NATIONAL INSTITUTE OF OCEANOGRAPHY
WORMLEY, GODALMING, SURREY

Waves at the Mersey Bar Light Vessel

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N. I. O. Internal Report No. A.37

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Figures:

Waves have been recorded by a Shipborne Wave Recorder (Tucker, 1956) placed on the Mersey Bar Light Vessel which is stationed in 9·6 fathoms of water 3 miles west of the buoyed channel to the Mersey. The records from one year of operation, from September 1965 - September 1966 have been analyzed, mainly following the method of analysis developed by Tucker (1961) from theoretical studies by Cartwright and Longuet-Higgins (1956). The method of presentation is that recently recommended for data for engineering purposes (Draper, 1966).

Records were taken at three-hourly intervals, and the analysis yields the following parameters:

(a) H_1 = The sum of the distances of the highest crest and the lowest trough from the mean water level.

(b) H_2 = The sum of the distances of the second highest crest and the second lowest trough from the mean water level.

(c) T_z = The mean zero-crossing period.

(d) T_c = The mean crest period.

From these measured parameters the following parameters have been calculated, after allowing for instrumental response:

(e) H_s = The significant wave height (mean height of the highest one-third of the waves): this is calculated separately from both H_1 and H_2, and an average taken. The relationship between the parameters is $H_1 = f(H_s)$ where f is a factor related to the number of zero-crossings in the records (Tucker, 1963). A similar relationship is used for the calculation of H_s from H_2.

(f) H_{max} (3 hours) = The most probable value of the height of the highest wave which occurred in the recording interval (Draper, 1963).

(g) ϵ = The spectral width parameter, which is calculated from T_z and T_c (Tucker, 1961):

$$\epsilon^2 = 1 - (T_c / T_z)^2$$

The results of these measurements are expressed graphically divided into seasons thus:

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

For each season a graph (Figures 1 - 4) shows the cumulative distribution of significant wave height H_s, and of the most probable value of the height of the highest wave in the recording interval, H_{max} (3 hours).

The distribution of zero-crossing period is given for each season (Figures 5 - 8).

The distribution of the spectral width parameter is given for the whole year (Figure 9).

Figure 10 is a scatter diagram relating significant wave height to zero-crossing period, for the whole year.

Figure 11 is a persistence diagram for the whole year.

Discussion of Results

From Figures 1 - 4 may be determined the proportion of time for which H_s or H_{max} (3 hours) exceeded any given height. For example, in the Winter the significant height exceeded 4 feet for 28 percent of the time. Wave heights are generally higher in the autumn and winter months, which was also the case when waves were recorded on Morecambe Bay Light Vessel, 1956-7. (N.I.O. Internal Report No. A.32). The highest measured wave (H_1) of 27 feet with a zero-crossing period of 8·7 seconds, occurred on 27th March. There is little seasonal variation in either the wave period or spectral width parameter. The scatter diagram of Figure 10 relates the significant wave height to zero-crossing period, with the numbers of occurrences expressed in parts per thousand; for example, the most common wave conditions were those with a significant height of between 2 and 3 feet and a zero-crossing period of between 4.0 and 4.5 seconds, which occurred for 61 thousandths, or 6.1 per cent, of the time. The rapid attenuation of the shorter waves with depth means that the pressure units, which are necessarily situated at about 5.65 feet below mean water level, do not record waves which have a period of less than about 3.5 seconds; this is the cause of the cut-off below that period.

A parameter which is sometimes of interest is the wave steepness, expressed as wave height: wave length; it may also be expressed as a decimal number. It should be noted that the steepness of a wave is not the same as the maximum slope of the water surface during the passage of a wave. Lines of constant steepness of 1 : 20 and 1 : 40 are drawn on Figure 10. (In this case, steepness relates to significant wave height: wave length calculated from the zero-crossing period.)

A fairly well-defined limit of steepness is observed at approximately 1:16 (0·06); this is also similar to the Morecambe Bay results. There is a theoretical limit for a progressive wave of 1:7 (0·14). From the persistence diagram, Figure 11, may be deduced the number and duration of the occasions in 1 year on which waves persisted at or above a given height. For example, if the limit for a particular operation of a vessel is a significant height of 4 feet, it would have been unable to operate for spells in excess of 10 hours on 49 occasions, or spells in excess of 20 hours on 24 occasions.

Acknowledgements

This analysis has been undertaken on behalf of the Marine Surveyor and Water Bailiff, Mersey Docks and Harbour Board. The costs are borne by both the Mersey Docks and Harbour Board and by the National Institute of Oceanography.

The authors wish to express their appreciation of the efforts of their colleagues Mr. J. W. Cherriman in maintaining the equipment, Mrs. E. G. Dobell for help during the analysis, Mrs. E. Pratley for collating the data and preparing the diagrams, and particularly Mr. J. A. Ewing for supervising the later stages of analysis during the absence of the authors.

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REFERENCES

TUCKER, M.J. 1956 A Shipborne Wave Recorder.
Trans. Instn. Nav. Archit. Lond. 98, 236-250.

DRAPER, L. 1966 The analysis and presentation of wave data - a plea for uniformity.
Proc. 10 Conf. on Coastal Engineering, Tokyo, Chapters 1 and 2.

TUCKER, M.J. 1961 Simple measurement of wave records.
Proc. Conf. Wave Recording for Civ. Engrs. (N.I.O.) 22-3.

TUCKER, M.J. 1963 Analysis of records of sea waves.
Proc. Instn. Civ. Engrs. 26, 304-316.

CARTWRIGHT, D.E. and LONGUET-HIGGINS, M.S. 1956 The statistical distribution of the maxima of a random function.
Proc. Roy. Soc. A 237, 212-232.

DARBYSHIRE, M. 1960 Waves in the North Sea.
Dock Harb. Author. 41, 225-228.

DRAPER, L. 1963 The derivation of a 'design-wave' from instrumental measurements of sea waves.
Proc. Inst. Civ. Engrs. 26, 291-304.

