STUDIES IN THE BIOLOGY OF NORTH AMERICAN ACRIDIDAE DEVELOPMENT AND HABITS

Norman Criddle

PREAMBLE TO PUBLICATION OF THE ORIGINAL MANUSCRIPT

N.J. Holliday[1] and L.J. Donald[2]

[1] Department of Entomology, University of Manitoba, Winnipeg, MB R3T 2N2
[2] Department of Microbiology, University of Manitoba, Winnipeg, MB R3T 2N2

From 1913 until his death in 1933, Norman Criddle was officer-in-charge at the Dominion Entomological Laboratory, Treesbank, Manitoba — the first federal government entomological laboratory in Manitoba. At the time of his death, Norman Criddle was in the process of developing three major publications on grasshoppers, one on eggs and egg-sacs, one on nymphs, and one on the natural history of grasshoppers. Vestiges of two of these publications remain; no trace has been found of the work on nymphs.
The most fully developed work was that on natural history. The archives of the Entomological Society of Manitoba contain a binder with a longhand manuscript entitled, "Studies in the Biology of North American Acrididae Development and Habits". The handwriting is almost certainly that of Norman himself. The binder's list of contents indicates that it contains also two typed versions of this work. Of these, one remains, and it has been corrected in two different hands, one of which may have been Norman's and the other that of the typist. Norman Criddle died on 4 May 1933, and it would appear that he had been expected to present the work in the Technical Sessions of the World's Grain Exhibition and Conference, held in Regina, Saskatchewan, 24 June–5 August 1933. A paper, with the title given earlier in this paragraph, was delivered at that conference, and subsequently appeared in its proceedings (Criddle 1933). The paper may have been presented by H. G. Crawford, as Crawford identifies himself as having made some editorial decisions in the proceedings. Crawford was a co-author of the official obituary of Norman Criddle (Gibson and Crawford 1933).

The version of "Studies in the Biology of North American Acrididae Development and Habits" published in the conference proceedings is difficult to obtain and not widely

known or cited, mostly because the proceedings are not a scientific journal. Furthermore, it appears that the editing process has introduced some errors that were not present in the original manuscript and typescript. To rectify these shortcomings, we present a version of this work that is as close as possible to Norman Criddle's original intent, and is based on the versions in the binder held in the archives of the Entomological Society of Manitoba. This version, published in the Society's *Proceedings* and available on line, will be accessible to all.

Except when there were clearly errors in spelling or typography, we have retained Criddle's original wording. We have made minor changes to the formatting of tables to improve their clarity. The original manuscript in the Society's archives differs in the order of the sections "References" and "Notes on the habits of various species" from that in Criddle (1933). The editing process for Criddle (1933) changed the order of grasshopper species treated in "Notes on the habits of various species", despite Criddle's insistence in his instructions to his typist that the order of species treatment in the handwritten version should be retained. We have restored the order of the two sections, and the order of the species treatments, to be as Criddle had intended. The reference section is not like a modern reference section with all entries corresponding to citations; also, the references do not always have full information such as page numbers. Where we are sure of the identity of the intended sources, we have added the missing information in square brackets so that the reader can more easily consult those sources. The section "Notes on the habits of various species" was not an integral part of the paper, but was possibly intended to be an appendix. It was included as part of both the handwritten and typed versions in the Society's archives, and is included here as it is certainly contributory to the material in the remainder.

We have retained Criddle's scientific nomenclature for insects and plants. Criddle's use of parentheses around authorities for scientific names was variable, and we have corrected errors of this type without notation of the correction. Where scientific nomenclature or authority designation now differs from that used by Criddle, we have included the current nomenclature in square brackets in addition to the original rendition. Current nomenclature of Orthoptera is from Cigliano *et al.* (2020), but with some interpretations deriving from Vickery and Kevan (1985). Current nomenclature for plants is from ITIS (2020) and VASCAN (2020) with some interpretations from Looman and Best (1979) and Scoggan (1957); where ITIS and VASCAN differed, the VASCAN nomenclature was used. Current nomenclature of lichens is from ITIS (2020) and was verified with Essling (2019).

We thank D. Johnson for reviewing the nomenclature of Orthoptera and E. Punter for reviewing that of plants and lichens.

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STUDIES IN THE BIOLOGY OF NORTH AMERICAN ACRIDIDAE DEVELOPMENT AND HABITS

Norman Criddle

Dominion Entomological Laboratory, Treesbank, Manitoba, Canada; obit May 4, 1933.

INTRODUCTION

This study is intended to form part of a general work on the life-histories of the Acrididae inhabiting Canada and, to some extent, the United States as well. The first part of the work dealing with the egg-sacs and eggs has already been prepared and it is hoped to publish a study of the nymphal instars at an early date.

No effort has been made to repeat what is already well known and the observations here recorded, even if previously noted by others, are my own. Their fragmentary nature is due to an effort on my part to avoid repetition with a view to providing what is lacking in previous studies rather than to include all the recognized facts in a more homogeneous sequence. It should be emphasized that these observations refer mostly to Manitoba conditions; this is especially true of the plant associations. The Acrydiinae [Tetrigidae] are not included in this paper.

DEVELOPMENT

Orthoptera in general, from the time they leave the egg until attaining maturity undergo certain definite morphological changes the most conspicuous of which are indicated in the various moults and the developments which accompany them. These progressive changes in development are marked by rather definite structural alterations, such as the acquisition of additional segments in the antennae, growth of the pronotum and of the wings, and general enlargement of all other parts, the details of which are well known.

Immediately after emergence from the egg and on attaining the surface of the soil the insect undergoes what has been termed the initial or natal moult. This moult is quite unlike those which follow in that the insect before this stage is unable to stand; moreover the skin is cast from the ground by a series of muscular contortions which gradually work it backwards and at the same time curl it up into a ball. The process, as we have already stated, is quite different to that of later moults. In the natal moult the skin is worked off the insect and curled up. In later moults the insect wriggles out of the skin which is left intact. The process of casting the natal skin is not unlike that of the final moult in Lepidoptera larvae when the pupae are formed. The later moults, on the other hand, bear

some resemblance to the pupal moult of Coleoptera. Whether the natal moult in Orthoptera is homologous to the final larval moult in Lepidoptera is a question which need not concern us here. All that is attempted is to show that the natal moult should not, in any way, be confused with the regular moults which accompany true nymphal development.

The number of moults during development are not the same in all species of the Acrididae. In those species which we have studied it has been found that a number of Acrididae only undergo four moults, although there appears to be some variation in the number. The Oedipodinae and Cyrtacanthacrinae [Cyrtacanthacridinae], on the other hand, invariably moult five or more times. As a rule those species which hibernate in one of the later nymphal stages have six moults, while those which pass the winter as eggs have five. There are, however, some exceptions to this rule and it is not very unusual to note six moults in such species as *Melanoplus bivittatus* and *differentialis*. The additional moult, however, is apt to be confined to the females. It always takes place in the development before the wing-pads become upturned.

Light, as a rule, neither influences the casting of the natal skin nor affects the colour pigmentation. Many species in my studies have emerged in darkness, moulted and assumed all their normal colour. In a few species, however, sunlight, or the evaporation due to it, seemed to hasten the natal moult and on rare occasions we have known the newly emerged individuals unable to free themselves of the skin when enclosed in a tight tin. There is reason to suspect, however, that the rapid drying when exposed to the air, as compared to the stable atmosphere within a container, may have more to do with the ease in moulting than does sunlight. In other words, a similar drying influence would provide an identical reaction in darkness.

Normal nymphal moulting usually requires a little less than half an hour to complete. A few examples of the time taken by *Melanoplus bivittatus* (Say) are: 13, 19, 23, 24, 24, 28 and 31 minutes. An individual of *Spharagemon collare* (Scud.) took 30 minutes to moult, a *Melanoplus foedus foedus* Scud. moulted in 22 minutes, while a *Trachyrachis kiowa kiowa* Thom. [*Trachyrhachys kiowa* (Thomas)] occupied 20 minutes and required an additional 30 minutes before folding its wings.

In addition to the time taken in actual moulting, several minutes may be taken up in seeking a suitable support and obtaining a firm hold. We give a single instance of the entire time taken by a specimen of *Melanoplus bivittatus* (Say): began seeking a support 11.43 A.M.; acquired the correct position at 11.45 A.M.; antennae drooped at 11.59; insect free of its skin at 12.23 P.M.

Moulting is more frequently undertaken in the morning but usually after the first period of feeding. So simultaneously are the 'hoppers taken sometimes with the impulse to moult that we have observed thousands occupied in the task at once and on some occasions have found the cast skins lying together in countless thousands.

In the Acrididae moulting is followed by a period of fasting which is not broken for two or more hours. The cast skin is never intentionally molested and in this respect the family differs from the Decticinae [Tettigoniinae] and Gryllidae, the species of which often feed immediately after moulting and not infrequently commence by eating their cast skins. Surprise has been expressed at the fact that the topmost eggs in a sac hatch first thus providing for a ready exit for the nymphs lower down. A moment's thought will suggest that this is due to the closer proximity to the surface, where the heat of the sun is first felt and there is more variation in temperature. Perhaps we should be astonished at the lower eggs hatching so nearly at the same time as the upper ones. As a rule a majority of the eggs hatch at the first time the soil warms up to the required temperature. A greater rise later in the day rarely induces additional emergence although it may provide for a greater hatch next day.

Soil moisture plays an important part in the hatching of the eggs. We have known several instances of eggs remaining under water for some weeks which hatched when the water receded. In 1932 by keeping eggs abnormally wet we were able to secure hatching of *Camnula* eggs from May until November, but a lesser percentage of the eggs hatched at the later period. Excess dryness also retards emergence and it destroys the eggs if carried beyond a certain point (See Parker 1928).

The time necessary for development from the hatching of the egg to adult state is naturally governed by various factors, much the most important of which are weather and food supply. Given optimum conditions a majority of our Acrididae will attain maturity in 30 days, but under normal conditions, such as are met with in nature, the time of development may be considerably longer. We believe, however, that most species will reach the adult state within 40 days. The following table is compiled from specimens of *Melanoplus bivittatus* reared under caged conditions in winter time:

Event	Date
Eggs hatched	January 27
First moult	February 1
Second moult	February 5
Third moult	February 8
Fourth moult	February 13
Fifth moult	February 21
First mating	March 5
First egg laying	March 26

Studies in *Melanoplus mexicanus mexicanus* [*Melanoplus sanguinipes sanguinipes* (Fabricius)], *M. confusus*, *M. foedus foedus*, *M. angustipennis* and several others show that these species have a very similar development to *bivittatus*, the time being approximately the same. *Camnula pellucida* on an average develops a little more quickly and the pre-oviposition period is a trifle shorter.

Egg-laying may take place at any time after the temperature rises above the minimum for activity of the species concerned and the sun is shining, but it is more frequently undertaken in the afternoon than during the morning. There is also a marked increase in laying after a few preceding cold days, as if the development of the eggs proceeded during the cool weather and so provided an abnormal number of ovipositing females when it became warm.

