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Adult male European earwig, *Forficula auricularia*, with a newly arrived aphid, *Uroleucon rudbeckiae*, on tall coneflower, *Rudbeckia laciniata*, in a Winnipeg garden, 2017-08-05. (Photo taken by P.A. McKay.)

Scientific Note

Earwigs (Dermaptera) of Manitoba: Records and Recent Discoveries

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The earwigs (Dermaptera) are a small order of insects (~1,800 described species) that are predominately tropical in distribution (Vickery and Kevan 1986; Hopkins *et al*. 2020). While earwigs tend to be secretive insects, some species are found in association with a variety of human-transported materials. As a result, humans have been responsible for the movement and introduction of a handful of synanthropic species well beyond their original distributions (Vickery and Kevan 1986). Although no known species of earwig is native to Manitoba or the Canadian Prairies, to our knowledge two species have become established following their introduction, and adventive species are also encountered, though infrequently. Here we document our limited but growing knowledge of the species of earwigs present in Manitoba and their distributions.

Forficulidae

Forficula auricularia (L.), the European earwig, is reported for the first time as resident in Winnipeg, Manitoba, Canada. The species was first recorded in Canada in British Columbia (Spencer 1926), where it became sufficiently numerous to reach minor pest status as a nuisance in gardens and orchards. Subsequently, it became established and sometimes abundant in the Maritime Provinces, southern Quebec and southern Ontario (Lamb 1979; Tourneur and Gingras 1992; Tourneur and Meunier 2019), but until now, European earwigs have not been reported as established in any of the three Prairie Provinces. No doubt European earwigs have arrived in Manitoba on numerous occasions, given the constant movement of nursery stock, fruits and vegetables from British Columbia and eastern Canada. The earwig behaviour of spending the day hidden in tight spaces could easily result in them being transported undetected across Canada (Lamb and Wellington 1975).

European earwigs overwinter as adults without a diapause, and during the epigean phase of the life-cycle, females lay their eggs and care for them in subterranean nests in winter (Lamb 1976). Although thought to be intolerant of sub-freezing temperatures, European earwigs are known to survive even where winter can be severe, as in Montreal, Canada (Tourneur and Gingras 1992). In such climates, females and their eggs probably die unless nests are protected from frost penetration by being near the foundations of heated buildings (Gingras and Tourneur 2001). In Manitoba, where winter temperatures are lower and insulating snow cover is often less than in Montreal, even some native insect species with a typical diapause cannot survive winter soil temperatures if the ground is not insulated by snow cover (Lamb *et al*. 1985). Thus, finding a resident population of European earwigs in Winnipeg was unexpected. The one nest observed in Winnipeg was at least 2 m from a heated foundation, within 5 cm of the surface under a flat stone. It may, however, have been protected from freezing by deep snow from a nearby walkway. We must accept that survival through severe winters is possible, since the populations of *F. auricularia* are well established in eastern Canada from ON to NL (Tourneur and Meunier 2019), and now in the prairies (Winnipeg).

The first European earwig observed (but not collected) in Winnipeg was a second- or third-instar nymph in a private garden in June, 2015. In the same garden, two adult female and three adult male earwigs were collected from 23 July 2016 – 9 September 2017. In 2018, 10 earwig traps (Lamb and Wellington 1974) and 10 pitfall traps were used to collect earwigs at the soil surface, and checked weekly through the spring, summer and autumn. Traps yielded an adult female on 17 June, three adult females on 8–15 August, and four nymphs on 29 June – 13 July (Table 1). Three second-instar nymphs were collected on 9 June 2018 as they escaped from a shallow subterranean nest disturbed when gardening, and an adult male was observed on 15 August, 2019. All collected specimens have been deposited in the J.B. Wallis/R.E. Roughley Museum of Entomology, Department of Entomology, University of Manitoba (Table 1).