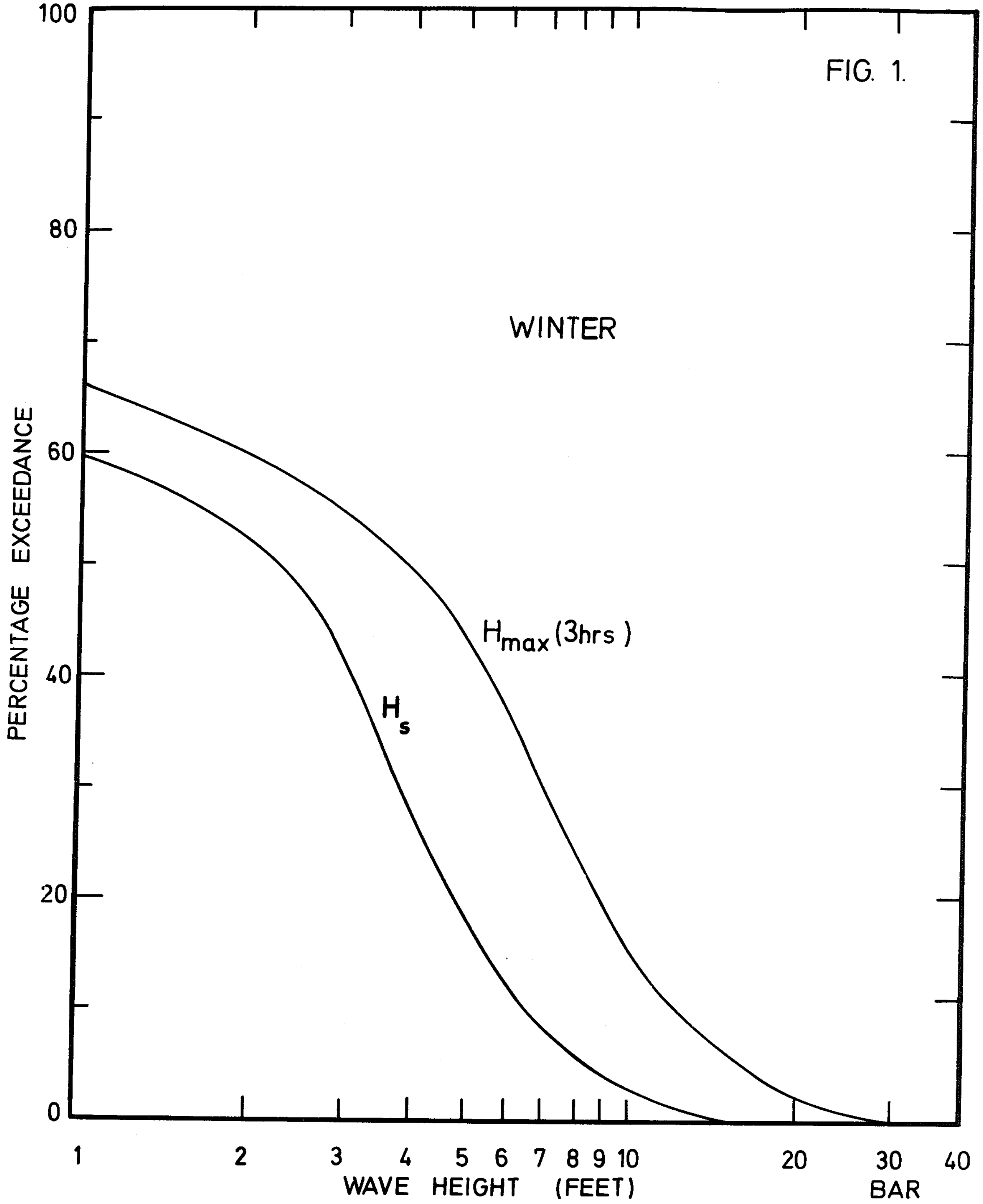
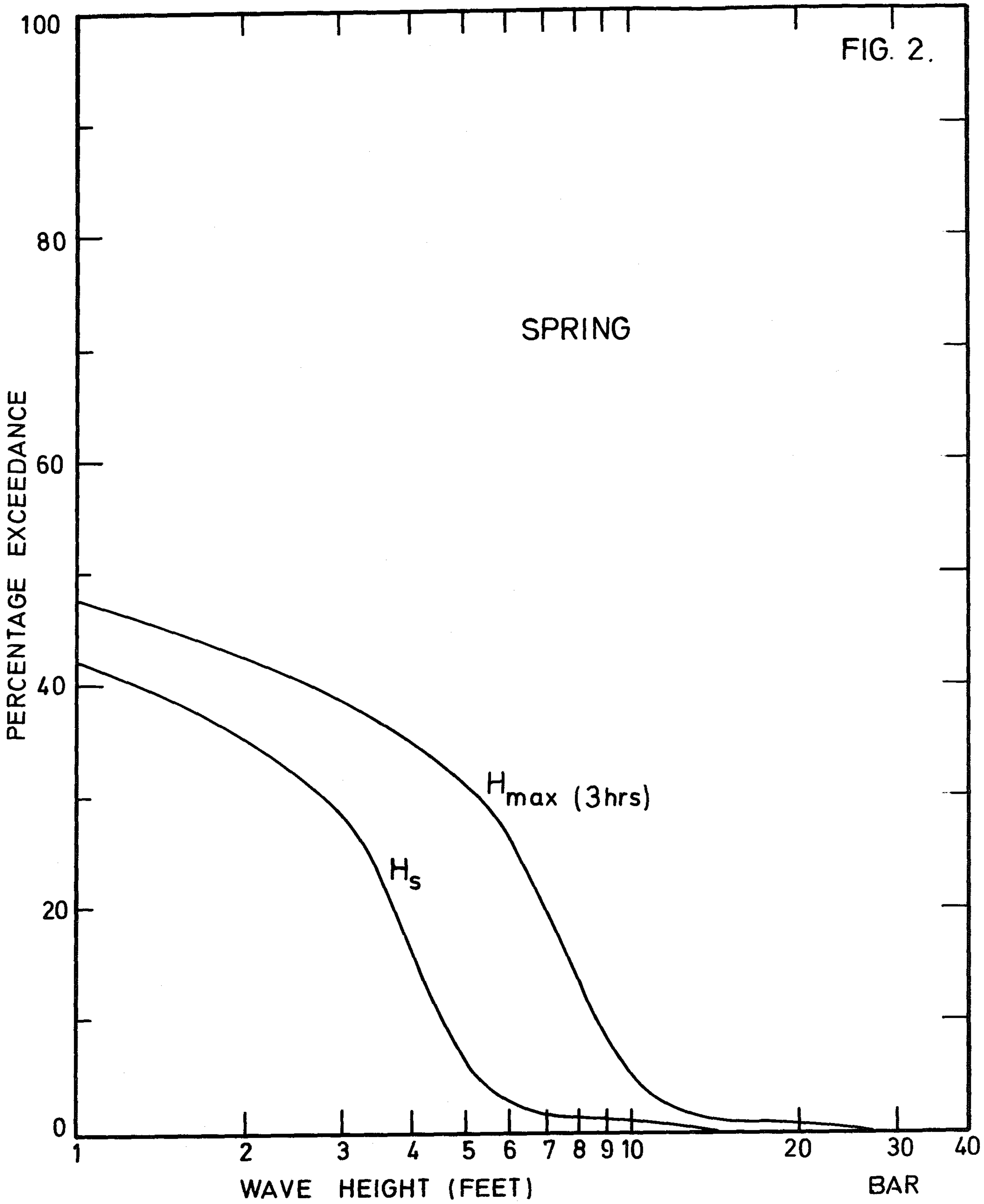


