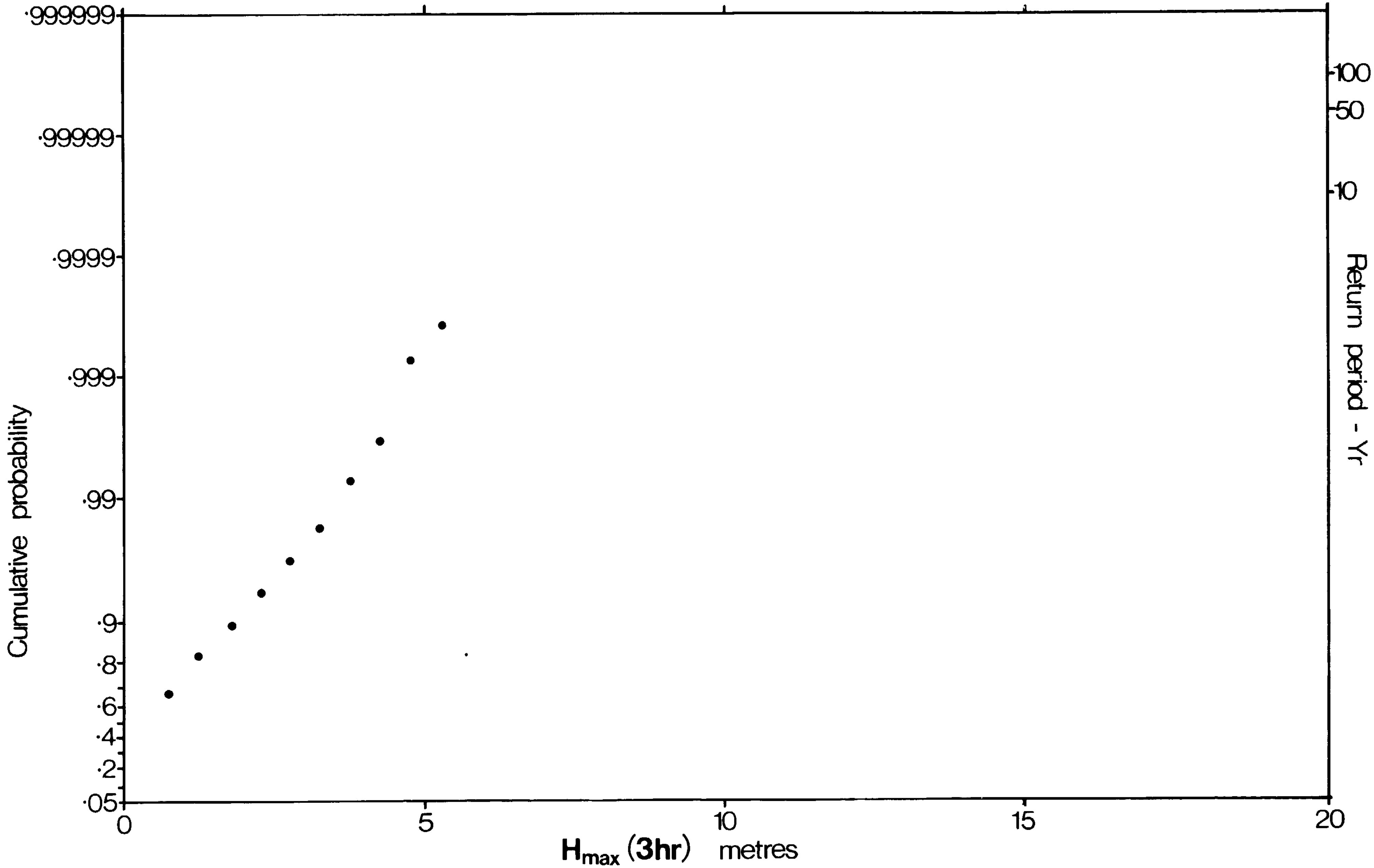
EC



Cumulative distribution of H_{max} (3hr) Log normal scale. Southwold' 75-6

Fig.80