Oviposition itself and the search for a suitable site in which to lay may occupy many hours. Indeed we have known a female to test more than twenty situations before locating one which suited her, and it is not unusual to find certain areas studded with abandoned holes, nor is this abnormal even with those species which oviposit in wood. On one occasion a female *Trimerotropis pistrinaria* began seeking an egg-laying site at 11.41 P.M. one day and did not finally finish egg-laying until 10.37 P.M. on the following day. After the insect has discovered a place to her liking the process of egg-laying is proceeded with in an orderly manner but it is rarely concluded in less than half an hour, and late in the season when the ground is cold we have timed the species of several genera, the individuals of which required almost two hours to complete their tasks.

The cavity in which the eggs are placed is nearly always carefully covered so that its location cannot he seen. The efforts of the female to hide the hole are equally energetic whether it is in bare ground, among grasses or in wood. It is interesting to note in connection with covering the egg-sac cavity that in the Acridinae and Oedipodinae this is done with the posterior legs by scraping, kicking and tramping the material into place, but

that in the Cyrtacanthacrinae [Cyrtacanthacridinae] the covering is done wholly with the abdomen by using the valves as a rake or shovel. So far we have found no exception to this rule.

The number of eggs deposited depends upon the species and upon various natural phenomena including weather and food supply. Much more work has to be done before we can speak with authority on this question. As a rule those species which deposit fewest eggs at one time oviposit more often than those which place a great number of eggs in a single sac. It is not abnormal, for example, for *Camnula pellucida* to deposit eight sacs of eggs, while *Melanoplus bivittatus* rarely produce more than four, yet the latter usually lays more eggs than the former.

Some species deposit eggs at very short intervals. We know of a female of *Trimerotropis pistrinaria* which deposited a second clutch of eggs three days after a former one. So short a period of time between egg-laying is not, we have reason to believe, usual. We give a few examples of the number of egg-sacs and eggs deposited by certain species. Unless specified the females were collected as adults and caged so that they might well have commenced to oviposit before being caught. Six females of *Opeia obscura* deposited 59 sacs of eggs, approximating 106 eggs to a specimen. The females were reared from nymphs. A single *Amphitornus coloradus* [*Amphitornus coloradus coloradus* (Thomas)] deposited 25 sacs of eggs of four eggs to a sac. Seven individuals of *Bruneria brunnea* produced 87 egg-masses in 60 days or a sac of eggs each about every five and a half days. Two female *Stethophyma lineatum* caged in early September deposited 16 masses of eggs by November 4. Two *Stethophyma gracile*, reared from nymphs, provided 24 masses of eggs, or about 216 eggs each. Three *Chorthippus curtipennis* [*Pseudochorthippus curtipennis curtipennis* (Harris)] deposited 36 sacs of eggs, or about 96 eggs each. A pair of *Cratypedes neglectus* deposited 22 sacs of eggs between them, comprising about 222 eggs each. Three female *Camnula pellucida* produced 27 sacs of eggs, equalling 9 each or about 150 eggs per female. A single *Trimerotropis pallidipennis salina* [*Trimerotropis salina* McNeill] provided eight clutches of eggs in 46 days. She had probably laid as many more before being captured. From three *Circotettix verrucullatus* [*Trimerotropis verruculata* (Kirby)] were obtained 24 sacs of eggs averaging 160 eggs to a female.

The following depicts some of our egg-laying records of the Cyrtacanthacrinae [Cyrtacanthacridinae]: Six *Aeoloplus turnbulli turnbulli* [*Aeoloplides turnbulli turnbulli* (Thomas)] deposited 72 sacs of eggs, or about 250 eggs per female. They had probably deposited some before being caged. Three female *Asemoplus montanus* produced 56 sacs of eggs, equalling 18 each, in 51 days — a truly remarkable performance. It seems

possible that this speeding up in egg-laying may be due to necessity under mountain conditions. Two female *Melanoplus bivittatus* deposited 11 sacs of eggs; a total of 217 eggs per female. A pair of female *Melanoplus flavidus* collected on September 1 had deposited 200 eggs by October 15. Two specimens of *Melanoplus mexicanus mexicanus* [*M. sanguinipes sanguinipes*] deposited 23 sacs of eggs, an average of 160 eggs per female. The specimens were reared from eggs. Three individuals of *Melanoplus foedus stonei* [*Melanoplus stonei* Rehn] deposited 36 sacs of eggs or about 192 eggs each. One *Melanoplus montanus* produced 12 sacs of eggs comprising a total of about 132 eggs. Two *Melanoplus dodgei huroni* [*Melanoplus huroni* Blatchley] laid 12 sacs of eggs or 120 eggs per female.

From the above specific examples and innumerable others in which the details are less complete, there is no doubt that all species oviposit repeatedly and that the number of egg-sacs produced range from 4 or 5 to fully 25. Further, that very few species produce less than a hundred eggs to a female while some examples doubtless exceed 500 eggs.

Factors Affecting Abundance and Distribution

1. VITALITY

With species in which the potential factors for increase are so great there must of necessity be innumerable checks to their multiplication, otherwise they would over-run the entire country. We know that these checks are many and varied and that they include meteorological variations, diseases, parasites and predators. All these have been discussed by numerous writers and it is therefore unnecessary to go into details here. As a rule the rise from minimum to maximum numbers is brought about through favourable weather combined with an absence of natural enemies. But apart from these factors there still appear to be others less well understood. One of these seems to be that the insects during the initial rise are abnormally virile, more eggs are deposited and there is a greater survival. Vitality indeed then seems to be at its height. The decline, on the other hand, after the peak is reached appears to be aided by a lessened vitality. Thus the rise attains a certain height in the form of an increase curve but the peak of the curve is obtuse because of the slowing up of reproduction, or the much higher mortality. The level is then perhaps maintained for a year after which there is a sharp downward line that finally depicts a low ebb in the insects' existence.

Referring to the 1931–33 outbreak of grasshoppers, for example, the rise for a few years was slow, then in 1930 there was a very appreciable increase and still greater ones on the two following years. But while the number of grasshoppers present in the summer of 1932 was vastly in excess of 1931, the total number of eggs deposited did not greatly exceed those of the former year. In other words, the number of eggs laid per female

probably dropped fifty percent. Whether an outbreak of this sort would actually drop to insignificance without the attack of diseases and other natural enemies is difficult to tell, but it seems possible that this might be so, just as it is apparently true of some other insects.

2. FOOD HABITS

The increase and spread of the Orthoptera in general is associated with a great many factors such as food and egg-laying habits, climatic conditions and natural enemies. The first two only need concern us here. It is obvious that if an insect is confined in its diet to one, or a comparatively few, plants that its range must be restricted to territory within their distribution. On the other hand, the more diversified an insect's food habits are, the greater is likely to be its range and abundance. All our serious grasshopper pests either have a wide selection of food plants or subsist on those kinds which are individually numerous and widespread. Thus by knowing the food habits we should be able to form a fairly accurate idea of whether a species has the possibilities of becoming abundant or not. Furthermore, by recognizing the species of wild plants eaten we can tell what cultivated ones are likely to be attacked. In this connection a few illustrations may not be out of place.

The sage-brush grasshopper, *Melanoplus bowditchi canus* Hebd., is restricted in feeding to a single species of plant, namely *Artemisia cana* Pursh. We have kept adults alive on the allied species *Artemisia ludoviciana* Nutt. but this has resulted in a marked reduction in egg-laying. The nymphs to begin with seemed to thrive well enough on this plant but with each succeeding instar the mortality became greater until finally out of some two hundred nymphs which originally hatched only one depauperized male reached maturity. The native food plant, however, is widespread and there is, therefore, no reason why this grasshopper should not become abundant. As a matter of fact it is often more or less so but the chances of its becoming of economic importance are remote.

Another interesting example of a restricted diet is found in *Hypochlora alba*. This is a non-flying species which practically lives its entire life on *Artemisia ludoviciana* Nutt. In this case, however, the range of the plant far exceeds that of the insect. Host plants, as a matter of fact, are always found beyond the distribution of the insects which feed upon them, although they do not always occur so far away as in the present instance.
While there are several Orthoptera which confine their feeding activities to a single species of plant it is also interesting to find that there are others which seem to be able to differentiate between families of plants. In the Acridinae for example, *Acrolophitus hirtipes* (Say), so far as we have been able to ascertain, subsists almost exclusively upon members of the Boraginaceae. We have tested it upon more than a hundred plants of other

families without favourable response, the only other plant eaten being *Phacelia*, a close relation. Among the species of Boraginaceae, however, there are quite a number which are palatable to it. These include *Lithospermum*, *Lappula*, *Echium*, and *Myosotis*. Of these it is probable that *Lithospermum angustifolium* Michx. [*Lithospermum incisum* Lehm.] constitutes the most important natural food plant.

The Oedipodinae provide several rather specialized feeders. We found, for example, that *Spharagemon equale* (Say), especially in the immature stages, showed a marked preference for members of the mustard family (Cruciferae) [Brassicaceae], while several species of *Trimerotropis* are partial to *Astragalus* species.

Passing to diversified feeders we encounter several well known pests such as *Melanoplus mexicanus mexicanus* Saus. [*M. sanguinipes sanguinipes*], *M. bivittatus* (Say) and *M. femurrubrum* (DeG.) These will eat almost any plant which grows and in the seventies the first named was even stated to have defoliated the poplar trees.

The clear-winged grasshopper, *Camnula pellucida* (Scud.), illustrates in a striking way another phase of the question where a more restricted feeder may become almost as abundant as one of diversified habits. In this case, however, the plants selected being chiefly grasses are so widespread and abundant that the insects meet with no impediment in so far as food is concerned. We might cite innumerable other examples but a number of these are indicated in the table presented a little further on.

Grasshoppers may be kept alive for weeks on an abnormal diet, but under these conditions they frequently neither mate nor lay eggs. On rearing species with which we were unfamiliar and the food plants unknown the fact that the insects were not breeding has frequently led to a change of diet and thus produced the desired results. Sometimes the plant provided may be allied to that which the insect normally eats, in which case a certain number of eggs may be deposited but the total is apt to be misleading in that it is not the natural number. For example, two species of the same genus of grass may be provided, one palatable the other not. This has proved true of the two species of wheat grass. *Agropyron tenerum* Vasey [*Elymus trachycaulus* (Link) Gould subsp. *trachycaulus*] and *Agropyron smithii* Rydb. [*Pascopyrum smithii* (Rydb.) Barkworth & D.R. Dewey].

An interesting fact from an agricultural point of view is that while all grain crops are eaten, some prove a more satisfactory diet to the grasshoppers than others. It has often been noted, for instance, that adult grasshoppers concentrate on late oats due to such crops remaining green longest. Yet a search for eggs late in the season may reveal very few. In

other words, green oats are not favourable food for reproduction purposes. It seems highly probable that other cultivated plants are also unsuitable for the grasshopper although readily eaten.