FIG. 1.
WINTER
PERCENTAGE EXCEEDANCE
100
80
60
40
20
0
H_{max} (3hrs)
H_s
1
2
3
4
5
6
7
8
9
10
20
30
40
WAVE HEIGHT (FEET)
BAR

FIG. 2.


100
80
60
40
20
0
PERCENTAGE EXCEEDANCE
SPRING
H_{max} (3hrs)
H_s
1
2
3
4
5
6
7
8
9
10
20
30
40
WAVE HEIGHT (FEET)
BAR

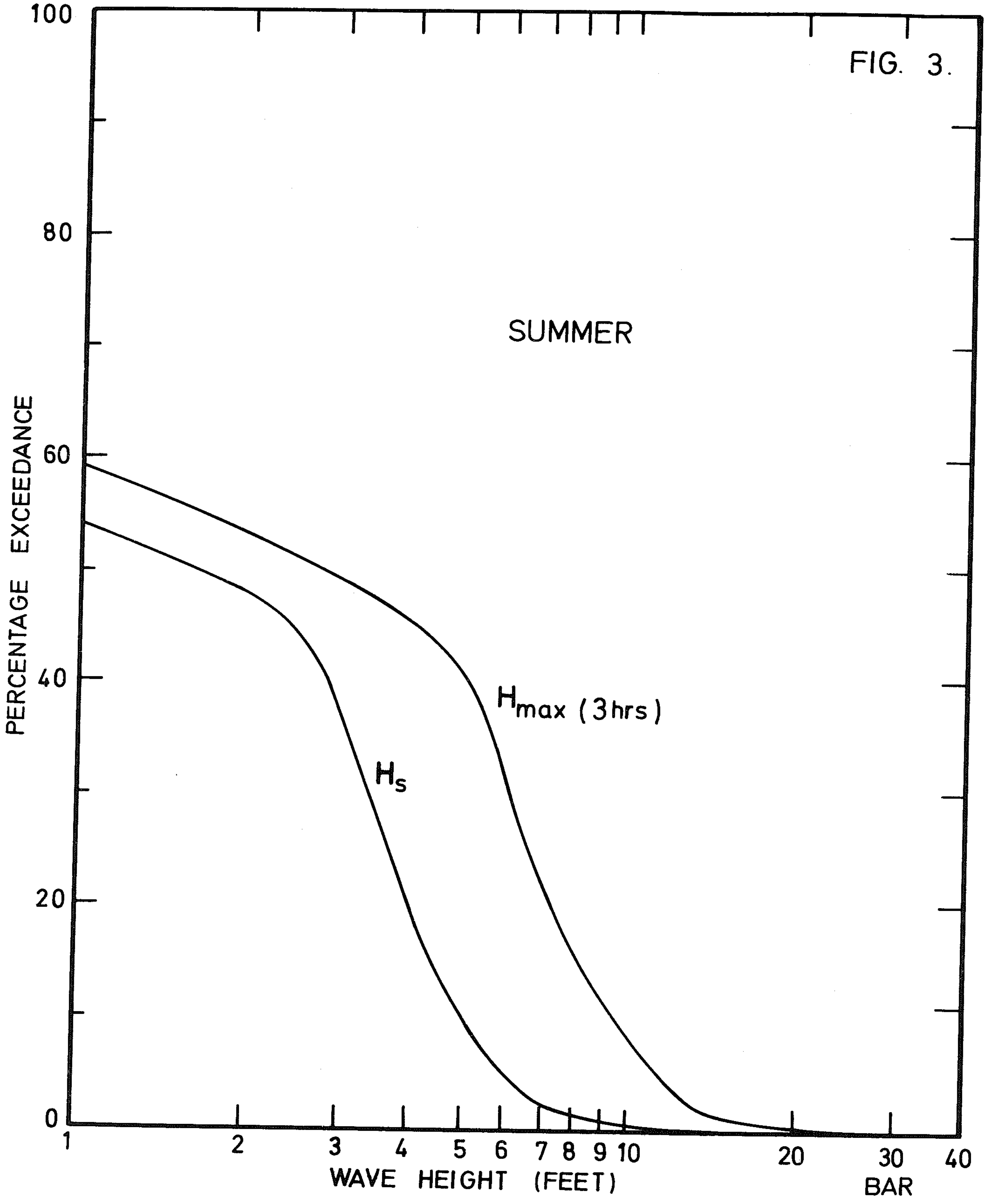


FIG. 3.
SUMMER
100
80
60
40
20
0
PERCENTAGE EXCEEDANCE
H_{max} (3hrs)
H_s
1
2
3
4
5
6
7
8
9
10
20
30
40
WAVE HEIGHT (FEET)
BAR