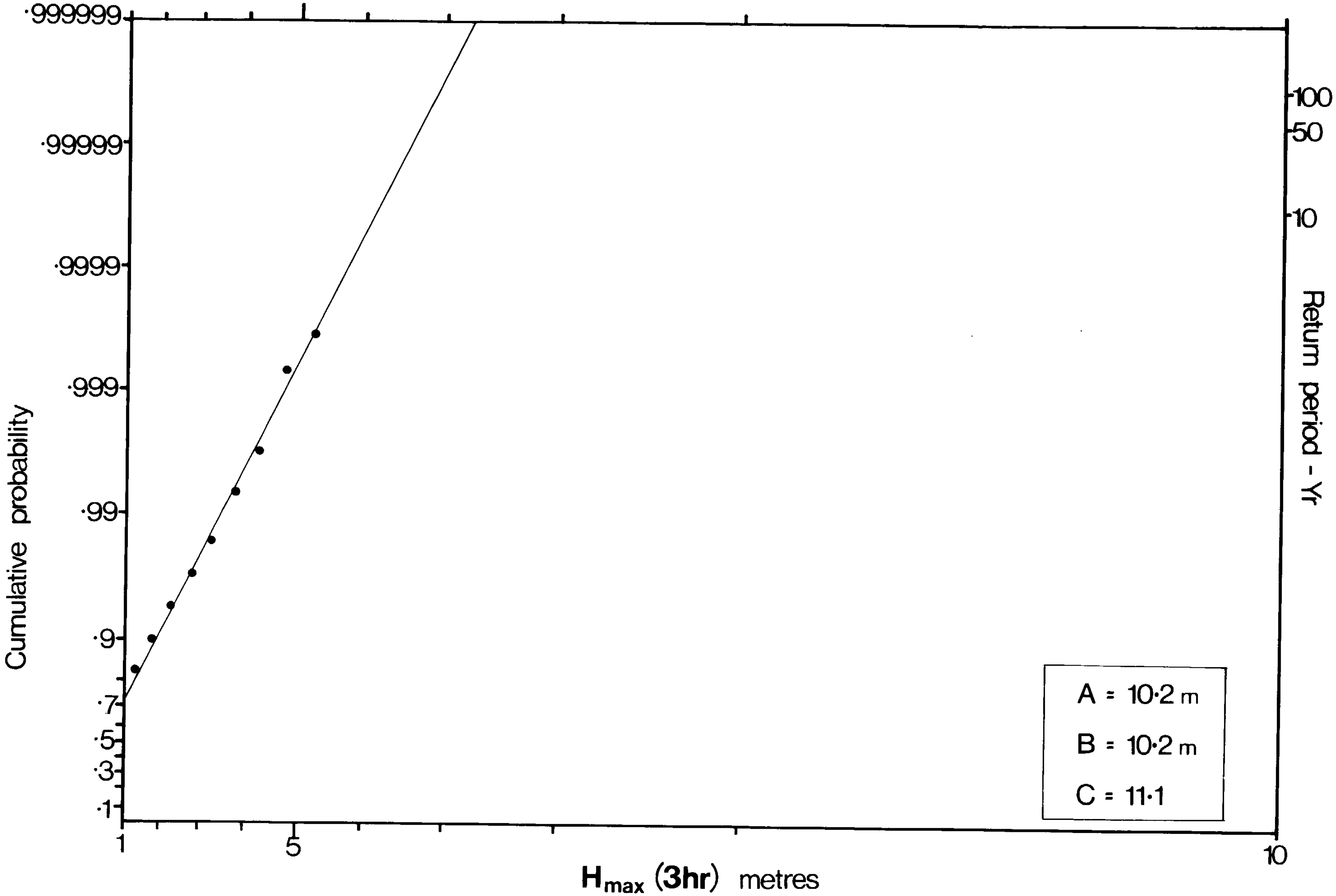
EC



Cumulative distribution of H_{max} (3hr) Gumbel I scale - Southwold' 75-6

Fig. 81

