

THE DISAPPEARANCE OF *ZOSTERA MARINA*

By W. R. G. Atkins, Sc.D., F.R.S.

Head of the Department of General Physiology at the Plymouth Laboratory

In his paper on "The autecology of *Zostera marina* in relation to its wasting disease", Tutin (1938) states that "In the British Isles the year 1931-2 showed a sunshine deficiency of about 20 % below normal, and no other year in the past ten showed a deficiency approaching this. The scanty figures available for other countries suggest that this unusual lack of sunshine was a general phenomenon, though in some countries it was less pronounced but of longer duration." His enquiries showed that about 1931 there was extensive mortality on the Atlantic coast of the U.S.A., though there was some evidence of a local decline in 1930. A year later, in 1932, *Zostera* had practically disappeared at Beaufort, North Carolina and as far north as Nova Scotia. In 1933 scarcity spread still farther northward to all localities in Canada. At Plymouth, England, the plant is believed to have begun to decrease towards the end of 1931. In § 6 of his summary Tutin writes: "It is suggested that the enfeeblement of the plant due to lack of sunshine in 1931-2 is the fundamental cause of the epidemic, and that recovery depends on the regeneration of the plant from seed and is therefore likely to proceed slowly."

It appeared desirable that this interesting suggestion should be tested by an extension of the examination of the meteorological records beyond ten years, as far as they go, namely back to 1897, and that the alleged 20 % deficiency should be checked. Accordingly, taking the sunshine normals as revised up to 1928, the amounts of sunshine received each year in each of the twelve districts of the British Isles were tabulated as percentages of the normal. As is customary mean values were obtained for the districts 1-10, namely excluding the north of Scotland (o) with adjacent islands, and the English Channel Islands (11). It appears unnecessary to give all the figures, especially as since 1928 such percentages have been published by the Meteorological Office on the 1928 basis, but the following comments may be made upon the records from 1897-1937 inclusive. The most striking thing in the series is the uniformity of the results. As regards low values, in 1898 Ireland S. had 81 % of its normal sunshine. In 1900 and 1902 England N.E. had 84 %, as had also Scotland E. in 1902. The year 1912 gave conspicuously low values, and averaged 83 % for the ten districts, Scotland E. and England N.E. showing 76 and 78 % respectively. In 1916 districts 0-4 inclusive showed 83-86 %. In 1920 England Midland, Scotland W. and Ireland S. had 84-86 %, and in 1924 Ireland S. had 84 %. In 1927 England M. had 82 %. In 1931, the year supposed to have been destructive for *Zostera*, England S.W. had 83 and England M. 85 %, both districts had 85 % in 1932 and England E.

had 85 %. In 1936 England S.W. had 85 % and in 1937 England E. had 84 %. There is obviously nothing very unusual in the low values which occurred in some districts in 1931 and 1932.

Turning to the high values, in 1899 England S.W. had 122 % of the normal sunshine with an average of 114, and in 1901 England N.W. had 119. England E. had 115 % in 1906 and England N.W. had 120 % in 1911, which averaged 115 %, the maximum average, followed by the minimum in 1912. England M. had 115 % in 1921 and England S.E. had 116 % in 1929 and 115 % in 1933.

Table I puts on record the values for the district including Plymouth, namely England S.W. and S. Wales, and the mean values for the ten British Isles districts as usually taken by the Meteorological Office. For neither are the low values of 1931-2 outstandingly low. They have been equalled or surpassed in earlier years.

TABLE I. PERCENTAGE OF NORMAL SUNSHINE

a, England S.W. and S. Wales (district No. 8) calculated on the normal value to 1928, namely 4.28 hr. a day.

b, The ten districts of the British Isles, calculated on the normal, 3.95 hr. a day.