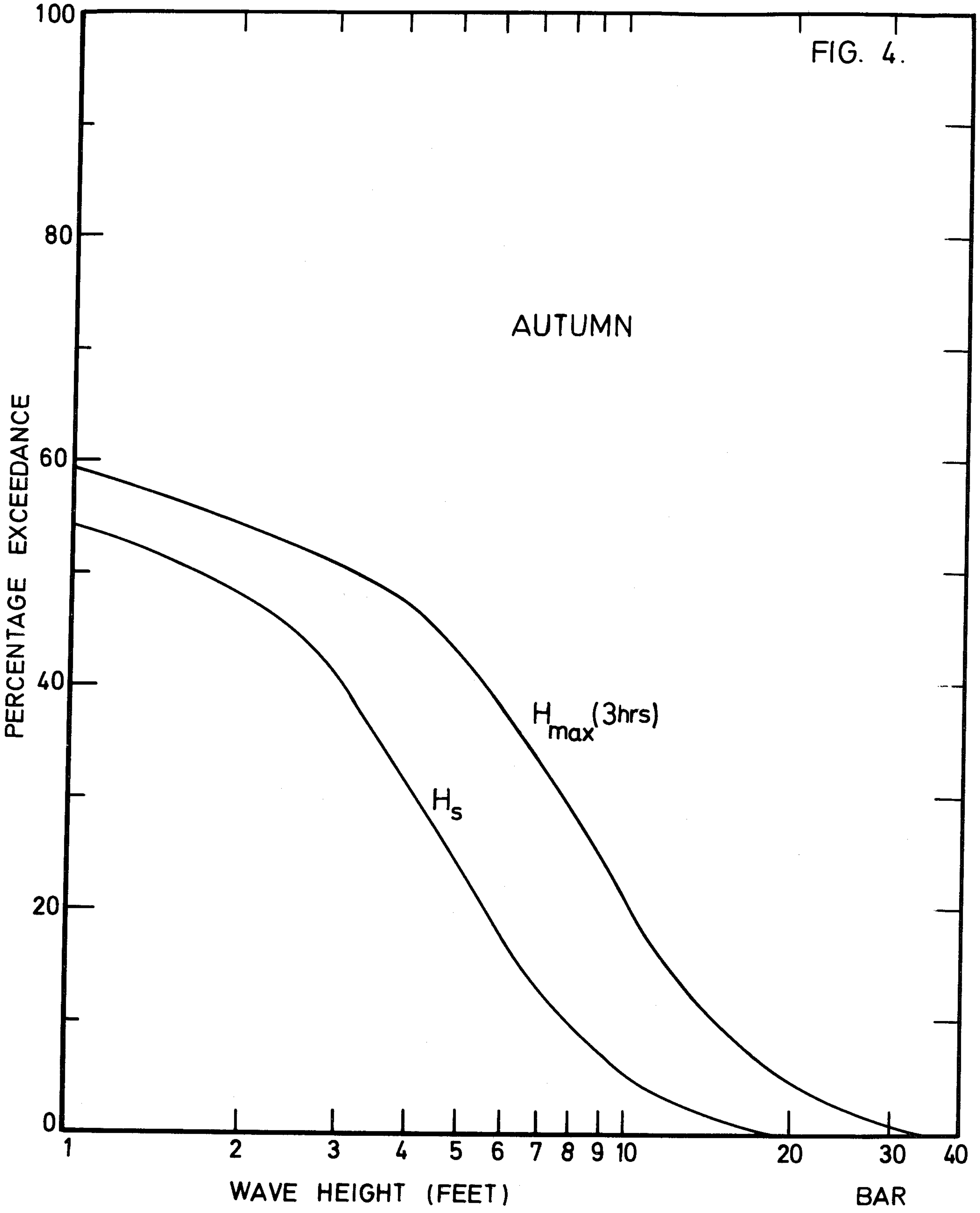
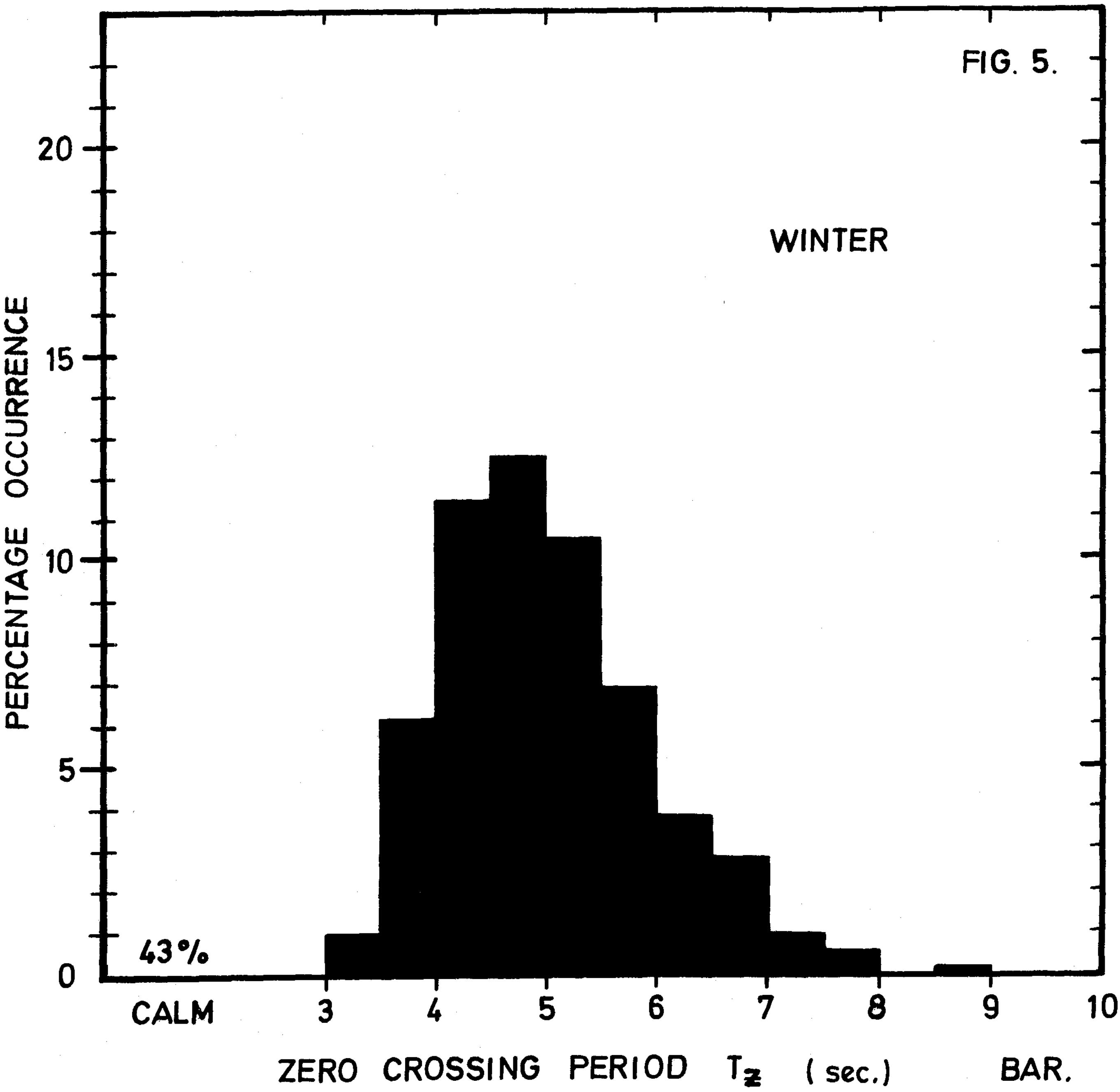


FIG. 4.
AUTUMN
PERCENTAGE EXCEEDANCE
100
80
60
40
20
0
H_{max}(3hrs)
H_s
1
2
3
4
5
6
7
8
9
10
20
30
40
WAVE HEIGHT (FEET)
BAR

FIG. 5.
WINTER
PERCENTAGE OCCURRENCE
0
5
10
15
20
43%
CALM
3
4
5
6
7
8
9
10
ZERO CROSSING PERIOD T_z (sec.)
BAR.

