MIGRATION AND SOLAR CYCLES.

BY LEONARD W. WING.

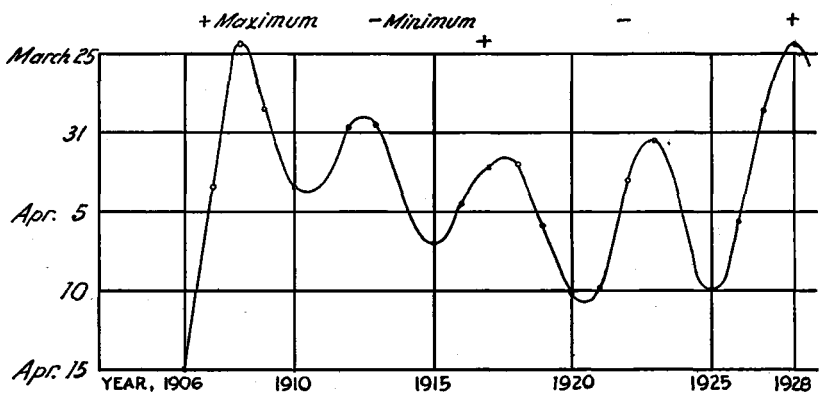
THE work of most ornithologists who have attempted to determine the external factors controlling migration, has been centered in correlating migration with the weather. Many have investigated a possible relation of the prevailing local temperature and bird movements, while others have used temperature data from north or south of their stations. Some have used atmospheric pressures, cloudiness of the sky, relative humidity and the like, as workable bases. The conclusions reached seemed to show that a species has a "normal" date of arrival but that departures from this normal are entirely fortuitous.

Few attempts have been made to link migration with the sun which appears to be the ultimate guiding influence in most terrestrial affairs. It is not surprising that the sun has not been considered. Most people consider the sun to be a fixed source of energy. They believe the amount of solar radiation to be constant and to reach the earth with variations due only to unfavorable atmospheric conditions. Even the scientific world once believed this. The measure of solar radiation was called the solar constant. It is now known that the output of radiant energy is not constant but is subject to varying periodicities. The fluctuations in the emission of solar radiation are of relatively small degree and measurable only with delicate instruments. However, it is demonstrable that these variations exert a profound influence over terrestrial affairs.

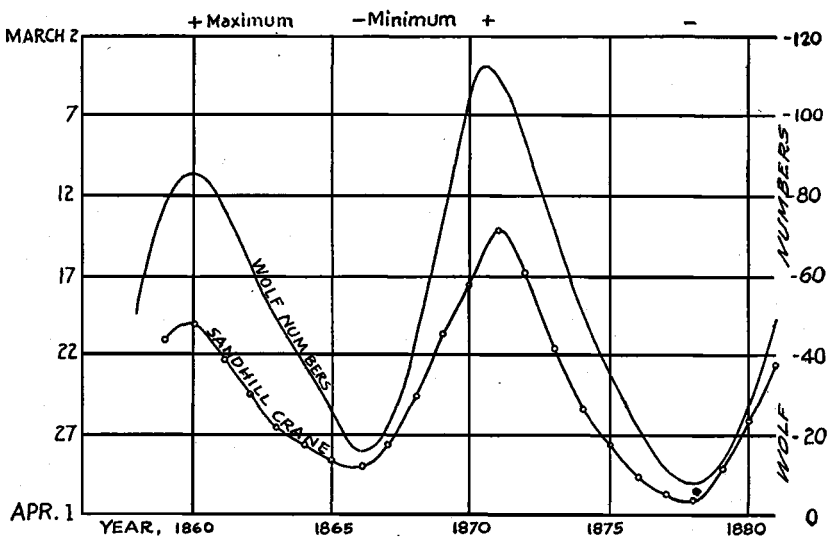
The most easily noticed cyclic variations in the sun are the sunspot cycles. Sunspots appear as dark blotches on the surface of the sun and move across its face somewhat in the manner of our high and low pressure areas. They were first noticed by astronomers in the early part of the 16th century. Careful record has been kept of the number of sunspots since that time. The data have been compiled, and properly weighted and are known as the Wolf Numbers, after their first compiler.