While there are some plants which are palatable to a great many grasshoppers there are others which these insects rarely touch. Among the grasses *Agropyron smithii* [*Pascopyrum smithii*] comprises perhaps the most striking of the former class, *Setaria viridis* an outstanding one of the latter. Brome grass, *Bromus inermis* is eaten by a number of species but it is not a favourite food, and in several instances when grasshoppers were fed exclusively on this plant the egg production was less. It seems highly probable that some plants are selected because of their moisture content. This is suggested by the greater consumption of these during dry hot spells. The common sow thistle, *Sonchus arvensis* L., is an illustration of this. The plant, when wounded, exudes a milky juice which is drunk by the grasshoppers. In 1932 the attack upon this weed by the two-striped grasshopper, *Melanoplus bivittatus*, was so great that thousands of acres were stripped bare. It is claimed by the farmers in the affected territory that much good was done by this destruction of a dangerous weed and that in this way the grasshoppers to some extent compensated for the harm they did by destroying crops. The attack on sow thistle, however. was largely brought about by one species of grasshopper.

On making a study of the Orthoptera of semi-arid regions it has been observed that a greater preponderance of the species selects as food plants those which tend to be most resistant to drouth and consequently remain green longest. Thus most of the upland species of the genus *Trimerotropis* feed rather exclusively on members of the genus *Astragalus*. *Schistocerca lineata* is usually associated with another member of the pea family, namely *Glycyrrhiza lepidota* Nutt. [*Glycyrrhiza lepidota* Pursh].
On the prairies more species of Orthoptera feed upon the grass *Agropyron smithii* Rydb. [*Pascopyrum smithii*] than on any other plant. Indeed if the insect is in any way a grain feeder it is almost sure to eat this species. As a matter of fact the leaves of this plant are rather stiff and hard but they are less tough than many others and they retain their freshness for a greater length of time.

In or around woodlands the indigenous species tend more to feed upon broad-leaved plants and in this connection we have found the small lily *Maianthemum* particularly attractive. For our cage studies we have discovered an excellent substitute for these broad-leaved plants in the common dandelion but there are some few species which refuse to accept this substitute. For further details of the peculiarities of diet and their influence on distribution the reader is referred to the list of species and food associates given below.

Water is also an important factor in grasshopper survival and reproduction. It may, of course, be in excess both in the food and in the atmosphere. Nevertheless, without moisture all species will perish and at extremely dry periods most species cease to breed and those which are in epidemic numbers and have spread beyond their normal range, perish.

In the list below an attempt has been made to show the general food habits of the species concerned. With so great a range of plants available as food it is almost certain that some have been overlooked, while in other cases there is little doubt that some species listed under one category at least occasionally eat plants belonging to another. On this account the segregations must be recognized as approximate rather than definite. Also it should be borne in mind that grasshoppers will eat various abnormal food plants on occasions of stress which temporarily appease the pangs of hunger although unsuitable to stimulate breeding and to perpetuate the species. If a grasshopper is carefully watched it will be seen to nibble many objects which it comes in contact with in its wanderings, but while these may be tasted they are not necessarily the normal food upon which the species thrives. We have made no efforts in this list to indicate these minor deviations but instead tried to show the food preferences in their broader aspects.

As we have pointed out elsewhere there are a few plants such as *Taraxacum* and *Tradescantia* which break down the normal antipathy in the insect's tastes and so are eaten when normally nothing else but the usual food would be. I have termed these neutral plants. It is chiefly plants of this kind which occasionally bridge the grass and broad-leaved feeders but even these plants do not by any means serve as universal provender and there are many species of grasshopper which refuse to accept them. It can only be claimed of these, therefore, that they are more apt to be accepted than any other abnormal food plant.

LIST OF GRASSHOPPERS ARRANGED ACCORDING TO FOOD PREFERENCES

SPECIES	FOOD PREFERENCE
GRASS FEEDING SPECIES	
ACRIDINAE	
Opeia obscura (Thom.)	*Agropyron smithii* Rydb. [*Pascopyrum smithii* (Rydb.) Barkworth & D.R. Dewey]
Amphitornus coloradus (Thom.) [*Amphitornus coloradus coloradus* (Thomas)]	Several species

SPECIES	FOOD PREFERENCE
Cordillacris occipitalis cinerea (Brun.) [*Cordillacris occipitalis* (Thomas]	A few species
Gomphocerus clavatus Thom. [*Aeropedellus clavatus* (Thomas)]	Several species
Ageneotettix deorum (Scud.)	Several species
Ageneotettix occidentalis (Brun.) [*Ageneotettix deorum* (Scudder)]	Several species
Bruneria brunnea (Thom.)	Several species
Aulocara elliotti (Thom.)	Several species
Chorthippus curtipennis (Harr.) [*Pseudochorthippus curtipennis curtipennis* (Harris)]	Several species
Phlibostroma quadrimaculatum (Thom.)	Several species
Psoloessa delicatula delicatula (Scud.) [*Psoloessa delicatula* (Scudder)]	Several species
Chloealtis conspersa (Harr.)	Several species
Neopodismopsis (*Chrysochraon*) *abdominalis* (Thom.) [*Chloealtis abdominalis* (Thomas)]	Several species
ACRIDINAE [GOMPHOCERINAE]	
Orphulella speciosa Say [*Orphulella speciosa* (Scudder)]	
Orphulella pelidna (Burm.)	
OEDIPODINAE	
Encoptolophus sordida (Burm.) [*Encoptolophus sordidus* (Burmeister)]	Several species
Encoptolophus costalis (Scud.)	Several species
Chortophaga viridifasciata (DeG.)	Several species
Camnula pellucida (Scud.)	Also a few broad-leaved plants
Trachyrhachis kiowa kiowa (Thom.) [*Trachyrhachys kiowa* (Thomas)]	Several species

SPECIES	FOOD PREFERENCE
Metator pardalinus (Saus.)	*Agropyron smithii* Rydb. [*Pascopyrum smithii*]
Metator nevadensis (Brun.)	Mostly *Agropyron* [Probably refers to *Pascopyrum smithii*]
Aerochoreutes carlinianus Thom. [*Circotettix carlinianus* (Thomas)]	Rarely broad-leaved plants
CYRTACANTHACRINAE [MELANOPLINAE]	
Melanoplus occidentalis occidentalis (Thom.) [*Melanoplus occidentalis* (Thomas)]	*Agropyron smithii* Rydb. [*Pascopyrum smithii*]
Melanoplus infantilis Scud.	Several species
Melanoplus gladstoni Scud.	Several species
Melanoplus kennicotti kennicotti (Thom.) [*Melanoplus kennicottii* Scudder]	Several species
Phoetaliotes nebrascensis (Thom.)	Mostly grass
SEDGE FEEDING SPECIES	
ACRIDINAE [OEDIPODINAE]	
Stethophyma lineatum (Scud.)	*Carex* spp.
Stethophyma gracile (Scud.)	*Carex* spp.
MIXED FEEDING SPECIES	
OEDIPODINAE	
Xanthippus corallipes latefasciatus Scud. [*Xanthippus corallipes* (Haldeman)].	
Xanthippus montanus (Thom.)	
Arphia pseudonietana (Thom.)	Mostly grass
Arphia conspersa Scud.	Mostly grass
Camnula pellucida (Scud.)	Mostly grass
Dissosteira carolina (L.)	Prefers broad-leaved plants

SPECIES	FOOD PREFERENCE
Spharagemon collare (Scud.)	Mostly grass
Trimerotropis agrestis McN.	
Trimerotropis gracilis sordida E. M. Walk. [*Trimerotropis gracilis* (Thomas)]	
Trimerotropis sparsa (Thom.)	*Astragalus, Agropyron* [Probably refers to *Pascopyrum smithii*]
Trimerotropis pallidipennis salina McN. [*Trimerotropis salina* McNeill]	Mostly grass
Trimerotropis laticincta Saus. [*Trimerotropis latifasciata* Scudder]	Mostly *Agropyron* [Probably refers to *Pascopyrum smithii*]
Trimerotropis campestris (McN.) [*Spharagemon campestris* (McNeill)]	Mostly *Astragalus*
Trimerotropis pistrinaria Saus.	Mostly *Astragalus*
Circotettix rabula rabula R. & H. [*Circotettix rabula* Rehn & Hebard]	
Aerochoreutes carlinianus carlinianus (Thom.) [*Circotettix carlinianus* (Thomas)]	Mostly *Agropyron smithii* Rydb. [*Pascopyrum smithii*].
CYRTACANTHACRINAE [CYRTACANTHACRIDINAE]	
Schistocerca lineata Scud.	*Glycyrrhiza* and others
[MELANOPLINAE]	
Melanoplus bivittatus (Say)	A very general feeder
Melanoplus differentialis (Thom.)	Many species
Melanoplus femur-rubrum DeG. [*Melanoplus femurrubrum* (De Geer)]	Many species
Melanoplus dawsoni (Scud.)	Mostly broad-leaved plants
Melanoplus keeleri luridus (Dodge)	
Melanoplus borealis junius (Dodge) [*Melanoplus borealis* (Fieber)]	
Melanoplus confusus Scud.	Prefers grass

SPECIES	FOOD PREFERENCE
Melanoplus mexicanus mexicanus (Saus.) [*Melanoplus sanguinipes sanguinipes* (Fabricius)]	A general feeder
Melanoplus bruneri Scud.	
Melanoplus flavidus Scud.	Prefers grass
Melanoplus packardii packardii Scud.	A general feeder
Melanoplus foedus foedus Scud.	A general feeder
Melanoplus angustipennis (Dodge)	Prefers grass
Melanoplus fasciatus (Walker)	Prefers broad-leaved plants
FEEDERS ON BROAD-LEAVED PLANTS	
ACRIDINAE [GOMPHOCERINAE]	
Acrolophitus hirtipes (Say)	Boraginaceae
OEDIPODINAE	
Hadrotettix trifasciatus (Say)	*Astragalus* and others
Pardalophora apiculata (Harr.)	Various species
Cratypedes neglectus (Thom.)	Several species
Spharagemon equale (Say)	Mostly Cruciferae [Brassicaceae]
Spharagemon bolli Scud.	
Circotettix verrucullatus Kby. [*Trimerotropis verruculata* (Kirby)]	Rarely grass
CYRTACANTHACRINAE [MELANOPLINAE]	
Hesperotettix viridis pratensis Scud.	*Solidago* and allies
Hypochlora alba (Dodge)	*Artemisia ludoviciana* Nutt.
Aeoloplus turnbulli turnbulli (Thom.) [*Aeoloplides turnbulli turnbulli* (Thomas)]	*Atriplex* and allies
Asemoplus montanus (Brun.)	Various species
Asemoplus somesi Hebard [*Buckellacris nuda nuda* (Walker)]	Various species
Melanoplus bowditchi canus Hebard	*Artemisia cana*

SPECIES	FOOD PREFERENCE
	[*Artemisia cana* Pursh]
Melanoplus foedus stonei [*Melanoplus stonei* Rehn]	Occasionally grains
Melanoplus mancus islandicus Blat. [*Melanoplus islandicus* Blatchley]	*Maianthemum* and others
Melanoplus montanus (Thom.)	Various species
Melanoplus dodgei huroni Blat. [*Melanoplus huroni* Blatchley]	*Maianthemum* and others

Choice of Egg-Laying Sites

The egg-laying restrictions of the Acrididae have to do chiefly with the texture of the soil or with some other feature necessary to the individual requirements of the grasshopper. It is obvious for example that such species as *Chloealtis conspersa* and *Neopodismopsis abdominalis* [*Chloealtis abdominalis* (Thomas)] which oviposit exclusively in decaying wood or in dung, must be restricted in egg-laying by these necessary materials. On this account the first named is confined to the vicinity of wood lands, while the latter, more frequently utilizing dung, has taken advantage of that of the buffalo, and of cattle, to spread on to the adjacent plains.