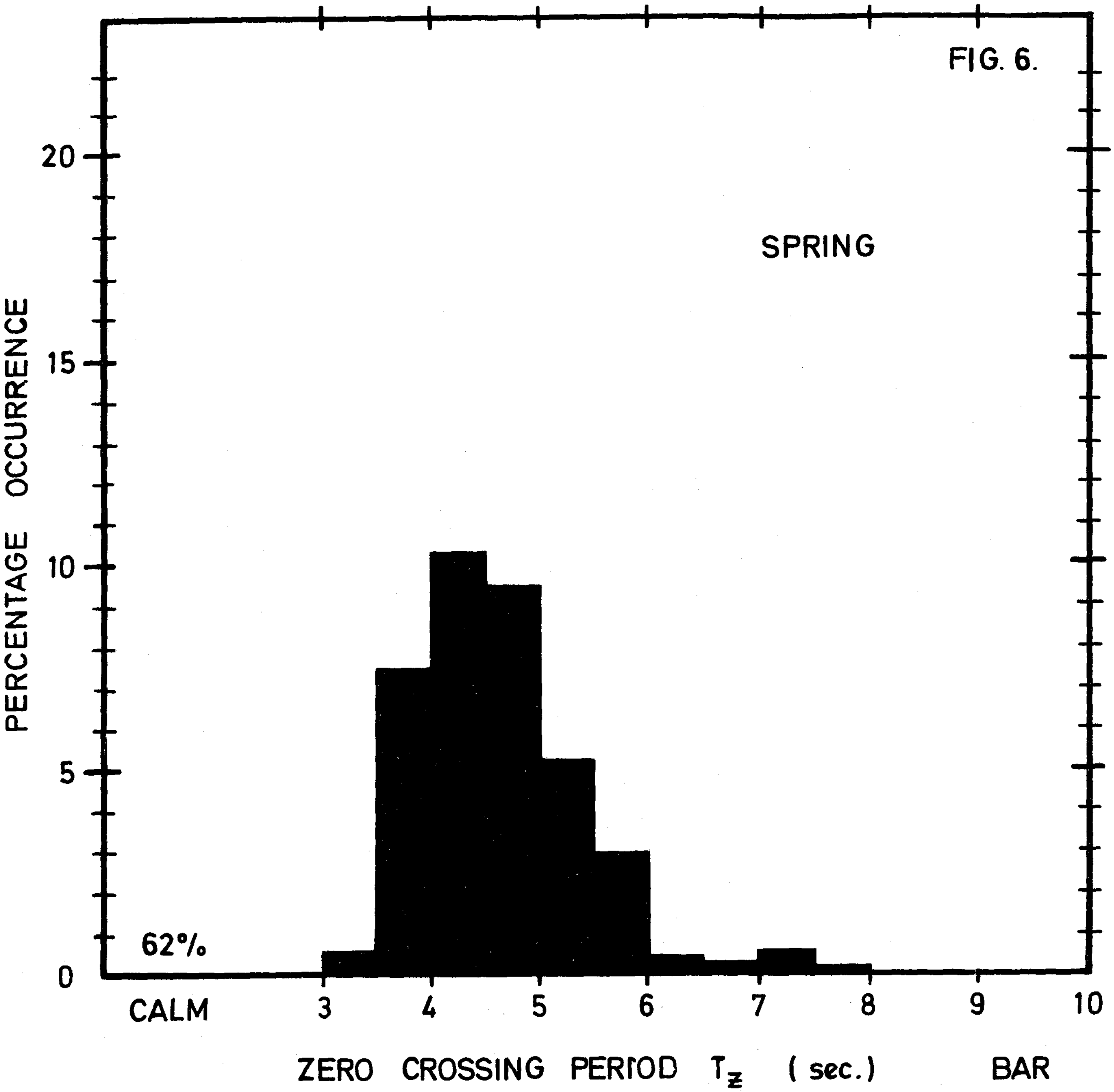


FIG. 6.

