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THE CORRELATION OF SUNSPOT PERIODICITY WITH GRASSHOPPER FLUCTUATION IN MANITOBA

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THE APPARENT correlation of sunspot periodicity with certain animal fluctuations was first brought to my attention by Dr. Ralph DeLury of the Dominion Observatory, Ottawa. The subject is by no means new but with the exception of Dr. DeLury few people in Canada have devoted much attention to the study.

The first attempt to correlate grasshopper cycles with those of sunspots seems to have been made by A. H. Swinton in England in an article entitled "Data obtained from Solar Physics and Earthquake Commotions Applied to Elucidate Locust Multiplication and Migration" (1878). In this article an attempt is made to correlate solar disturbances with locust prevalence both in Europe and America. The evidence is far from conclusive although it does suggest that periods of sunspot minima are most favourable to grasshopper outbreaks.

If, as has been claimed by Dr. DeLury, there are actually marked atmospheric changes due to sunspot cycles, it follows that these may have an important effect upon animal and plant life. Indeed the available evidence strongly indicates that this is so, both in the case of game animals and in trees. In the present paper I have attempted to show to what extent grasshoppers fall within the same sphere of influence.

In order to understand the causes of grasshopper fluctuation we should first know the maximum possibilities for reproduction in the species involved. This has been ascertained by study of the egg-laying capacity of those insects. We find that the average number of eggs under favourable conditions deposited in a year by *Melanoplus mexicanus* Sans., *M. femur-rubrum* De G., or *Camnula pellucida* Scud. to be approximately 150 per female, while *Melanoplus bivittatus* Say produces at least 200 eggs. The possibilities for reproduction under optimum conditions are thus seen to be very great, and the evidence leaves no doubt in our minds as to why grasshoppers rapidly increase when conditions are favourable.

As a rule grasshoppers are kept within bounds by a combination of meteorological factors and natural enemies. Should these conditions exert their maximum effect at the same time, then grasshoppers would become very scarce indeed, but generally the weather conditions which are detrimental to grasshoppers are also adverse to their insect foes; hence the two rarely act in unison. The meteorological factors, in particular, have a most important bearing on grasshopper survival and without favourable weather it is doubtful whether these insects would ever, in our territory, attain sufficient abundance to become an agricultural pest. This fact has long been recognized as the following quotation from the "Second Report of the United States Entomological Commission" (1878) will indicate:—"We may state, therefore, as a proposition which we presume will be admitted as correct, that the development and movements of locusts are very largely influenced by meteorological conditions."

The seasons which most favour the development of grasshoppers are those in which dryness is combined with heat and sunshine. The optimum conditions would probably be a late, comparatively dry autumn followed by an early, warm spring with a maximum of sunshine throughout the summer. Moisture, however, either in the form of green herbage, dew or rain, is essential to grasshopper survival and short, heavy thunderstorms, providing a maximum of precipitation without greatly interfering with the heat and sunshine, would provide an impetus to rapid development. Such conditions combined with a comparative absence of important natural enemies, would almost surely bring about a grasshopper outbreak from normal numbers within three years.

From the above it will be noted that grasshopper fluctuation is largely brought about by two factors, namely, weather and invertebrate enemies. Both play an important role in the inception of an outbreak while the decline, in spite of favourable weather, may be due to natural enemies alone. As a rule favourable weather is most important at the beginning of a grasshopper outbreak while parasites and diseases do most to reduce it.

It is usually assumed that extreme dryness is favourable to grasshoppers but as a matter of fact this is not true. Not only do the eggs require a certain amount of moisture in autumn to survive but moist soil is also important to assist development and ensure a maximum hatching in spring. Moisture also becomes necessary after the hoppers hatch and without succulent food they would inevitably perish.

In attempting to reach a conclusion as to the possible correlation between the periodicity of sunspots and the fluctuation of grasshoppers I have availed myself of as many of the old references to grasshoppers as possible. These records are far from being complete and a majority of them appear to relate to invasions rather than to local outbreaks. Moreover, they invariably refer to abundance, never to rarity. On making comparisons of early grasshopper activities we must therefore, rely wholly upon the records of the insects in vast numbers and assume that the indigenous insects were usually at the height of their activities at similar times. Needless to add this only furnishes us with approximate data.