	1897	1898	1899	1900	1901	1902	1903
a	106	109	122	111	111	97	98
b	104	97	114	100	111	93	94
	1904	1905	1906	1907	1908	1909	1910
a	99	101	110	98	102	109	98
b	99	104	111	98	99	104	97
	1911	1912	1913	1914	1915	1916	1917
a	118	81	91	104	101	96	99
b	115	83	91	104	102	89	98
	1918	1919	1920	1921	1922	1923	1924
a	104	105	85	111	97	95	89
b	100	103	90	111	98	96	91
	1925	1926	1927	1928	1929	1930	1931
a	105	93	91	99	113	90	83
b	101	94	93	101	109	95	89
	1932	1933	1934	1935	1936	1937	
a	85	107	100	97	85	88	
b	89	106	102	104	93	90	

Table II shows the normal values for the hours of sunshine for the ten districts and the corresponding percentages calculated with respect to the maximum, England S.E., and to the mean. The value for the north of Ireland 3.51 hr. is only 78 % of the maximum, and only 89 % of the mean. In spite of this *Zostera* formerly grew well in the north of Ireland, though a reduction of sunshine to 89 % of the mean is suggested as having been the cause of the fatal nature of the *Zostera* disease.

Furthermore, the illumination due to sunshine in the north of Ireland or of Scotland is on the average less than that in the south of England in which with a midsummer maximum solar altitude of 63°, for latitude 50°, the vertical

component of the light from sun and sky is about 122 kilolux (Atkins, Ball & Poole, 1937); for the north of Ireland, around latitude 55° , the maximum altitude is 58° , so the illumination is about 117 kl., similarly with altitude 55° in the north of Scotland the maximum illumination is around 110 kl. This is to some extent offset by the longer duration of daylight during the summer, though the vertical illumination from a low angle sun is small. *Zostera* has been reported as growing (Börgesen, 1903) as far north as $61^{\circ} 28' N.$ in 2-4 m. of water in Vaagfjord in Syderö, the most southerly of the Faeröes. The mean sea temperature at the adjacent Thorshaven is $7.8^{\circ} C.$ with minimum 5.4° and maximum 10.6° . No sunshine records are available for the Faeröes.

TABLE II. NORMAL SUNSHINE (1928) AND PERCENTAGES CALCULATED ON THE MAXIMUM AND MEAN VALUES

District	Hours	%	%
Scotland E.	3.63	81	92
England N.E.	3.93	87	100
England E.	4.32	96	109
England M.	3.82	85	97
England S.E.	4.49	100	114
Scotland W.	3.70	82	94
England N.W. and N. Wales	3.89	87	99
England S.W. and S. Wales	4.28	95	108
Ireland N.	3.57	78	89
Ireland S.	3.96	88	100
Mean	3.95	88	100

But the assumption that a greater duration of sunlight necessarily means a greater amount of light is not correct. It has been shown (Atkins, 1938) that though the relation usually holds over a year, it does not always do so, for the altitude of the sun when clear is of great importance. According to photo-electric measurements made at Plymouth the year 1931 stood third on the list of eight years 1930-7, as regards the amount of light received, and 1932 was almost identical with four of the other years. Furthermore, the radiation records at London show that in 1931 the amount received was not unusually low but rather above normal.

Finally, with a water plant, one has to consider the extinction coefficient of the water. In estuarine and coastal waters this is subject to large variations, from about 0.2 to 2.5 even in June, thus introducing more than a tenfold variation in the amount of light reaching the plants (Poole & Atkins, 1937; Cooper & Milne, 1938).

At Plymouth *Zostera* has been under observation since the opening of the laboratory, as it was always exhibited in one of the aquarium tanks. I am indebted to Dr E. J. Allen for the information that never within his 42 years' experience was there a scarcity of *Zostera* in any way comparable to the shortage of the last few years. There is certainly no ground for attributing its disappearance to any decrease in illumination leaving the plant, thus weakened, an easier prey to disease.

SUMMARY

The suggestion that the enfeeblement of *Zostera marina* due to lack of sunshine in 1931-2 is the fundamental cause of the epidemic is not supported by the meteorological data available from 1897 onwards, or by the known extinction coefficients of the water.

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