SPRING
PERCENTAGE OCCURRENCE
20
15
10
5
0
62%
CALM
3
4
5
6
7
8
9
10
ZERO CROSSING PERIOD T_z (sec.)
BAR

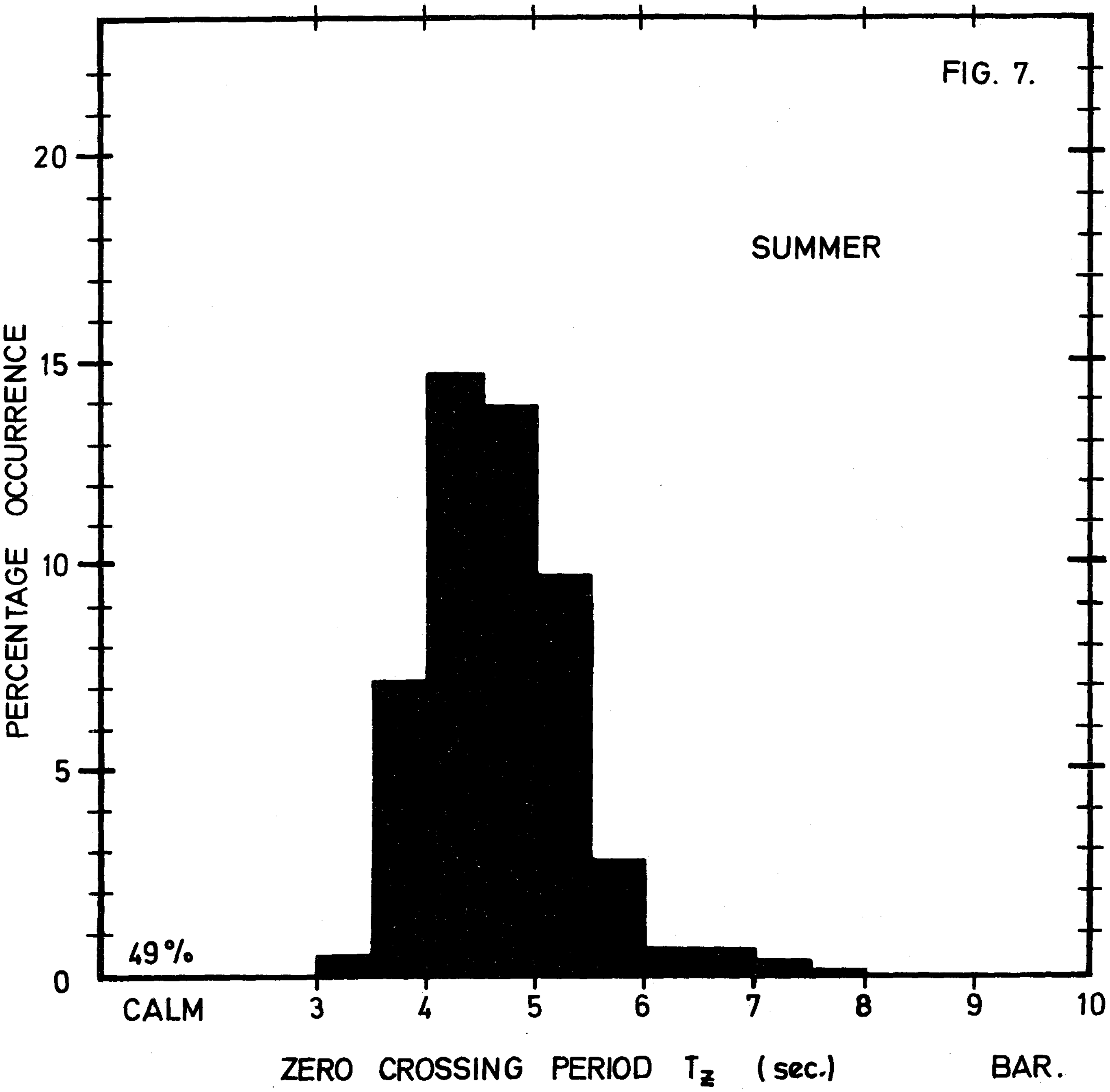
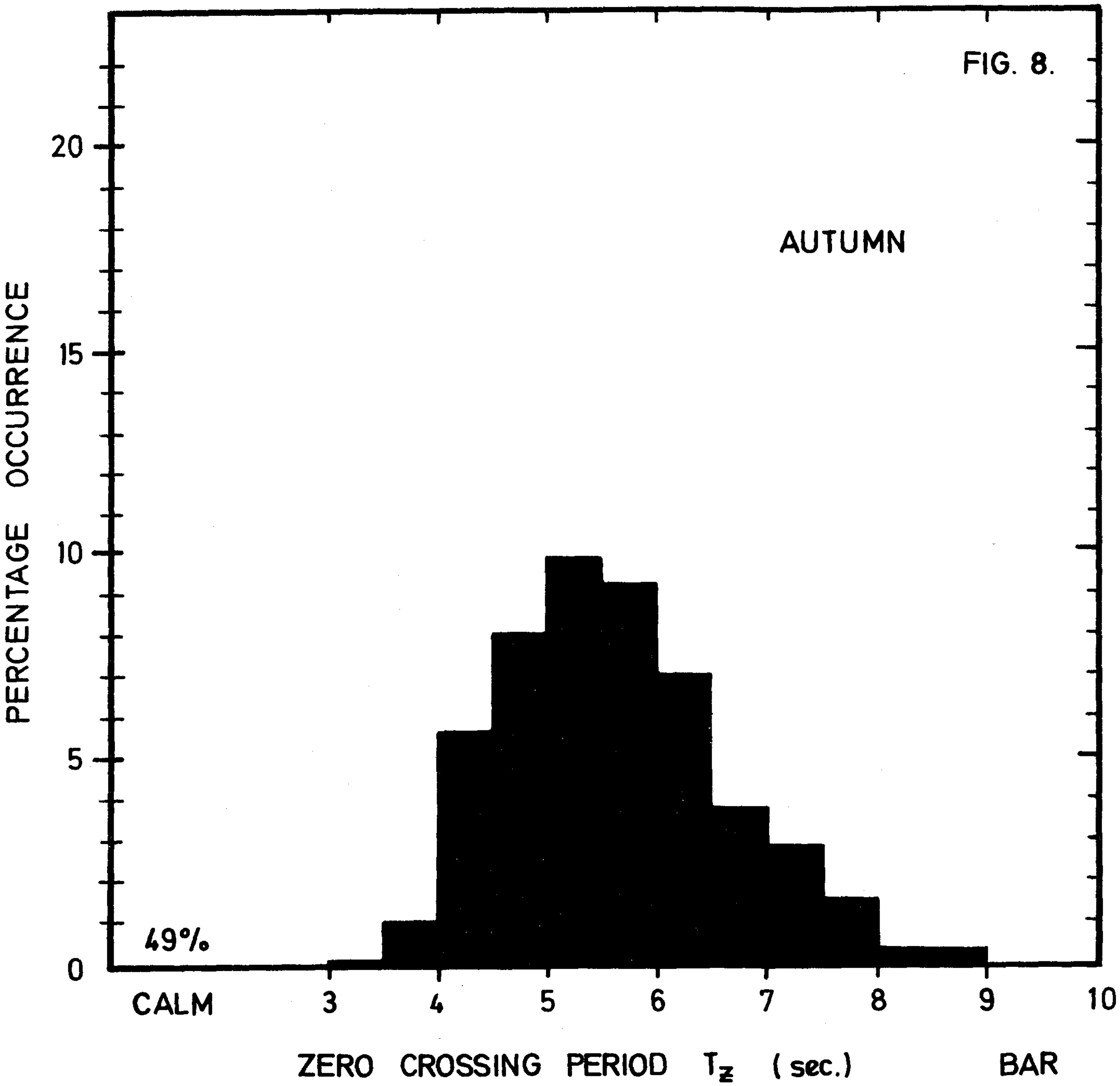

SUMMER
PERCENTAGE OCCURRENCE
0
5
10
15
20
49%
CALM
3
4
5
6
7
8
9
10
ZERO CROSSING PERIOD T_z (sec.)
BAR.