Analysis shows the Wolf Numbers to have a primary cycle of 11.2 years and a number of other cycles that are multiples or sub-

multiples of this figure. Variations in terrestrial magnetism, rainfall, solar constant values etc., have been found to have a relation to these cycles.



RESIDUAL CURVE COMPUTED FROM SPRING ARRIVALS OF LOON AT ANN ARBOR, MICHIGAN. L.W. WING, 1932



CURVES SHOWING SPRING ARRIVALS OF SANDHILL CRANE AT LOCKE, INGHAM CO., MICHIGAN AND REVISED WOLF SUN-SPOT NUMBERS L.W. WING 1932

The migration data that I have used in this study, have been taken, for the most part, from records covering the Ann Arbor, Michigan, area. In many cases the records go back to 1875. These records have been deposited in the Museum of Zoology, of the University of Michigan, by the various observers and have been compiled for publication by N. A. Wood and A. D. Tinker. The editing of the records was entrusted to me and during the process of editing, I discovered apparent periodicities in the yearly arrivals and departures of various species.

Statistical analysis, discloses these periodicities. It demonstrates the existence of a relationship between the arrivals and departures at Ann Arbor and certain solar activities. The farther the investigation proceeds the more evident it becomes, that the variations in the times of arrivals and departures are ultimately traceable to the sun. Whether the sun is responsible for the so-called normal date of arrival, will be reserved for a later discussion.

The data for the arrival of the Loon, at Ann Arbor, were smoothed by the formula $\frac{2 + 4b + 6c + 4d + e}{16}$. The term Loon refers to the species, *Gavia immer*. The two races *immer* and *elasson* occur at Ann Arbor during migration but are not subspecifically separable in the field. The residual, thus computed, was then plotted as shown in Figure 1. I have placed plus signs to indicate the maxima of the sunspots and minus signs to indicate the minima. It becomes at once apparent, that the peaks of the Loon curve fall at sunspot maxima or minima. Our consecutive records for the species cover but five sunspot periods. Three of the earliest records fall the exact year of sunspot maxima or minima while two lagged a year. It shows that the Loon arrives earlier the nearer we approach a sunspot maximum or minimum with retrograde arrivals as the maximum or minimum is passed.

One of the sunspot cycles is approximately half the eleven year cycle, with peaks at the maxima and minima of the eleven year cycle. It has been called the half sunspot cycle. It is known that rainfall, stream run-off and ground water levels are controlled by the half sunspot cycle. Whether this cycle exercises a direct influence on the Loon, through water levels or other means, is not readily apparent. It is sufficient, for the present, to note that for

the past twenty-seven years, at Ann Arbor, the Loon has faithfully followed the half sunspot cycle.

Figure 2 shows the residual computed from the data for the spring arrival of the Sandhill Crane, from 1856 to 1884, at Locke, Ingham County, Michigan, adjacent to the Ann Arbor area. The arrivals were recorded by H. A. Atkins, an old time Michigan ornithologist. I have placed plus and minus signs to indicate maxima and minima as in the first figure. I have also added the curve of the Wolf Numbers. An apparent correspondence at once appears. It will be noted that the curve of the Sandhill Crane, exactly parallels the sunspot curve. The greater degree of amplitude of the maximum of 1871 as compared to the maximum of 1861, and of the minimum of 1878 as compared to the minimum of 1866, is mirrored in the Sandhill Crane curve. A striking correspondence!

I have been working with the data for many other species. The two examples I have just given will suffice for our present purpose. In some cases the migration follows the eleven year cycle, while in others it follows the half sunspot cycle as shown in the Loon. In still others, the records indicate a periodicity of uncertain affinities.

In general, closely related birds respond to the same cycle. Land birds usually follow the eleven year cycle in phase, while water birds appear to be governed by the half sunspot cycle.

The manner in which the sun exerts an influence over migration cannot be predicated at this time. It is probable that the variations in the amount of the sun's radiant energy are the basic controlling factors. The investigation also shows that certain normal and abnormal activities of the individual bird are responsive to changes in the solar radiation and gives promise of interesting results.

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