As a general rule there are more species which oviposit in spaces free from vegetation than there are of those which place their eggs among the clumps of grass. *Camnula* is one of the most important economic species which is an exception to this rule, while some other abundant species such as *Melanoplus bivittatus* lay almost anywhere. But even this latter species shows some discrimination and, as is to be expected, it is much more selective at times of scarcity than during outbreak conditions. In this connection we must not lose sight of the fact that an insect's habits, when it occurs in great numbers, are apt to be dissimilar to those of normal times.

Observation has shown that a number of species indicate a marked preference for semi-soft soil for placing their eggs, and in this respect the numerous burrowing mammals play no small part in the perpetuation of certain species of Orthoptera. Indeed the old mounds of the pocket gopher are extremely profitable hunting grounds for the orthopterist in search of eggs, and we have no doubt that mole hills would prove equally fruitful.
It is interesting to speculate on the probable influence of the buffalo, in former days, on the grasshopper population. We know how over-grazed pastures favour the increase of several species. This in part is because the insects prefer the short grass as being less

restrictive to their movements and more exposed to the sun, but there is also the trampled and torn up sod to be considered as forming egg-laying sites. How great an influence the herds of millions of buffalo had on the perpetuation of Orthoptera can only be guessed, but it may have been considerable.

It is well known that the constituents of the soil play an important part in the distribution of Orthoptera, a phase of the question which need not be gone into here. As a rule upland, sandy soils favour a larger grasshopper population than do the richer lowland soils. Humidity, however, plays a part in their choice of a situation and while the locality may be too wet, it may also be too dry, few Orthoptera being able to perpetuate under conditions of extreme aridity during which succulent food is entirely lacking.
There is no doubt that the choice of an egg-laying site not only depends upon the texture of the soil or the presence or absence of vegetation but also, at times, on the local topography. During the early part of the egg-laying season, for example. when the sun is hot and the soil warm, level, or eastern slopes, are apt to be chosen while towards fall the cooler conditions induce the grasshoppers to collect in sunny exposures and then southern and western slopes are favoured. In this connection *Camnula pellucida*, which begins to oviposit early, more often chooses flat areas or hillsides with an eastern slope. *Melanoplus mexicanus mexicanus* [*Melanoplus sanguinipes sanguinipes*] and *M. packardii*, which usually begin to oviposit later and continue longer often concentrate their eggs on more southern or western slopes. But as we have already intimated the egg-site chosen depends somewhat upon the time of year when the eggs are laid. In any case the access to suitable food is an important consideration to oviposition in any given locality.

Meterological Influence on Survival

The influence of weather upon grasshopper survival has naturally received much attention by students of economic entomology. There are occasions when some extreme of temperature or precipitation has resulted in a high mortality. From recent evidence, however, the destruction of the nymphs seems to be brought about more by abnormally heavy rain falls which injure and beat the insects into the ground, than by either cold or prolonged damp spells. Examples of destruction by heavy rainfalls were witnessed in the Peace River District in the spring of 1927 and in South Dakota in 1932. We have observed several cases when cold and lightly falling precipitation failed to have the effect which uninformed prophets predicted.

On the evening of May 18, 1931, after a comparatively warm day, a storm began with a high northerly wind followed by light rain and four degrees of frost. By the following morning nine inches of snow covered the ground. The weather moderated next day when

most of the snow melted but there was more frost at night and ice persisted all next day. A search, after the adverse weather was past, showed that the grasshopper population was practically as numerous as before.

It is evident that heavy rains to be effective must come when the hoppers are quite small, a majority at least being in the first instar. During the grasshopper outbreak in 1901, there was a storm of rain and snow on the night of June 6 and by next morning two inches of the latter covered the ground with the thermometer registering 32 °F and a drop to 27 °F on the following night. The hoppers, however, had hatched early that spring and most of them were in their second or third instar when the snow came. They did not suffer to any noticeable extent.

There is a popular belief that much rain will destroy the insects, yet in June 1901 when grasshoppers were extremely abundant there were seventeen days when rain fell with a total precipitation of seven inches and eighty-four hundredths. On the following June when grasshoppers were even more troublesome there were again 17 days when rain was registered, with a total of three inches and seventeen hundredths.

Adverse weather seems to be more detrimental to the adults late in the season than to the nymphs in spring time. This, however, is usually after the females have deposited many eggs. During 1932, for example, a cold, wet spell in late August killed most of the grasshoppers in central and eastern Manitoba but they had already deposited great quantities of eggs. In western areas where *Melanoplus mexicanus mexicanus* [*Melanoplus sanguinipes sanguinipes*] dominated, comparatively few suffered from the adverse weather. On October 9, 1932, the temperature at Treesbank, Man., dropped to 5 °F which killed every adult grasshopper.

As a rule the grasshopper population in Manitoba, apart from the overwintering species, has vanished by the first of November, but in 1931 some species persisted up to November 14.

HIBERNATION

Broadly speaking there are two methods of passing the winter in the Acrididae, namely as an egg, or a partly developed nymph. In the Acrydiinae [Tetrigidae], however, adults also occasionally survive the winter although a majority of the species appear to hibernate in a partly developed form.

While the methods of passing the winter outlined above are constant there appears to be a rather striking variation in the diapause in some of the species. Certain Oedipodinae, for

example, in which the eggs normally hatch within a month or two of the time they are laid, occasionally fail to do so in which case a period of twelve months may occur before hatching takes place. In our cage studies this has happened in *Pardalophora*, *Xanthippus* and *Arphia*.

A still more striking prolongation of the egg stage has taken place in certain Cyrtacanthacrinae [Melanoplinae], such as *Aeloplus turnbulli* [*Aeoloplides turnbulli*] *Melanoplus dodgei huroni* [*Melanoplus huroni*] and *Asemoplus somesi* [*Buckellacris nuda nuda* (Walker)] which have refused to hatch for two years. In other words, eggs laid in 1930 did not hatch until 1932. We have also a single example of delayed hatching in the Acridinae [Gomphocerinae], namely in *Acrolophitus hirtipes*.

We would add that while these examples were all under artificial rearing the conditions did not differ to any marked extent from those outside and that the eggs were placed outside in winter time where they were subject to all the weather variations including frost which they would normally undergo in nature. Moreover some of the eggs were placed outside in the spring so that the hatching conditions might be normal.

There seems no very great reason why eggs of such species as *Pardalophora apiculata* laid late in the summer should fail to hatch until the following year, but there is more reason to be suspicious of those in which the diapause continues over two winters. An inhabitant of wooded areas such *Melanoplus dodgei huroni* [*Melanoplus huroni*] might more reasonably have such a habit, and a reason for mountain-inhabiting species doing so can be imagined, but there seems less reason why the habit should be met with in *Acrolophitus* or *Aeoloplus* [*Aeoloplides*]. We therefore quote all the evidence, such as it is, and must await experiments under absolutely natural conditions to verify or disprove it. Perhaps it would be interesting to add that we have obtained a diapause of three years in *Anabrus simplex* Halde.

In connection with the hibernation of nymphs, this in our studies has been shown to be confined to the Acrydiinae [Tetrigidae], Acridinae and Oedipodinae. But one species of Acridinae, in our territory, is known to pass the winter in a partly developed stage namely, *Psoloessa delicatula delicatula* Scud. [*Psoloessa delicatula* (Scudder)]. The individuals of this species remain active late in the fall and as winter approaches bury themselves among the herbage or occasionally in the ground.

The hibernating Oedipodinae are less particular and they usually content themselves with crawling under a leaf or squatting among a clump of grass. There seems to be a tendency in all cases to get near to the ground, probably to avoid the danger of drying out by being

too greatly exposed to the atmosphere. These hibernating nymphs may be found active at any month of the year providing there is bare ground and the temperature rises high enough.

It can safely be said that the pairing of nymphs in any stage of development, claimed to have been observed by more than one observer, does not take place. As a matter of fact the stimulus to mate cannot be expected until the adults become sexually mature which is always some days after the final moult, and in a number of instances one or more weeks afterwards. We have watched thousands of individuals of different species in our cages and millions in nature and never once observed attempts to mate until the male was sexually mature, nor was a male successful in his attempt until the female felt a corresponding urge. It seems probable that the supposed matings of immature forms in reality was due to faulty observation, the insects being those with aborted wings which were mistaken for nymphs.

Organs of Sound

Among the Acrididae musical performances, if we may call them such, are most specialized in the Acridinae and least so in the Cyrtacanthacrinae [Cyrtacanthacridinae]. Indeed no species in the last named subfamily, so far studied, has been found to produce sound, although many of them jerk their posterior legs in a manner suggesting the method of producing sound in other groups.

Sound production is a feature of most of the Oedipodinae and it has been observed in nearly every species which has come under our notice; this includes, *Pardalophora*, *Xanthippus*, *Arphia*, *Dissosteira*, *Spharagemon*, *Trimerotropis,* and *Circotettix*. But not all the species in these genera are equally proficient in making sound by leg action. The sounds are perhaps loudest in the first three genera and in *Circotettix verrucullatus* [*Trimerotropis verruculata*]. *C. rabula rabula* [*C. rabula* Rehn & Hebard], on the other hand, is practically silent. All the sounds produced in this subfamily are similar, the only difference being in the volume of sound emitted.

The noises made in flight are quite different. Moreover, they are not uncommonly made by either sex although loudest in the males. So far as we know the Oedipodinae alone are specialized in the production of wing sounds.

While there is still some question as to whether the stridulations of Orthoptera are actually attractive to the females or to other males, there is no doubt that they produce a reaction of similar effect to hearing. This has been demonstrated on several occasions in our cages by *Scudderia curvicauda curvicauda* (DeG.) and *S. pistillata* Brun. of the

Phaneropterinae. The response, in these cases, was always by males. Usually the insect, as a prelude to the regular music, provides a few ticking notes much less loud than the others. These frequently continue at irregular intervals for some time. No sooner, however, were they sounded by a male in one cage than they would be answered from another cage by another male. The response was so striking and was repeated so continuously that it left no question in my mind that the second male was aware of the sounds of the first one. The two cages were about twelve feet apart.