FIG. 7.

FIG. 8.


AUTUMN
PERCENTAGE OCCURRENCE
0
5
10
15
20
49%
CALM
3
4
5
6
7
8
9
10
ZERO CROSSING PERIOD T_z (sec.)
BAR

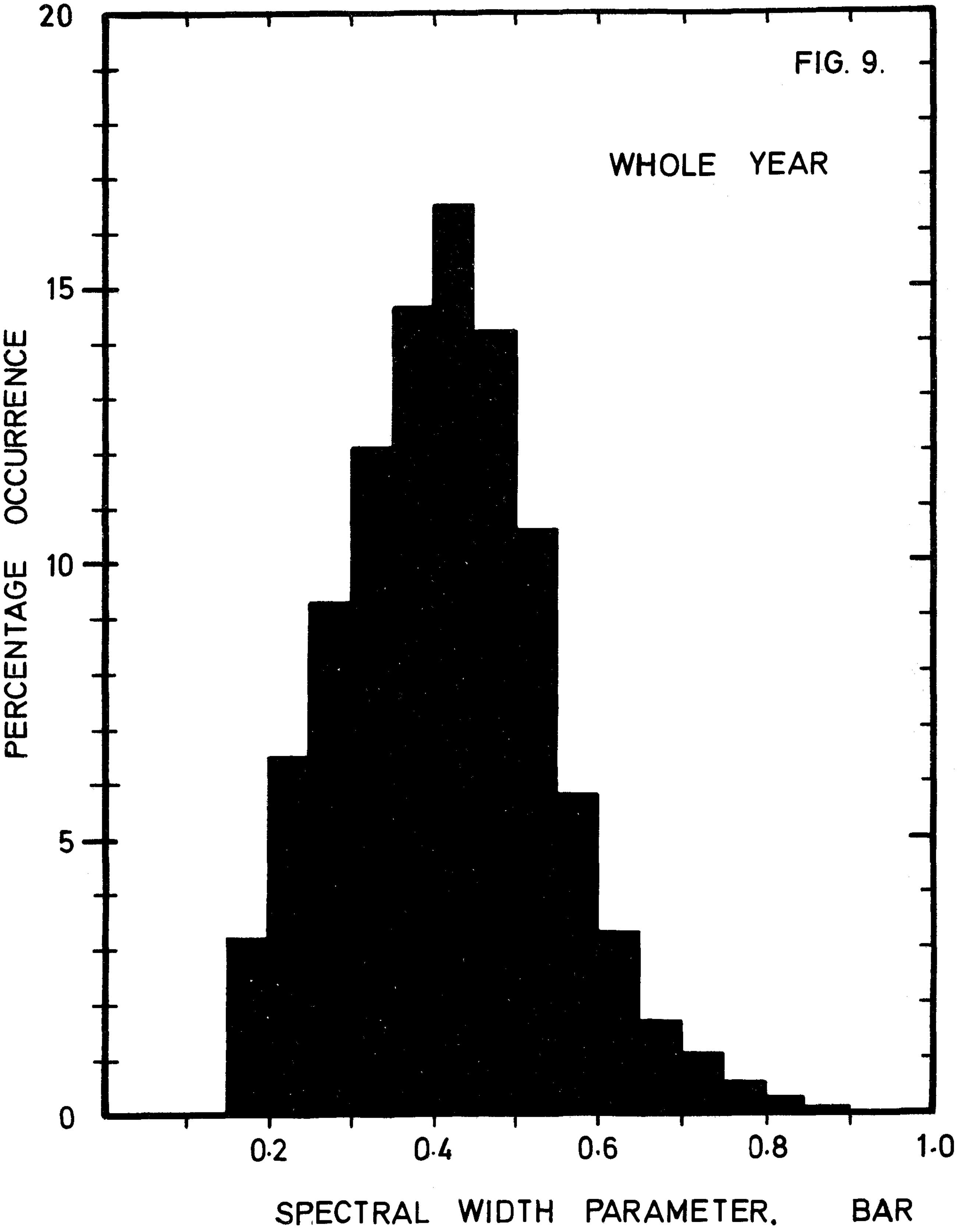


FIG. 9.