From a review of the literature we discover that there have been at least 32 years when grasshoppers were abundant between 1800 and 1930 these were 1800, 1802, 1808, 1818, 1819, 1821, 1830 1851, 1858, 1864, 1865, 1866, 1867, 1868, 1869 1870, 1872, 1873, 1874, 1875, 1876, 1898, 1899 1900, 1901, 1902, 1903, 1912, 1919, 1920, 1921 1922. While the above records are all from Manitoba it must be borne in mind that a number of them undoubtedly relate to invasions and it is highly probable that in some of them the grasshoppers originated in regions quite remote from the province.

A reference to the accompanying chart—admittedly incomplete in respect to grasshoppers—will indicate the extent of the correlation between grasshopper fluctuation and sunspot cycles. (Fig. 1).

It will be noted that the first grasshopper outbreak of which we have any record, namely that of 1800, immediately followed a period of sunspot minima. The next one, 1808, was also during a low sunspot period although it began to rise and attained its maximum before the minimum of sunspots. The year 1818 was one of maximum grasshopper activities. Its rise in 1817 was almost at the height of a sunspot period while at its greatest intensity it was half way down the sunspot decline. This great outbreak, however, had visibly fallen before the low ebb in sunspots was reached. There was a light grasshopper outbreak recorded in 1830 and in the neighbouring state of Minnesota one was recorded in 1842 and in Dakota another occurred in 1853, but in Manitoba we had no further trouble until 1857 when the great outbreak, which extended with variable intensity until 1876, began. At this time any relation to sunspots was almost entirely absent and the insects maintained their numbers even over the great sunspot year of 1870. This as we shall point out later, was doubless due to repeated invasions from other sections of the continent. After this period there was a low ebb in grasshopper activity which lasted until 1898 when the insects again began to rise in numbers and by 1901 they had attained another high point. A reference to the chart will show that this outbreak had its inception considerably before the sunspots had reached their minimum but that its maximum closely coincided with the minimum in sunspots. The 1912 peak in grasshoppers again had its rise half way down the sunspot decline but the much more intensive outbreak of 1919-23 began well up the sunspot peak and was falling before the minimum was reached.

By far the most important evidence in our chart begins with the year 1882 because we know that all grasshopper outbreaks after that time have been of local origin, whereas before that date the rise or fall of indigenous species is only conjectural. Nevertheless the evidence from the records of early outbreaks is by no means without value and there is much which indicates a correlation between grasshopper and sunspot cycles.

That there is a correlation between sunspot minimum, or decline, and a rise in the number of grasshoppers seems evident, but the presence of a number of other factors greatly complicates the problem and often obscures what might otherwise be plain.

On reviewing the accounts of early grasshopper outbreaks in Manitoba it becomes evident that a majority of these were due to invasion from foreign territory, more often than not from far to the southward. Thus we find several records of the winged insects appearing in June at a time when the local grasshoppers of the same species would be little more than half grown. This means that the invaders had their inception several