We have noticed a similar response in *Stethophyma gracile* of the Acridinae [*Stethophyma* is now placed in Oedopodinae]. Perhaps these musical performances are more for the purpose of a challenge to the males than to attract the females just as are the songs of so many birds. In our studies of field crickets, *Gryllus assimilis* (Fab.), we noted that the shrill stridulations quite frequently attracted another male, usually resulting in a fight and the retreat of one combatant. Nevertheless, there was also evidence to warrant our suspecting that the females were also attracted. This likewise seemed to be so in the tree cricket, *Oecanthus nigricornis quadripunctatus* Beut. [*Oecanthus quadripunctatus* Beutenmüller]. Apart from these considerations, however, the production of sound is undoubtedly stimulated by the close proximity of the females.

We have been unable to discover that the wing sounds produced by the Oedipodinae in any way influence the females. Moreover they are not always confined to the males. The sustained hovering flight of the male Carolina grasshopper, *Dissosteira carolina*, and the even more remarkable one of *Aerochoreutes carlinianus* [*Circotettix carlinianus* (Thomas)], are striking examples of sexual flights. Neither of these species emit a cracking sound but instead there is a rustling noise.

Of the groups discussed in this paper the Acridinae are much the more specialized in the production of sound although there are some species so far as we could discover, which are silent.

Flight Migration

So much has been written about the migratory movements of Orthoptera that to go into details here would be to repeat what has already been described.

From our own observation we believe that nearly all species make some effort to disseminate themselves, although the movements with that end in view are naturally more conspicuous in times of abundance than they are when an insect is rare. There were occasions when we have observed sustained flight in a great many species including members of the Acrydiinae [Tetrigidae], Acridinae, Oedipodinae, Cyrtacanthacrinae

[Cyrtacanthacridinae], Conocephalinae and Gryllidae. As a rule these migrations were performed by adults but at times the nymphs were equally active in sustained movements. There seems no doubt that some of these migrations are in search of new feeding ground. This is especially true of those species which select breeding grounds on the uplands and as these become arid with the advancement of the season, move to more succulent pastures. But the most frequent flights in our part of the world seem to owe their origin to an impulse in which food plays no part. It may be an instinctive desire, common to most organic forms of life, to disseminate themselves as widely as possible over the land. All we do know is that the migration and dissemination take place and that the mortality due to the insects alighting in unsuitable surroundings is immense. It is rarely, however, that enough individuals are not left behind to perpetuate the species in numbers as great, or greater, than they were before.

Grasshoppers at times of drought are often induced to leave their normal habitats in search of more succulent food or of water. At such times species normally upland prairie forms may be found frequenting the margins of wooded areas and even encircling the treed zones, while many others move down into the marshes and may frequent the shores of ponds and lakes. Vestal (1913) seems to have met with some such condition in recording such a well known grass inhabitant as *Camnula pellucida* inhabiting bare sand near water and in the upland, *Arphia pseudonietana* being frequent under similar conditions. Either the meteorological conditions were abnormal or the locality chosen for the study was an unfortunate one to depict the true habitats of the species listed. While drought forces many Orthoptera to seek moister or cooler situations a converse condition may have an exactly opposite effect, and at such times there is a marked increase in the grasshoppers on the uplands, and if the excess precipitation is persisted in, usually arid areas may become a source of danger by permitting the abnormal increase of species which otherwise would not breed there at all.

Group Associations

Since a great many of the Acrididae we are dealing with inhabit similar areas and have the same plant associations we shall group these together rather than deal with each separately, in this way not only saving space but also giving a better idea of the associations of the species and their relation to the various environmental factors involved in these segregations.

Probably soil is the most important factor in assigning the assemblage of certain Orthoptera to definite zonal areas. The associations of plants and insects certainly owe much to soil, although elevation is also important because both high and low lands may have identical soil constituents and still harbour entirely different classes of plants and

insects. It is necessary, therefore, to classify our soils of identical texture as upland and lowland and the species of Orthoptera inhabiting them under a similar designation. Humidity and sunshine must also be taken into account when attempting to map the various animal and plant zones. This is by no means an easy task and all we have attempted is to indicate what species there are in the areas depicted.

Ecological Associations

The ecological associations here roughly sketched out are at the best approximate. What has been attempted is to indicate the typical surroundings of the different species when the latter are in normal or small numbers. At times of abundance they naturally spread out into adjacent territory and there are times too when abnormal meteorological conditions temporarily affect certain areas so that they become more or less suitable to species which normally frequent other zones. Such abnormalities are not here considered. The soil conditions and plant associations are naturally only approximate because no definite line can be drawn between one and another. Many dominant plants, for example, thrive under very varied conditions and these will be met with in a majority of the zones. In like manner many of the Orthoptera here listed inhabit vast stretches of the country. Nevertheless, nearly every plant and animal has a favourite habitat where it is most apt to perpetuate under adverse conditions and it is this area which we have attempted to depict in these notes. What is intended is to show species peculiar to a certain zone. A certain plant, for example, may not in any way be necessary to a certain orthopteron but the environment may be suitable to both, hence both will be found together. It is such associations which we have tried to show.

We would add that these associations deal largely with conditions found in Manitoba where it has been possible to study them in detail. The haunts of a species, as we have already indicated, are so greatly affected by meteorological conditions, especially humidity, that an inhabitant of sandy areas under semi-wet climatical conditions may frequent much richer soils when there is less precipitation. Under these circumstances the plant associations may undergo considerable modification.

AREA NO. 1, PINE WOODS

The area is confined in Manitoba to eastern and northern districts. It is always sandy although within it are grassy meadows and bogs, the former studded with willows, the latter with larch, black spruce and some cedar. The uplands support a varying stand of jack pine and here and there are mixed woods of poplar, birch and other trees. The chief herbaceous plant associations on the dryer areas are *Cladonia rangiferina* L. [*Cladonia rangiferina* (L.) Weber *ex* F. H. Wigg], *Pteris aquilina* L. [*Pteridium aquilinum* (L.) Kuhn], *Calamagrostis canadensis* (Michx.) [*Calamagrostis canadensis* (Michx.) P.

Beauv.], *Andropogon furcatus* Muhl. [*Andropogon gerardii* Vitman], *Oryzopsis asperifolia* Michx., *Avena striata* Michx. [*Schizachne purpurascens* (Torr.) Swallen], *Clintonia borealis* (Ait.) [*Clintonia borealis* (Ait.) Raf.], *Maianthemum canadense* Desf., *Cypripedium acaule* Ait., *Anemone quinquefolia* L., *Fragaria virginiana* Miller, *Potentilla tridentata* Ack. [*Sibbaldiopsis tridentata* (Ait.) Paule & Soják], *Rosa acicularis* Lindl., *Polygala senega* L., *Gaultheria procumbens* L., *Lathyrus maritimus* L. [*Lathyrus japonicus* Willd.], *Arctostaphylos uva-ursi* (L.) [*Arctostaphylos uva-ursi* (L.) Spreng.], *Vaccinium canadense* Richards [*Vaccinium myrtilloides* Michx.], *V. pennsylvanicum* Lam. [probably *Vaccinium angustifolium* Ait.], and *Antennaria campestris* Rydb. [*Antennaria neglecta* Greene].

In this area the dominant Acrididae are *Melanoplus mancus islandicus* Blat. [*Melanoplus islandicus* Blatchley], *M. foedus stonei* Rehn [*M. stonei*], *M. fasciatus* (Walk.) and *M. dodgei huroni* Blat. [*M. huroni*]. Associated with these, but not confined to this type of country, are a number of others such as, *Acrydium granulatum* Kby. [*Tetrix subulata* (L.)], *A. ornatum* Say [*Tetrix ornata* (Say)], *Chloealtis conspersa* (Harr.), *Neopodismopsis abdominalis* (Thom.) [*Chloealtis abdominalis*], *Pardalophora apiculata* (Harr.), *Arphia conspersa* Scud., *Circotettix verrucullatus* Kby. [*Trimerotropis verruculata*], *Melanoplus keeleri luridus* (Dodge), *M. bivittatus* (Say), *M. dawsoni* (Scud.), *M. femurrubrum* (DeG.), and *M. bruneri* Scud.

AREA NO. 2, SANDY UPLANDS

This area comprises the sand dune country and a few more segregated sections elsewhere. The dominant trees are aspen poplar, but in the sand dunes proper there are scattered white spruce, paper birch, cottonwoods, bur oaks, and innumerable shrubs. The trees and shrubs are largely concentrated on the northern slopes or in the valleys. The herbaceous plant associations are very varied and we can, therefore, only give a comparatively few of the most important ones, they are: *Cladonia rangiferina* L. [*Cladonia rangiferina* (L.) Weber ex F. H. Wigg], *C. fimbriata* (L.) Fr., *Polytrichum* sp., *Selaginella densa* Rydb., *Juniperus horizontalis* Moen., *Stipa spartea* Trin. [*Hesperostipa spartea* (Trin.) Barkworth], *S. comata* Trin. [*Hesperostipa comata* (Trin. & Rupr.) Barkworth subsp. *comata*], *Bouteloua curtipendula* Michx. [*Bouteloua curtipendula* (Michx.) Torr.], *B. oligostachya* (Nutt.) [*Bouteloua gracilis* (Kunth) Lag. *ex* Griffiths], *Calamovilfa longifolia* (Hook.) [*Sporobolus rigidus* (Buckley) P.M. Peterson var. *rigidus*], *Carex pensylvanica* Lam., *Lilium pennsylvanicum andinum* Nutt. [*Lilium philadelphicum* L.], *Cerastium arvense* L., *Anemone patens Wolfgangiana* (Bess.) [*Pulsatilla nuttalliana* (DC.) Berchtold *ex* J. Presl], *Erysimum asperum* D.C. [*Erysimum asperum* (Nutt.) DC.], *Potentilla strigosa* Pall. [*Potentilla pensylvanica* L.], *Geum triflorum* Pursh, *Opuntia frigida* Nutt. [probably refers to *Opuntia fragilis* (Nutt.) Haw.], *Penstemon albidus* Nutt.,

Petalostemon purpureus Vent. [*Dalea purpurea* Vent. var. *purpurea*], *Galium boreale* L., *Campanula rotundifolia* L., *Liatris punctata* Hook. [*Liatris punctata* Hook. var. *punctata*], *Chrysopsis villosa* Nutt. [*Heterotheca villosa* (Pursh) Shinners var. *villosa*], *Antennaria campestris* Rydb. [*Antennaria neglecta* Greene], *Gaillardia aristata* Pursh, *Artemisia frigida* Willd., and *A. dracunculoides* Pursh [*Artemisia dracunculus* L.].
The dominant Acrididae here are *Gomphocerus clavatus* Thom. [*Aeropedellus clavatus* (Thomas)], *Ageneotettix deorum* (Scud.), *Psoloessa delicatula delicatula* (Scud.) [*Psoloessa delicatula*], *Orphulella speciosa* (Scud.), *Xanthippus corrallipes latefasciatus* Scud. [*Xanthippus corallipes* (Haldeman)], *Arphia conspersa* Scud., *A. pseudonietana* Thom., *Spharagemon collare* (Scud.), *Melanoplus infantilis* Scud., *M. gladstoni* Scud., *M. foedus foedus* Scud., and *M. mexicanus mexicanus* (Saus.) [*Melanoplus sanguinipes sanguinipes*].