WHOLE YEAR

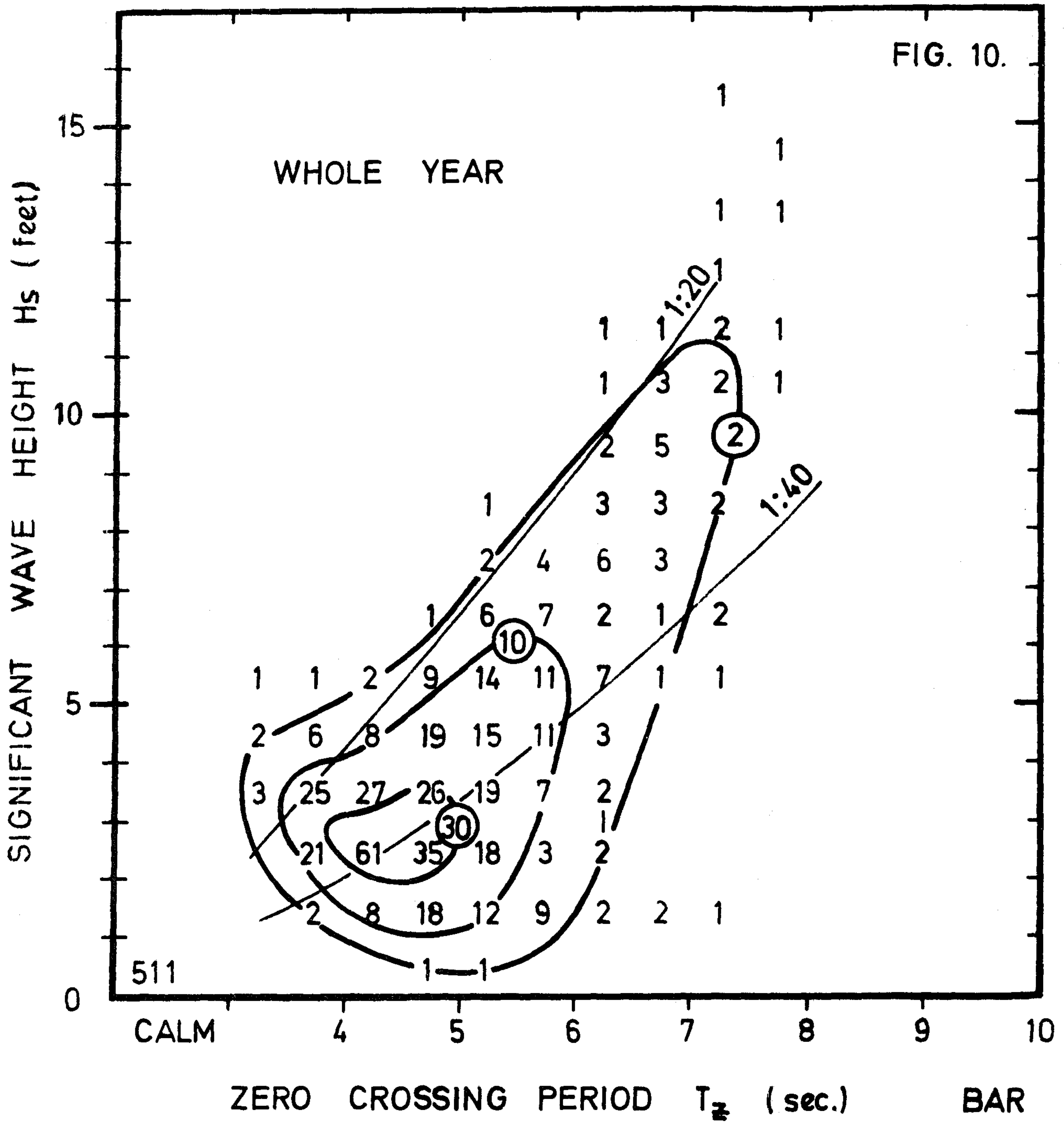


FIG. 10.

WHOLE YEAR
SIGNIFICANT WAVE HEIGHT Hs (feet)
ZERO CROSSING PERIOD Tz (sec.)
BAR
CALM
0
5
10
15
4
5
6
7
8
9
10
1:20
1:40
1
1
1 1
1
1 1 2 1
1 3 2 1
2 5 2
1 3 3 2
2 4 6 3
1 6 7 2 1 2
10
1 1 2 9 14 11 7 1 1
2 6 8 19 15 11 3
3 25 27 26 19 7 2
30 1
21 61 35 18 3 2
2 8 18 12 9 2 2 1
1 1
511

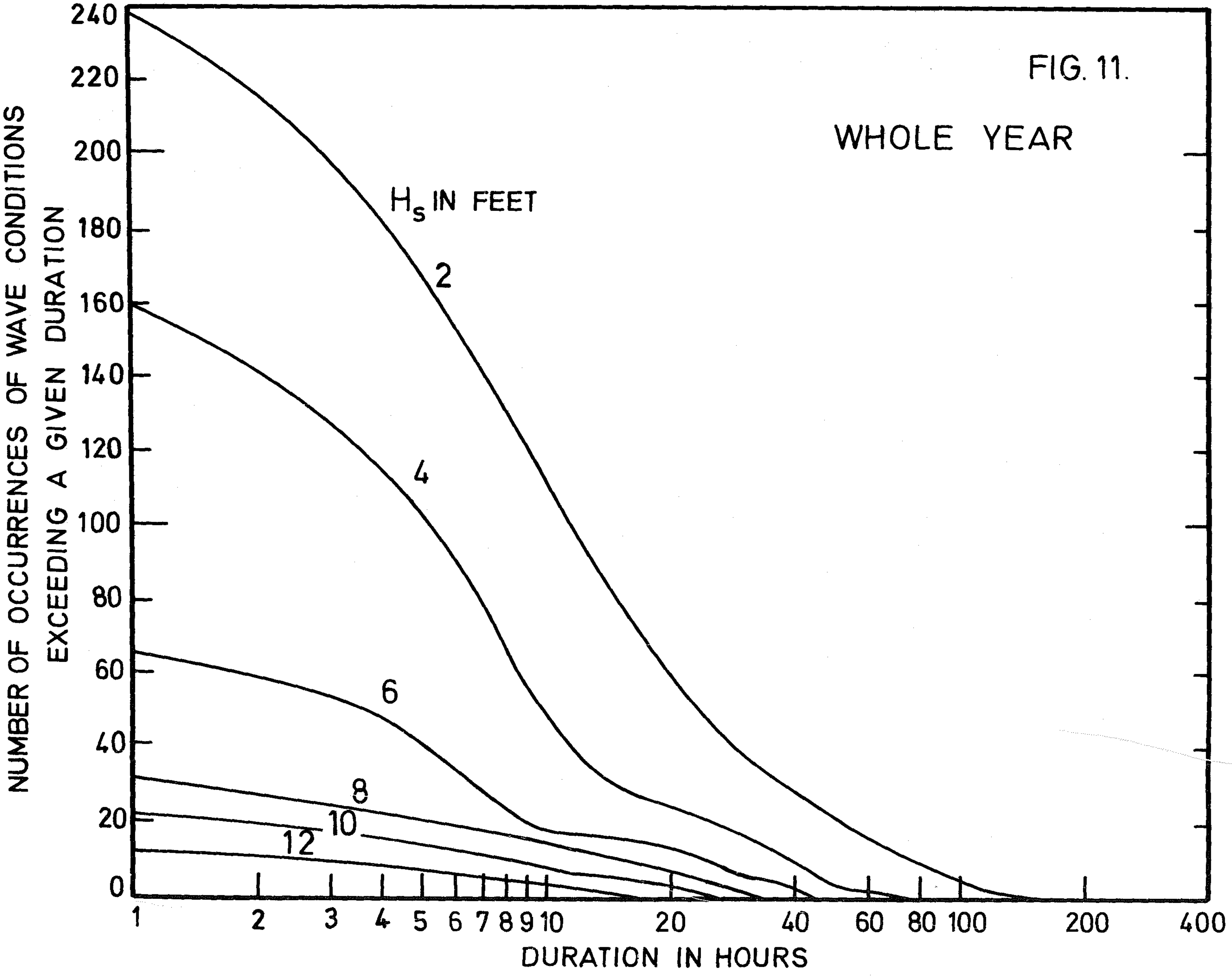

WHOLE YEAR
H_s IN FEET
2
4
6
8
10
12
NUMBER OF OCCURRENCES OF WAVE CONDITIONS EXCEEDING A GIVEN DURATION
240
220
200
180
160
140
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
20
40
60
80
100
200
400
DURATION IN HOURS

FIG. 11.