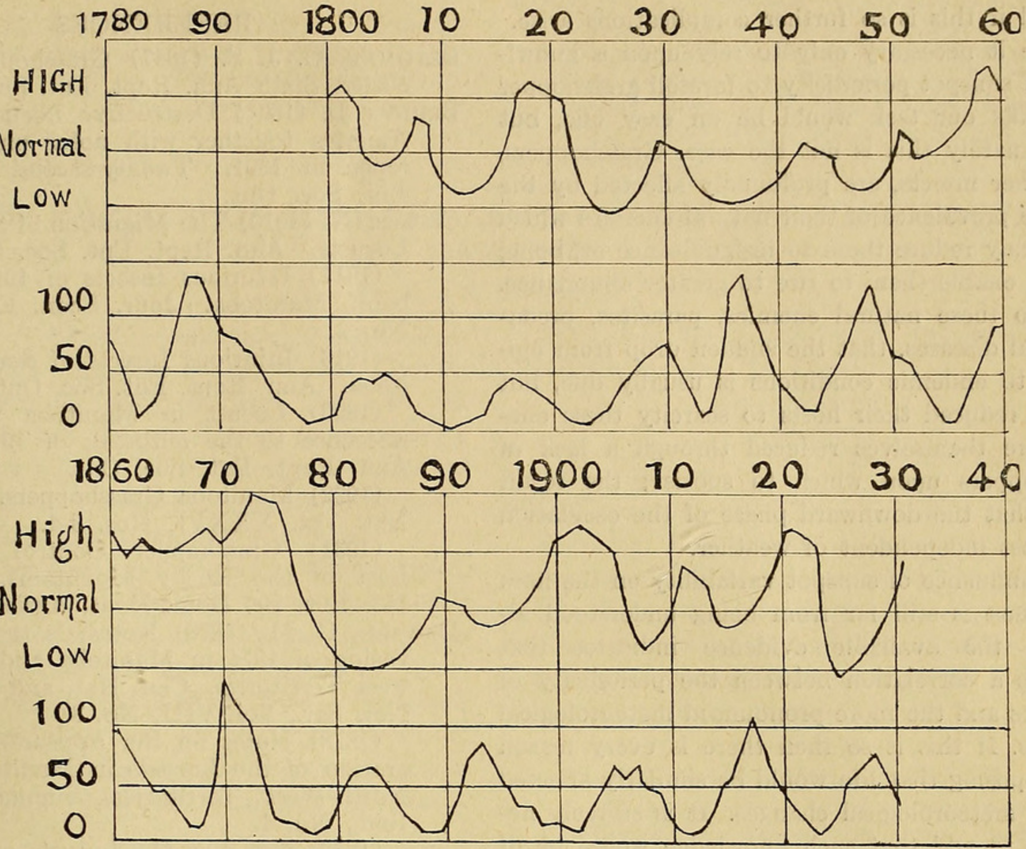

Chart showing Sunspot and Grasshopper Cycles. The upper curves represents grasshoppers, the lower ones Sunspots (Original)

hundred miles to the south of us. These foreign swarms nearly always left their eggs in the invaded territory and their progeny, hatching the following spring, played far greater havoc with the crops than their progenitors had done before them. As a rule the progeny on acquiring wings, flew elsewhere, and unless fresh swarms arrived the country might be comparatively free from grasshoppers the following year.

The point to be emphasized in connection with these invasions is that the invaders probably originated in more arid sections of the continent where increased rainfall might actually be a benefit to the grasshoppers by stimulating plant growth and providing water for drinking, whereas extreme aridity might, in these sections, be less favourable to survival. In other words while the minimum rain period might benefit local grasshopper development, in arid areas a converse condition might be more favourable. The mean rainfall necessary to increase being the same in both cases although occurring at opposite phases in the sunspot cycle. If this were so then it would explain the invasions of Manitoba which took place during supposedly adverse local conditions.

There is reason for believing that the great grasshopper period from 1857 to 1876 was maintained by repeated invasions, rather than through the reproduction of local species and that the 1817-18 outbreak was also due to invaders. If this was so then the almost negligible local correlation with sunspot influence at those times is explained.

The next group of factors which complicate the rhythm in sunspot-grasshopper periodicity are parasites, predators and diseases. As a rule the first essential to grasshopper increase is an absence of the more important natural enemies, nearly all of which are insects. It is largely due to insect enemies that grasshoppers are not in perpetual outbreak in certain favourable sections of the country and there is little doubt that a marked fluctuation, due to insect enemies, occurs irrespective of either sunspot cycles or any other natural phenomena. It is doubtless due to this fact that the increase in grasshoppers often begins well up in the maximum sunspot period and declines before the minimum in sunspots is reached. Furthermore, there is the probability that some of the natural enemies are more susceptible to certain meteorological conditions than are others and if this is so further complications arise.