AREA NO. 3, SANDY BLOWOUTS

These are comparatively small areas found within the confines of the large area No. 2. The dominant plants are *Juniperus communis* L., *J. horizontalis* Moen., *Andropogon furcatus* Muhl. [*Andropogon gerardii*], *Oryzopsis cuspidata* Nutt. [*Eriocoma hymenoides* (Roem & Schult.) Rydb.], *Koeleria cristata* (L.) [*Koeleria macrantha* (Ledeb.) Schult.], *Calamovilfa longifolia* (Hook.) [*Sporobolus rigidus* var. *rigidus*], *Cycloloma atriplicifolium* (Spreng.) [*Cycloloma atriplicifolium* (Spreng.) J.M. Coult.], *Corispermum hyssopifolium* L. [*Corispermum americanum* (Nutt.) Nutt. var. *americanum*], *Rumex venosus* Pursh, *Lesquerella argentea* (Pursh) [*Physaria arenosa* (Richardson) O'Kane & Al-Shehbaz subsp. *arenosa*], *Petalostemon villosus* Nutt. [*Dalea villosa* (Nutt.) Spreng. var. *villosa*], *P. candidus* (Willd.) [*Dalea candida* Willd.], *Linum rigidum* Pursh, *Lithospermum angustifolium* Michx. [*Lithospermum incisum*], *Acerates viridiflora* (Raf.) [*Asclepias viridiflora* Raf.], *Lygodesmia juncea* (Pursh) [*Shinnersoseris rostrata* (A. Gray) Tomb], *Helianthus petiolaris* Nutt., *Senecio manitobensis* Greenm. [*Packera tridenticulata* (Rydb.) W.A. Weber & Á. Löve], and *Townsendia exscapa* (Rich.) [*Townsendia exscapa* (Richardson) Porter].

In this area are found *Cordillacris occipitalis cinerea* (Brun.) [*Cordillacris occipitalis* (Thomas)], *Xanthippus montanus* (Thom.), *Cratypedes neglectus* (Thom.), *Trimerotropis agrestis* McN., and *Melanoplus flavidus* Scud. *Trimerotropis agrestis* on the pure sand, the others around its margins. *Melanoplus foedus foedus* Scud., is also common here and *M. fasciatus* (Walk.) occurs abundantly among the surrounding scattered spruce.

AREA NO. 4, PRAIRIE PARK ZONE

The park or savanna zone in Manitoba represents open grasslands intermixed with poplar woods and isolated clumps of trees. The soil, for the most part, is sandy loam. A few of

the typical plants are: *Stipa comata* Trin. [*Hesperostipa comata* subsp. *comata*], *Sporobolus brevifolius* (Nutt.) [*Muhlenbergia cuspidata* (Torr. *ex* Hook.) Rydb.], *Sporobolus cryptandrus* (Torr.) [*Sporobolus cryptandrus* (Torr.) A. Gray], *Calamovilfa longifolia* (Hook.) [*Sporobolus rigidus* var. *rigidus*], *Poa pratensis* L., *Festuca hallii* Vasy. [*Festuca hallii* (Vasey) Piper], *Agropyron smithii* Rydb. [*Pascopyrum smithii*], *Allium reticulatum* Frass. [*Allium textile* A. Nels. & J.F. Macbr.], *Anemone patens Wolfgangiana* (Bess.) [*Pulsatilla nuttalliana*], *Potentilla concinna* Rich., *P. strigosa* Pall. [*Potentilla pensylvanica*], *Astragalus caryocarpus* Ker. [*Astragalus crassicarpus* Nutt. var. *crassicarpus*], *Campanula rotundifolia* L., *Liatris punctata* Hook., *Gutierrezia sarothrae* (Pursh) [*Gutierrezia sarothrae* (Pursh) Britton & Rusby], *Grindelia squarrosa* (Pursh) [*Grindelia squarrosa* (Pursh) Dunal], *Aster commutatus* T. and G. [*Symphyotrichum falcatum* var. *commutatum* (Torr. & A. Gray) G.L. Nesom], *Solidago racemosa* Greene [*Solidago* sp. (*S. racemosa* does not occur in western North America)], and *Brauneria angustifolia* (D.C.) [*Echinacea angustifolia* DC.].
The western meadow lark is a typical bird and the striped ground squirrel a common mammal.

The grasshopper population in this zone is numerous due to the rather wide differences within it. The most indigenous are: *Orphulella speciosa* (Scud.), *Encoptolophus costalis* (Scud.), *Arphia pseudonietana* (Thom.), *Trachyrhachis kiowa kiowa* (Thom.) [*Trachyrhachys kiowa* (Thomas)], *Melanoplus mexicanus mexicanus* (Saus.) [*Melanoplus sanguinipes sanguinipes*], *M. confusus* Scud., and *M. angustipennis* (Dodge). Here also stray *Xanthippus corallipes latefasciatus* Scud. [*Xanthippus corallipes*], *Arphia conspersa* Scud., *Camnula pellucida* (Scud.) and several others. The area proves a typical one for *Conocephalus saltans* (Scud.) and *Oecanthus nigricornis quadripunctatus* Beut. [*Oecanthus quadripunctatus*].

AREA NO. 5, INTERMEDIATE ZONE

This comprises areas of rather denser vegetation met with between the wet and dry zones, usually associated with hillsides or flat spaces not far removed from trees or shrubs. The soil is varied but tends to be mixed with some leaf mould. Plant life is abundant and we can only list some typical examples which are: *Andropogon furcatus* Muhl. [*Andropogon gerardii*], *Poa pratensis* L., *Agropyron richardsonii* Schr. [*Elymus trachycaulus* subsp. *subsecundus* (Link) Á. Löve & D. Löve], *Bromus ciliatus* L., *Allium stellatum* Ker. [*Allium stellatum* Fraser *ex* Ker Gawler], *Arabis brachycarpa* (T. and G.) [*Boechera grahamii* (Lehm.) Windham & Al-Shehbaz], *Anemone cylindrica* Gray, *Lathyrus ochroleucus* Hook., *Vicia americana* Muhl., *Symphoricarpos occidentalis* Hook., *Viola conspersa* Rich. [*Viola labradorica* Schrank], *Lithospermum canescens* (Michx.) [*Lithospermum canescens* (Michx.) Lehm.], *Oenothera serrulata* Nutt., *Monarda mollis*

L. [*Monarda fistulosa* var. *mollis* (L.) Benth.], *Liatris squarrosa* Willd. [*Liatris squarrosa* (L.) Michx.], *Erigeron glabellus* Nutt., *Antennaria microphylla* Rydb., and *Aster laevis* L. [*Symphyotrichum laeve* (L.) Á. Löve & D. Löve].
The clay-coloured sparrow and jumping mouse (*Zapus*) are common vertebrates in this area.

Dominant Acrididae are *Chloealtis conspersa* (Harr.), *Neopodismopsis abdominalis* (Thom.) [*Chloealtis abdominalis*], *Chortophaga viridifasciata* (DeG.), *Pardalophora apiculata* (Harr.), *Spharagemon bolli* Scud., *Melanoplus bivittatus* (Say), *M. dawsoni* Scud., *M. keeleri luridus* (Dodge), *M. confusus* Scud., *M. bruneri* Scud., and *M. angustipennis* (Dodge).

AREA NO. 6, RICH SOILS ZONE

This zone is characterized by the Red River valley although not necessarily confined to it. The plant associations include the dominant *Agropyron smithii* Rydb. [*Pascopyrum smithii*], *Poa pratensis* L., *Hordeum jubatum* L., *Chenopodium glaucum* L., *Potentilla anserina* Pursh [*Potentilla anserina* L.], *Amorpha canescens* Pursh, *Zizia cordata* (Walt.) [*Zizia aptera* (A. Gray) Fern.], *Mentha canadensis* L., *Sonchus arvensis* L., *Grindelia squarrosa* (Pursh) [*Grindelia squarrosa* (Pursh) Dunal], *Lepachys columnaris* Sims. [*Ratibida columnifera* (Nutt.) Wooton & Standl.], and *Helianthus tuberosus* L.
The Acrididae here are confined to a comparatively few species of which the following find a permanent abode: *Camnula pellucida* (Scud.), *Melanoplus bivittatus* (Say), and *M. femurrubrum* (DeG.).

AREA NO. 7, SUB-ARID ZONE

This zone is characterized by a rather light precipitation, the soil is clayey which bakes and cracks with the sun. There are no trees on the uplands. The most peculiar plant associations are: *Andropogon furcatus* Muhl. [*Andropogon gerardii*], *Sorghastrum nutans* L. [*Sorghastrum nutans* (L.) Nash], *Stipa viridula* Trin. [*Nassella viridula* (Trin.) Barkworth], *Sporobolus cryptandrus* (Torr.) [*Sporobolus cryptandrus* (Torr.) A. Gray], *S. brevifolius* (Nutt.) [*Muhlenbergia cuspidata*], *Spartina michauxiana* Hitch. [*Sporobolus michauxianus* (Hitchcock) P.M. Peterson & Saarela], *Bouteloua oligostachya* (Nutt.) [*Bouteloua gracilis*], *Agropyron smithii* Rydb. [*Pascopyrum smithii*], *Vicia sparsifolia* Nutt. [*Vicia americana* var. *minor* Hook.], *Solidago rugosa* Mill. [*Solidago* sp. (*S. rugosa* does not occur in the area of Criddle's studies)], *Artemisia frigida* Willd., and *A. ludoviciana* Nutt.

Richardson's ground squirrel is the dominant mammal, horned larks and longspurs the commonest birds.

Scattered over this area are to be found *Opeia obscura* (Thom.), *Encoptolophus costalis* (Scud.), *Xanthippus corallipes latefasciatus* Scud. [*Xanthippus corallipes*], *Arphia pseudonietana* (Thom.), *Metator pardalinus* (Saus.), *Trachyrhachis kiowa kiowa* (Thom.) [*Trachyrhachys kiowa*], *Trimerotropis campestris* McN. [*Spharagemon campestris* (McNeill)], *Aerochoreutes carlinianus* (Thom.) [*Circotettix carlinianus*], *Hypochlora alba* (Dodge), *Melanoplus mexicanus mexicanus* (Saus.) [*Melanoplus sanguinipes sanguinipes*], *M. packardii packardii* Scud., and *Phoetaliotes nebrascensis* (Thom.).

AREA NO. 8, GRAVEL RIDGES

Here we have hilly country consisting largely of glacial drift, usually of a gravelly texture, more rarely intermixed with clay. The humidity is the same as in area 7, within which these ridges are situated.