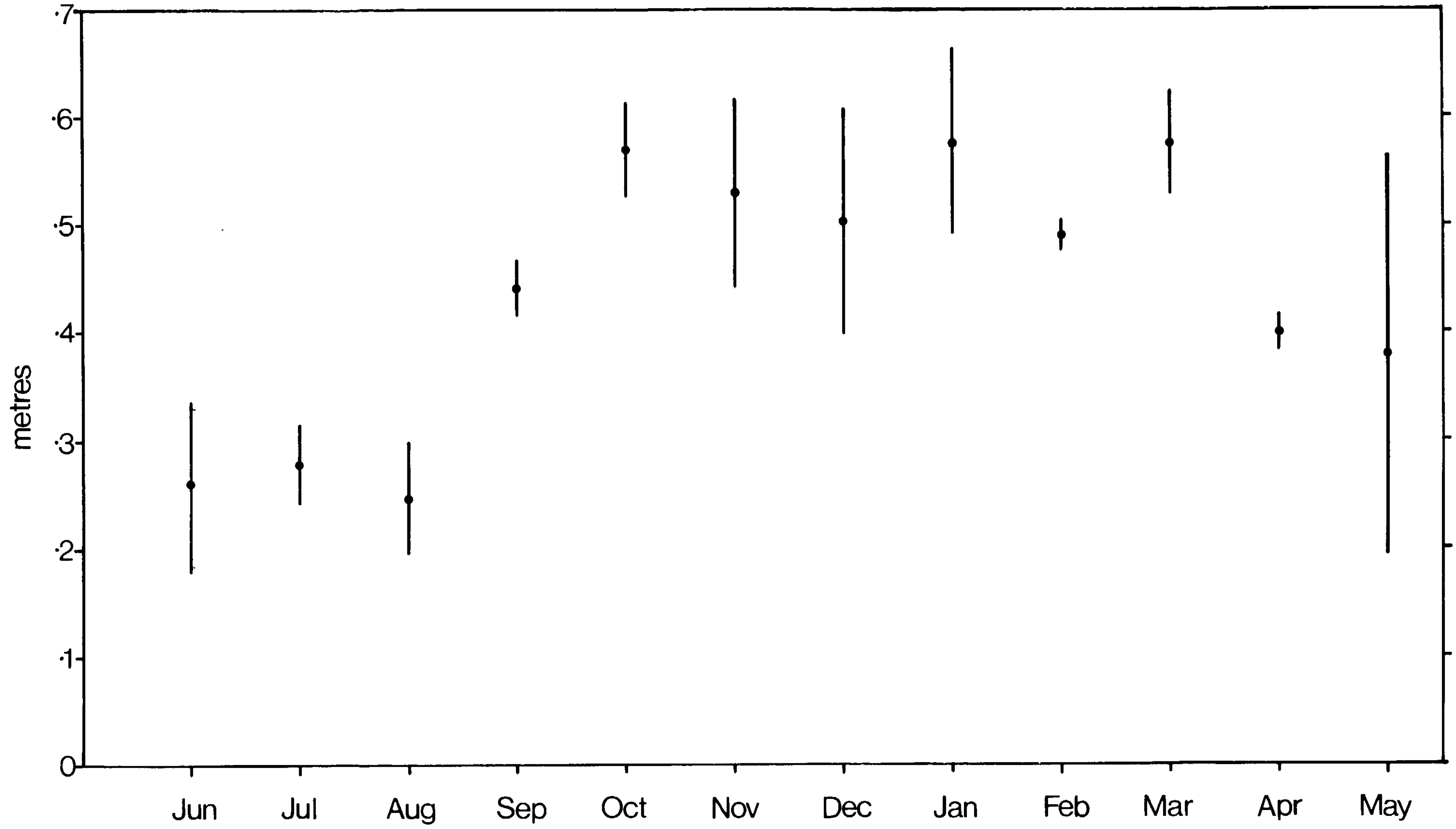
EC



Cumulative distribution of H_{max} (3hr) Gumbel III scale - Southwold' 75-6

Fig. 82

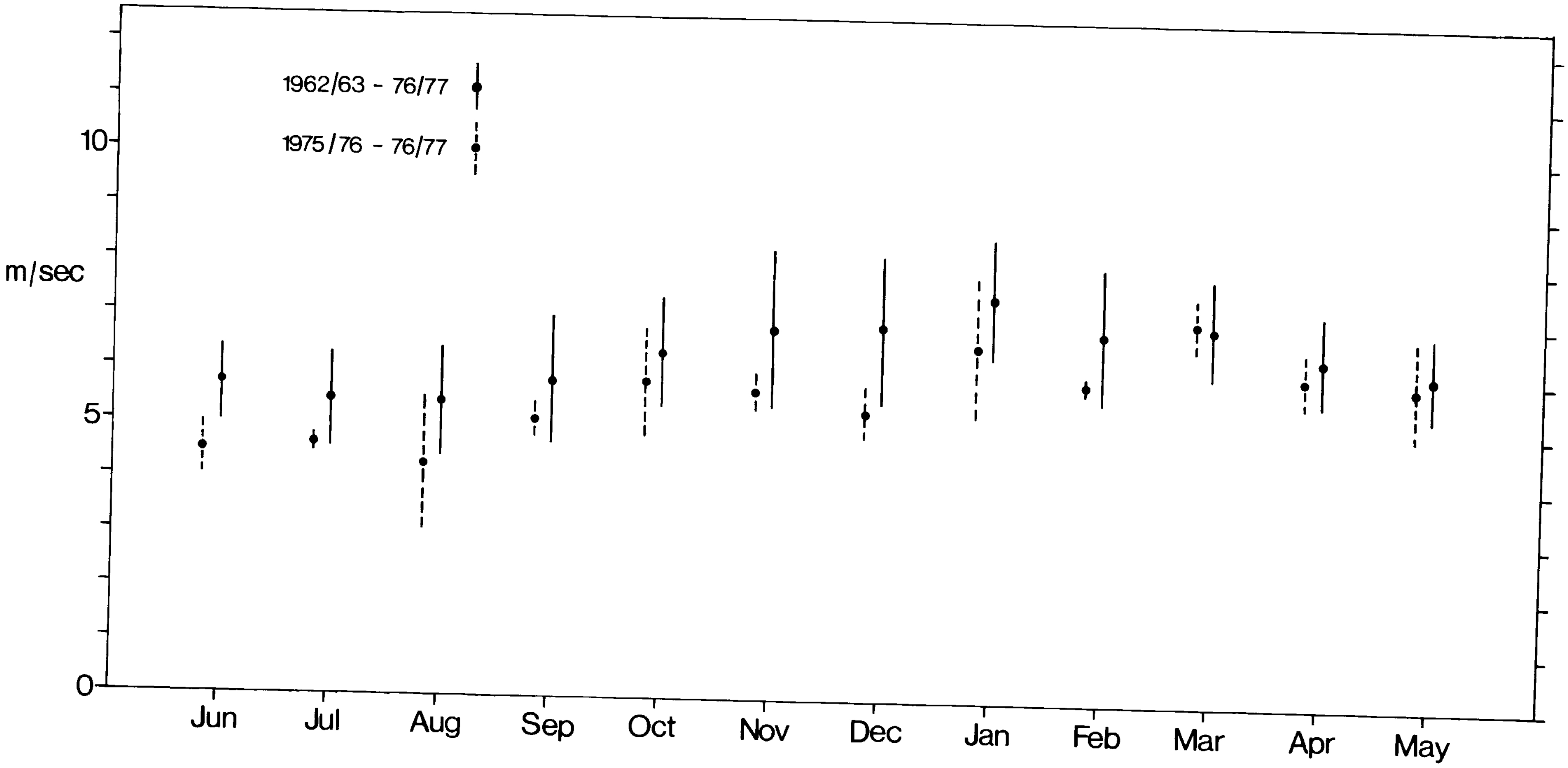
EC



The mean and standard deviation of the average value of significant wave height for each month - all site-years