Were it necessary only to rely upon a knowledge of sunspot periodicity to foretell grasshopper outbreaks our task would be an easy one, but unfortunately this is not the case. Grasshoppers, like other insects, are profoundly affected by the relative prevalence of their natural enemies which alone may reduce them to insignificance or, being absent, enable them to rise to greater abundance. It is to these natural enemies, parasites, predators and diseases, that the sudden drop from epidemic to endemic conditions is usually due, but having reduced their hosts to scarcity these enemies are themselves reduced through a lack of grasshoppers upon which to subsist; the result being that the downward phase of the oscillation is almost independent of weather.

The influence of sunspot variability on the flora and fauna is still far from being understood although the available evidence indicates that there is a correlation between the periodicity of sunspots and the more pronounced meteorological changes. If this is so then there is every reason for supposing that life would be similarly affected by the meteorological changes. It is scarcely necessary to add that such knowledge would be of immeasurable value as an aid to forecasting insect activities and it might furnish us with at least one of the reasons for grasshopper fluctuation. We believe, after reviewing the evidence summarized above, that there is a distinct correlation in the periodicity of sunspots and grasshoppers and, omitting the possibility of invasions, we should expect a high point in grasshopper prevalence approximately every eleven years and that this maximum in abundance is to be looked for, on an average, at the minimum sunspot period, although the increase may begin well up the sunspot decline and there may not be much abatement in its intensity until the low sunspot period is past. Our next grasshopper outbreak, according to this theory should reach its high point in 1932, which, as a matter of fact, there is every prospect of its doing. As we have already pointed out, there are several factors which militate against so simple a forecast and all we can reasonably claim in this connection is that the meteorological conditions favourable to grasshopper increase, will probably be at their best during the period we have stated. It will be the task of the entomologist to ascertain the biological conditions prevailing at the time and to take these into consideration when making his forecasts.

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*A NEW VARIETY OF VALVATA LEWISI FROM THE PLEISTOCENE OF ONTARIO**

By A. LA ROCQUE

IN A SMALL collection of marl shells from Shallow Lake, Grey County, Ontario, received from Mr. W. R. McColl of Owen Sound, there occurs a loosely coiled *Valvata* which belongs to the group of *Valvata lewisi* Currier but appears to be new.

Valvata lewisi mccolli var. nov.

Shell of fair size for the genus; whorls, three. The first one and one-half in contact with each other and coiled almost in the same plane; the last one and one-half loosely coiled and free, forming a rapidly descending tube. Sculpture of fine, thread-like lines on all three whorls of the shell, as in typical *lewisi;* there is no trace of spiral lines. Aperture rounded; peristome simple.

Type locality and horizon: Shallow Lake, Grey Co., Ont.; in marl of late Wisconsin age (Pleistocene). Collected by W. R. McColl.

Types: Holotype, N.M.C. No. 7392; paratypes N.M.C. Nos. 7392a and 7392b. Deposited in the National Museum of Canada.

MEASUREMENTS

in millimetres

	Lgth.	Wdth.	Ap. L.	Ap. W.
Holotype N.M.C. No. 7392	3.5	3.5	1.25	1.25
Paratype " " 7392a.....	4.5	4.0	1.75	1.5
Paratype " " 7392b.....	3.25	3.5	1.5	1.5

Remarks: This variety of *Valvata lewisi* is near to *ontariensis* Baker (Nautilus 44:119, 1931), but differs from it in its larger size and especially in the absence of the rib-like lamellae on the last whorl. Named in honour of W. R. McColl Esq., the collector of the type lot.

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EXPLANATION OF PLATE.

All figures eight times natural size.

1. *Valvata lewisi mccolli* var. nov. Paratype 1, N.M.C. No. 7392b. a. Side view; b. umbilical view; c. side opposite aperture.
2. *Valvata lewisi mccolli* var. nov. Holotype N.M.C. No. 7392. a. Side view; b. umbilical view; c. side opposite aperture.
3. *Valvata lewisi mccolli* var. nov. Paratype 2, N.M.C. No. 7392a. a. Side view; b. umbilical view; c. side opposite aperture.