The plants more or less peculiar to the zone are *Sporobolus brevifolius* (Nutt.) [*Muhlenbergia cuspidata*], *S. cryptandrus* (Torr.) [*Sporobolus cryptandrus* (Torr.) A. Gray], *Bouteloua oligostachya* (Nutt.) [*Bouteloua gracilis*], *Oxytropis splendens* Doug. [*Oxytropis splendens* Douglas *ex* Hook.], *Phlox hoodii* Rich., *Liatris punctata* Hook., *Gutierrezia sarothrae* (Pursh) [*Gutierrezia sarothrae* (Pursh) Britton & Rusby], *Aplopappus spinulosus* Pursh [*Xanthisma spinulosum* (Pursh) D.R. Morgan & R.L. Hartm.], *Solidago rugosa* Mill. [*Solidago* sp.], *S. missouriensis* Nutt., and *Artemisia frigida* Willd.

In this area the permanent Acrididae are *Bruneria brunnea* (Thom.), *Psoloessa delicatula delicatula* (Scud.) [*Psoloessa delicatula*], *Encoptolophus costalis* (Scud.), *Hesperotettix viridis pratensis* Scud., *Melanoplus infantilis* Scud., and *M. gladstoni* Scud. *Xanthippus corallipes latefasciatus* Scud. [*Xanthippus corallipes*], *Arphia conspersa* Scud., and *A. pseudonietana* (Thom.) are also frequently found here.
In Manitoba the zone is confined to the extreme south-west.

AREA NO. 9, LOW GRASSLAND

Low sub-marshy tracts, not strikingly alkaline. The dominant plants are *Agrostis alba* L. [Could be *Agrostis gigantea* Roth. or *A. stolonifera* L.], *Calamagrostis canadensis* (Michx.) [*Calamagrostis canadensis* (Michx.) P. Beauv. var. *canadensis*], *C. langsdorffi* (Link.) [*Calamagrostis canadensis* var. *langsdorffii* (Link) Inman], *Carex* sp., *Parnassia palustris* L., *Gentiana amarella* L. [*Gentianella amarella* subsp. *acuta* (Michx.) J.M. Gillett], *Stachys palustris* L., *Lycopus americanus* Muhl. [*Lycopus americanus* Muhl. *ex* W.P.C. Barton], *Mentha canadensis* L., *Castilleja coccinea* (L.) [*Castilleja coccinea* (L.) Spreng.], *Solidago decumbens* Greene [*Solidago glutinosa* Nutt.], and *Aster paniculatus* Lam. [*Symphyotrichum lanceolatum* Willd. G.L. Nesom subsp. *lanceolatum*].

The only dominant Acrididae here is *Chorthippus curtipennis* (Harr.) [*Pseudochorthippus curtipennis curtipennis*]. *Acrydium granulatum* Kby. [*Tetrix subulata*] is not uncommon and *Melanoplus borealis junius* (Dodge) [*Melanoplus borealis* (Fieber)] often occurs in the dryer parts. It is a chosen resort of *Conocephalus fasciatus fasciatus* DeG. [*Conocephalus* (*Anisoptera*) *fasciatus* (De Geer)].

AREA NO. 10, CLIFFS AND BANKS

Dry clayey banks facing the sun, usually associated with rivers or deep coulees. The chief plant associations in Manitoba are *Agropyron Richardsonii* Schrad. [*Elymus trachycaulus* subsp. *subsecundus*], *Oxybaphus hirsutus* Pursh [*Mirabilis albida* (Walt.) Heimerl], *Glycyrrhiza lepidota* Nutt. [*Glycyrrhiza lepidota* Pursh], and *Polanisia graveolens* Raf. [*Polanisia dodecandra* (L.) DC.].

The only indigenous grasshopper in these areas is *Circotettix rabula rabula* R. and H. [*Circotettix rabula*].

To the westward where the conditions are more arid this species is much less restricted and its plant associations are then more diversified.

AREA NO. 11, ALKALINE SHORES

These are restricted areas of low land usually, but not always, bordering ponds and lakes. The soil is strongly alkaline and the plant growth is rather restricted. Some characteristic examples are *Distichlis spicata* (L.) [*Distichlis spicata* (L.) Greene], *Agropyron smithii* Rydb. [*Pascopyrum smithii*], *Juncus* sp., *Atriplex hastata* L. [*Atriplex prostrata* Boucher *ex* DC.], *Suaeda depressa* Pursh [*Suaeda calceoliformis* (Hooker) Moquin-Tandon], and *Monolepis nuttalliana* (R. & S.) [*Monolepis nuttalliana* (Schult.) Greene].
The more permanent acridiidians of this zone are *Orphulella pelidna* (Burm.) and *Trimerotropis pallidipennis salina* McN. [*Trimerotropis salina*]. On the border line between it and the hillsides may be found *Opeia obscura* (Thom.), *Chorthippus curtipennis* (Harr.) [*Pseudochorthippus curtipennis curtipennis*], *Camnula pellucida* (Scud.) and *Melanoplus femur-rubrum* DeG. [*Melanoplus femurrubrum* (DeG.)].

AREA NO. 12, ALKALINE FLATS

Alkaline flats of sub-marshy condition, the chief plants peculiar to the locality being *Atriplex nuttallii* S. Wats. [*Atriplex gardneri* (Moquin—Tandon) D. Dietrich] and *Sarcobatus vermiculatus* (Hook.).

This locality is a favourite habitat of *Trimerotropis gracilis sordida* E. M. Walk. [*Trimerotropis gracilis* (Thomas)], *T. laticincta* Saus. [*Trimerotropis latifasciata*

Scudder], *T. pallidipennis salina* McN. [*Trimerotropis salina*] and *Aeoloplus turnbulli turnbulli* Thom. [*Aeoloplides turnbulli turnbulli*].
The zone is a western one which scarcely reaches Manitoba. It is associated with the semi-arid areas of no. 7 and links up to the westward with the sage brush country.

AREA NO. 13, SEDGE ZONE

Bogs or marshes the chief plant group being various coarse sedges (*Carex* sp.). These form the haunts and food of *Stethophyma lineatum* (Scud.) and *S. gracile* (Scud.).

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NOTES ON THE HABITS OF VARIOUS SPECIES

***Metator pardalinus* (Saus.)**
This insect looks very like *Xanthippus* and its habits are also similar. It passes the winter in the egg-stage and in its food selection shows a strong preference for *Agropyron smithii* Rydb. [*Pascopyrum smithii*]. The species is an inhabitant of rather arid prairies. It has only been taken in Manitoba near Goodlands in the southwest, but is not uncommon at Estevan, Sask., and on westward across Alberta.

***Arphia pseudonietana* (Thom.)**
The haunts of this species are very similar to those of [*A.*] *conspersa* although it is rather more confined to prairie uplands. It differs in that it hatches from eggs in springtime, matures rather late in the year and winters as an egg. The cracking notes from its wings are louder than those of [*A.*] *conspersa*.

***Arphia conspersa* Scud.**
An inhabitant of sandy areas in upland situations, frequently associated with the margins of trees or open pine woods. It hibernates in one of the later nymphal stages and is usually on the wing early in May. Egg-laying takes place in late May, June and occasionally in July, and as a rule the eggs hatch during the last named month or early in August. Occasionally some of them remain unhatched until the following summer. The insect is a grass feeder and occurs over a wide territory from the eastern boundary of Manitoba to the Rocky Mountains and north to at least The Pas.

***Trimerotropis laticincta* Saus. [*Trimerotropis latifasciata* Scudder]**
Associated with *sordida* [*Trimerotropis gracilis*] and [*T.*] *salina*. A rather quiet species its noise when flying being soft. It appears to prefer broad leaved plants as food.

***Trimerotropis pallidipennis salina* McN. [*Trimerotropis salina* McNeill]**
The habits of this species are similar to those of *laticincta* [*Trimerotropis latifasciata*] but it has a greater range of food plants, eating both grass and broad-leaved plants. It is also more widely distributed.

***Trimerotropis gracilis sordida* E. M. Walk. [*Trimerotropis gracilis* (Thomas)]**
An inhabitant of alkaline soils having a number of the characteristics of *Circotettix* and producing a loud cracking sound when flying. The insect appears to be a grass feeder.

***Hesperotettix viridis pratensis* Scud.**
Egg-laying: The egg-laying activities do not differ from those of *Hypochlora alba* (Dodge).
General Habits: This species is less restricted in its food habits than *Hypochlora* although confining its activities to certain members of the Compositae with a marked preference to those of the genus *Solidago*. The greatest number ever taken by me was on a large clump of *Solidago rugosa* [*Solidago* sp.], the specimens being all nymphs. Later it was found to eat *S. missouriensis*, *S. nemorosa* [*Solidago nemoralis* Ait.] and *S. decumbens* Greene [*Solidago glutinosa*]. Also *Aplopappus spinulosus* Pursh [*Xanthisma spinulosum*] and *Chrysopsis villosa* Nutt. [*Heterotheca villosa* var. *villosa*].
The insect is quite frequently met with at a distance from its host plants, the wanderings being doubtless often due to a scarcity of food. We took it commonly both at Lethbridge, Alberta, and Estevan, Sask., but while it occurs on the Turtle Mountain in North Dakota we have only once encountered it in Manitoba and that was near Goodlands.

***Hypochlora alba* (Dodge)**
Egg-laying: In excavating the hole for egg-laying the female holds on to some upright herbage and sits very erect with the posterior legs held high which gives her the appearance of a squirrel sitting up. As usual with the Acrididae she tests many places before finding one which suits her. She then extends her abdomen to its utmost extremity into the soil and while ovipositing rests in an almost perpendicular position with the hind femora held at an acute angle. She rarely kicks during the process of drilling. An individual under observation began drilling at 3.10 P.M. and finished egg-laying at 4.25 P.M., at a temperature of about 70 °F. She then covered the cavity with her abdomen, a task which was not completed until 4.57 P.M.
Food Plants: In our experience this species is confined in its diet entirely to the common white sage, *Artemisia ludoviciana*, a plant which it rarely leaves except for the purpose of egg-laying. It has an astonishingly close colour resemblance to its host plant to which it clings with great pertinacity. We would add that the sexes are nearly always in copulation and not unfrequently die in that condition. In this frequent and prolonged mating they resemble *Hesperotettix* and *Schistocerca*.
The specimens from which these studies were made came from Westhope, N.D. The species is only found in the extreme southwestern portion of Manitoba although plentiful in both North Dakota and Montana near the international boundary.

***Melanoplus dodgei huroni* Blat. [*Melanoplus huroni* Blatchley]**
In this insect we have another denizen of the wooded areas in sandy situations. It is frequently found associating with [*M.*] *islandicus* and [*M.*] *fasciatus* but seems on the

whole to prefer rather denser vegetation. Its food is substantially the same as [*M.*] *islandicus*. We have taken it in the pine woods at Sandilands and among poplars at Victoria Beach. At Cowan it was associated with jack pine and blueberry and in the Porcupine Mountains with pine and *Arctostaphylos*. In all instances the soil was very sandy.