Fig. 83

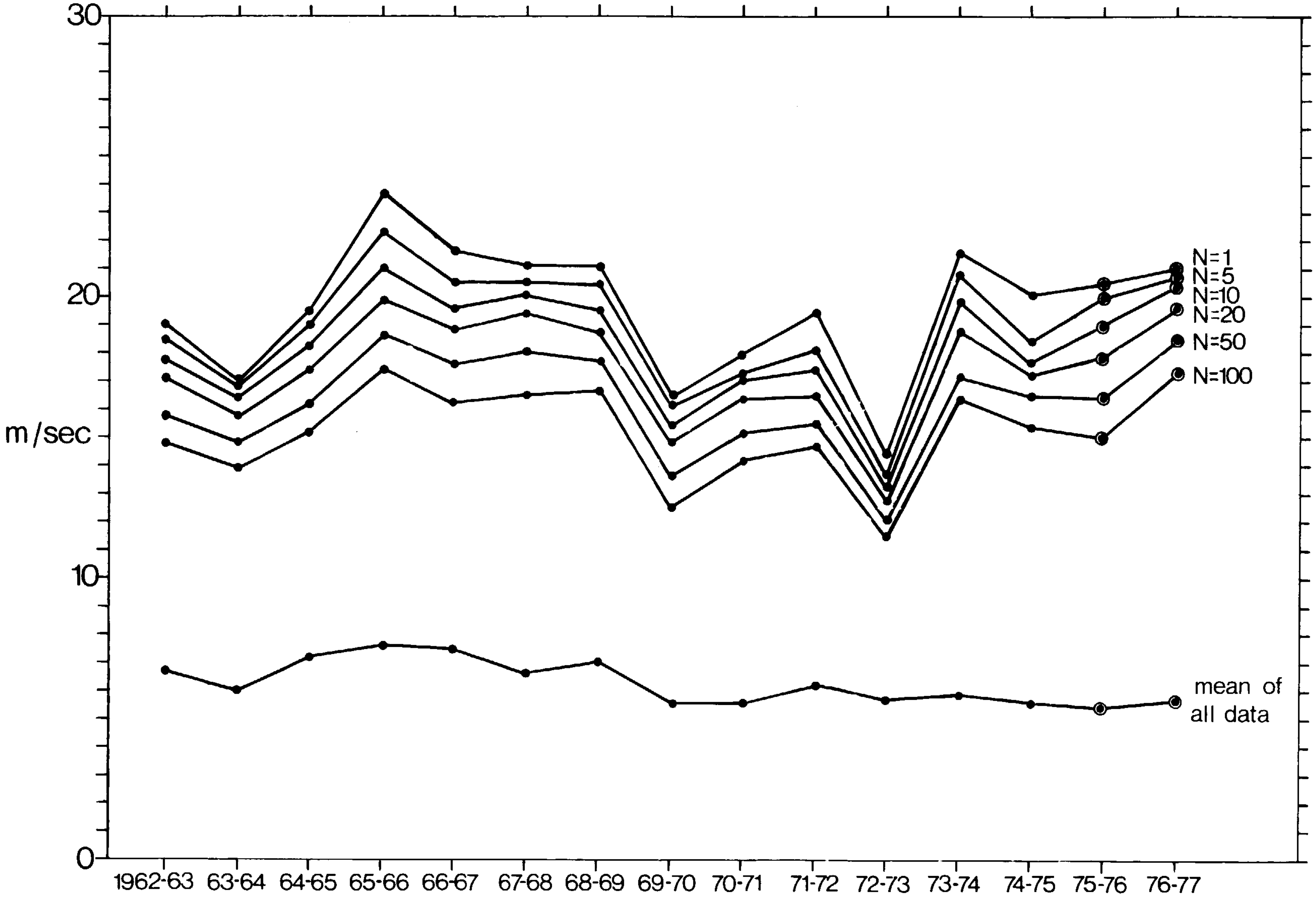
EC



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

Fig. 84

EC



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

Fig. 85

EC