***Melanoplus mancus islandicus* Blat. [*Melanoplus islandicus* Blatchley]**
This is a sylvan species rather definitely associated with open pine woods and sandy situations. It is rarely found in the dense wood, however, but instead frequents the sunny openings where blueberry and *Potentilla tridentata* [*Sibbaldiopsis tridentata*] abound. It is not a grass feeder but has a relish for the small lily, *Maianthemum*, and a few other broad-leaved plants. In Manitoba the species is confined to the pine woods of the east from Minnesota to at least as far north as Victoria Beach.

***Melanoplus bruneri* Scud.**
This insect is an inhabitant of shrubby areas in which there are open spaces. We have found it most frequently in openings among mixed woods in which its chief plant associates were *Amelanchier*, *Symphoricarpos*, *Arctostaphylos* and a few coarse grasses or herbaceous plants. It seems on the whole to be more boreal in distribution than *mexicanus* [*Melanoplus sanguinipes sanguinipes*] and prefers a greater amount of shade. Its food habits are quite diversified.

***Melanoplus fasciatus* (Walk.)**
This species frequents semi-wooded areas from the margins of bogs to dry uplands. It seems to prefer sandy situations but is by no means confined to them. Then again it is most often met with among evergreens but may occur miles away from such trees. As a rule, however, it seeks some sort of shade and in this connection we have found the sand dune country with scattered clumps of spruce and a low covering of *Arctostaphylos* to provide the insect in its greatest numbers. It is rather more diversified in its food habits than either [*M.*] *huroni* or [*M.*] *islandicus* but prefers broad-leaved plants to grasses.

***Melanoplus dawsoni* (Scud.)**
This small species is an inhabitant of cool situations or low lying areas from which, in times of abundance, it spreads to the uplands. It prefers open shrubby places and seems to be most at home in sandy areas. In Manitoba the low growing shrub *Arctostaphylos* is a common associate. The insect is a fairly general feeder although preferring broad-leaved plants.

***Melanoplus bivittatus* (Say)**
This is a semi-lowland grasshopper which normally inhabits rather rank herbage and roadside ditches. At times of abundance it spreads out over wide stretches of country and becomes a pest of major importance. At such times too it may acquire abnormally long wings and then migrate for many miles. It is one of the most prolific of all our species depositing many eggs and having unusually large egg-sacs. Its size and the size of its egg-sacs apparently attract many enemies to it and on this account it rarely rises to the great numbers which it attained during the outbreak in Minnesota, the Dakotas and Manitoba in 1931–33. It is perhaps even more omnivorous than *mexicanus* [*Melanoplus sanguinipes sanguinipes*] and when in equal quantities outdistances all other species in destructiveness with the possible exception of its close ally [*M.*] *differentialis*. The eggs are deposited in a great variety of situations, such as weedy fields, clover fields, fence rows and the margins of roadside ditches. We have known them to be deposited between planks and also in semi-dry cattle dung.

***Melanoplus gladstoni* Scud.**
This insect and [*M.*] *infantilis* are both found on dry uplands usually associated with sandy or gravelly soils disassociated with trees. They are rather late to hatch and develop. Their plant associations are many but perhaps the most characteristic are *Selaginella densa* Rydb., *Bouteloua oligostachya* (Nutt.) [*Bouteloua gracilis*], *Potentilla strigosa* Pall. [*Potentilla pensylvanica*], and *Artemisia frigida* (Willd.).

***Melanoplus confusus* Scud.**
[*Melanoplus*] c*onfusus* like *borealis junius* [*Melanoplus borealis*] is among the first orthopteran to hatch from eggs in springtime and with that species it appears in the winged state before any other of the genus. Both are frequently found inhabiting the same situation but as a rule *confusus* prefers rather drier locations such as semi-upland areas among low shrubs. Some of its notable plant associations are *Andropogon furcatus* Muhl. [*Andropogon gerardii*], *Allium stellatum* Ker. [*Allium stellatum* Fraser *ex* Ker Gawler], *Ranunculus rhomboideus* Gold., *Erigeron glabellus* Nutt., and *Antennaria microphylla* Rydb.

***Melanoplus flavidus* Scud.**
This insect seems to be definitely associated with dry, sandy uplands. We have taken it in company with [*M.*] *foedus* among the drifting sand dunes near Onah and on old grain fields at Aweme. At Medicine Hat, Alberta, it likewise frequented the areas of sparse vegetation in sandy places. It is a grass feeder.

***Melanoplus borealis junius* (Dodge) [*Melanoplus borealis* (Fieber)]**
An inhabitant of semi-wooded areas in usually rather low situations although occasionally found in heavy timber. We have found it in greatest numbers on old overgrown fields in which rank weeds dominated. Some of its chief plant associates are *Muhlenbergia sylvatica* (Torr.), *Agrostis stolonifera* L., *Calamagrostis canadensis* (Michx.) [*Calamagrostis canadensis* (Michx.) P. Beauv.], *Bromus ciliatus* L., *Mentha canadensis* L., *Helianthus tuberosus* L., and *Rudbeckia laciniata* L.

***Chorthippus curtipennis* Harr. [*Pseudochorthippus curtipennis curtipennis* (Harris)]**
An inhabitant of low semi-marshy situations. It is rather late in maturing and one of the last to disappear in autumn. Grain crops around the margins of marshes have occasionally been injured by this species. It places its eggs in or near clumps of grass and occasionally in decaying wood. It occurs wherever its chosen habitats are present at least as far north as Churchill.

***Orphulella pelidna* (Burm.)**
This insect is an inhabitant of semi-dry alkaline flats where its chief food associations are *Distichlis spicata* (L.) [*Distichlis spicata* (L.) Greene], *Juncus* sp., *Monolepis nuttalliana* (R. and S.) [*Blitum nuttallianum* Schult.], *Atriplex hastata* L. [*Atriplex prostrata* Boucher *ex* DC.], *Suaeda depressa* [*Suaeda calceoliformis*], and *Grindelia squarrosa* (Pursh) [*Grindelia squarrosa* (Pursh) Dunal]. It feeds upon grasses.

***Orphulella speciosa* Say [*Orphulella speciosa* (Scudder)]**
This is another upland prairie species but it seems to be rather local in distribution. As a rule we have found its major plant associations to be similar to those of *Amphitornus*.

***Cordillacris occipitalis cinerea* (Brun.) [*Cordillacris occipitalis* (Thomas)]**
This is a sand-loving insect usually found on dry gravelly hills or on the margins of drifting sand. In such places its plant associations are comparatively few but among the most common are *Oryzopsis cuspidata* Vasey [*Achnatherum hymenoides*], *Koeleria cristata* (L.) [*Koeleria macrantha*], *Cycloloma atriplicifolium* (Spreng) [*Cycloloma atriplicifolium* (Spreng.) J.M. Coult.], and *Senecio manitobensis* Greenm. [*Packera tridenticulata*].

***Aeoloplus turnbulli turnbulli* Thom. [*Aeoloplides turnbulli turnbulli* (Thomas)]**
This species appears to be rather definitely associated with alkaline areas over which *Atriplex nuttallii* S. Wats. [*Atriplex gardneri*] abounds and which is seemingly the chief food plant although the insects have also been known to eat other species of *Atriplex* as well as *Chenopodium*. The insect shows a considerable colour resemblance to its chief

food plant and on that account is difficult to locate. It is a strong hopper and in its jumps dodges back and forth to avoid its pursuer.
Our specimens came from Hatton and Kincaid, Sask., where it frequented wide stretches of alkaline flats covered with its chief food plant *Atriplex nuttallii* [*A. gardneri*].

***Amphitornus coloradus* (Thom.) [*Amphitornus coloradus coloradus* (Thomas)]**
This is an upland prairie species preferring gravelly sandy soils. In Manitoba it is rather closely associated with the following plants: *Selaginella densa* Rydb., *Stipa comata* Trin. [*Hesperostipa comata* subsp. *comata*], *S. spartea* Trin. [*Hesperostipa spartea*], *Sporobolus heterolepis* A. Gray [*Sporobolus heterolepis* (A. Gray) A. Gray], *Koeleria cristata* (L.) [*Koeleria macracantha*], *Bouteloua oligostachya* (Nutt.) [*Bouteloua gracilis*], *Lithospermum angustifolium* Michx. [*Lithospermum incisum*], *Liatris punctata* (Hook.), and *Artemisia frigida* Willd. It is a grass feeder.

***Melanoplus mexicanus mexicanus* (Saus.) [*Melanoplus sanguinipes sanguinipes* (Fabricius)]**
This well known pest is largely confined in its breeding activities to dry uplands and it rarely enters the wooded areas excepting during the period of flight and practically never breeds there unless amid openings. It is almost omnivorous in its food habits which doubtless accounts for its wide distribution and general abundance. The species is an exceptionally strong flyer and at times migrates long distances.

***Melanoplus foedus foedus* Scud.**
This insect is rather definitely associated with sandy uplands and its chosen food plants are grass. For oviposition it usually chooses semi-soft ground such as is provided by an old pocket gopher mound. Cultivated grain fields or stubble fields are also utilized for egg-laying. It usually rises in numbers with other species and under such circumstances has occasionally caused some damage to crops in southern Manitoba.

***Melanoplus packardii packardii* Scud.**
This species is an inhabitant of the Great Plains being a true prairie species, only entering the sandy park lands or savannah country to a small extent. The insect is a general feeder and as such has reached a rather high point of destructiveness in Saskatchewan and parts of Alberta. The cultivated fields have been utilized to a marked extent for egg beds and in this way the insect has been enabled to multiply much beyond its former numbers. Indeed it has the potential possibilities for becoming a serious pest.

***Spharagemon equale* (Say)**
A western species of somewhat local distribution, usually confined to upland prairies. The insect is a trifle specialized in its food proclivities, partaking very sparingly of grasses but showing a marked preference for the Cruciferae [Brassicaceae]. We reared it from eggs on such plants as *Lepidium*, *Capsella*, and *Arabis*. It is doubtful whether any of these are its native food plants.

***Spharagemon bolli* Scud.**
This species prefers situations near woods and we have found it most often in open glades or around the margins of shrubby areas. It is not a grass eater but partakes of a number of broad-leaved plants such as dandelion and some of the vetches.

***Spharagemon collare* (Scud.)**
A frequenter of uplands, rarely entering woods though found around their margins. It is a more general feeder than either of the other [*Spharagemon*] species and occasionally has been known to become of economic importance by attacking grain crops. This insect shows a marked preference for firm cultivated soil in which to deposit its eggs. Pocket gopher mounds are frequently utilized for this purpose.

***Pardalophora apiculata* (Harr.)**
An inhabitant of situations around or in openings in woodlands, but rarely met with on the open prairie. It will eat sparingly of grass but prefers broad-leaved plants such as dandelion. The males are strong active flyers. The females rarely fly at all.
The eggs are deposited in June and July and usually hatch in August, the nymphs wintering in one of the two latest instars. In our breeding studies the eggs have not infrequently failed to hatch until the following year and in view of the fact that egg-laying may continue into August it seems not unlikely that delayed hatching also occurs in nature.