We conclude that *F. auricularia* is resident in at least this one garden (N49.85, W97.13) in Winnipeg, where individuals, including young nymphs in a nest, have been observed in five successive years. Although only 19 individuals have been observed, the seasonal pattern of observations is consistent with successful overwintering: young juveniles and an adult female in early to mid-June, older juveniles in late June and early July, adult females and males from early August to September. This pattern is similar to that of earwigs in Montreal (Gingras and Tourneur 2001; Tourneur 2017), and fits the expected pattern of nesting and oviposition seen for populations living in a north-temperate climate with a severe winter (Tourneur and Meunier 2019). No other resident populations of *F. auricularia* have been reported in southern Manitoba, which is perhaps surprising as the adults often shelter during the day under or in the blooms of flowering plants in gardens.

As relatively large, darkly-coloured insects with highly visible "pincers", they are likely to be encountered by the general public, but such encounters have not been reported. The population of resident *F. auricularia* must still be relatively low, possibly with a restricted distribution in Manitoba. Whether or not the apparent restricted distribution results from this earwig's limited ability to survive a Manitoba winter remains to be determined.

Genetically distinct populations of European earwigs have been identified in North America, possibly reflecting introductions from different parts of Europe (Guillet *et al.* 2000). The genotypic characteristics of the specimens from Manitoba have yet to be determined, but based on the descriptions provided in Guillet *et al.* (2000), we expect the Manitoba population to be 'Species A', like those found in Quebec and other cooler, continental regions.

Spongiphoridae

Labia minor (L.)

Labia minor, the lesser earwig, is a cosmopolitan species that has been present in Manitoba since at least 1909 (based on our earliest record, Table 1), possibly longer since it was first recorded in North America in 1838 (Wanborough, NY) and was noted as being widespread by the early 1900's (Doubleday 1838, Caudell 1913, Langston and Powell 1975). *Labia minor* is believed to have been introduced from Europe (Buckell 1929), but that introduction would have occurred at least 182 years ago and is likely impossible to retrace. Vickery and Kevan (1986) listed the Canadian distribution of *L. minor* as British Columbia to Nova Scotia, but only mapped two collection localities in the Canadian Prairies (Aweme, Manitoba, and one site near the Alberta-Saskatchewan border).

Although *L. minor* has now been present in Manitoba for over a century, it has been infrequently collected because it is rather inconspicuous (Langston and Powell 1975) (Table 1), and we are not aware of any previous efforts to document the occurrence of earwigs in the province beyond Vickery and Kevan (1986). Recent collections at a dairy farm near Whitemouth, in southeastern Manitoba, have yielded numerous specimens by focusing on areas with abundant muscid fly maggots (predominately *Musca domestica* (L.) but also *Stomoxys calcitrans* (L.)). Specimens were most reliably collected at the interface of straw mixed with manure and the underlying soil, generally matching previously documented habitat preferences (Hebard 1917, Morse 1920). Several specimens were also collected at the interface of spilled feed grain and the soil. Four specimens were collected at light traps or exterior lights, which has also been previously reported (Vickery and Kevan 1986).

In Manitoba, adults of *L. minor* were recorded from 17 April until 21 October based on all known records, with the largest number of collections in August (Table 1). All records, are from southern Manitoba (below 50° latitude), we do not know how far north this species can be found. Specimens have been collected from the same site (dairy farm near Whitemouth MB) for consecutive years, demonstrating this species' ability to overwinter successfully even in Manitoba's cold, continental climate, something few other species of earwigs appear to achieve (Langston and Powell 1975, Vickery and Kevan 1986).

Marava arachidis Yersin

Marava arachidis, the bone-house (or chief) earwig, is recorded from Africa, Australia, Caribbean, Europe, Asia (with the exception of China), and North and South America (Hopkins *et al*. 2020). The origins of this species are not fully known other than the assumption of it being a tropical species (Patel and Habib 1978). In California, *M. arachidis* was first detected in 1920, and has since been documented breeding in the state (Dowell *et al.* 2016). The species has also been recorded in AZ, TX, NJ, FL, HI, and MA (Vickery and Kevan 1986; Tullis and Goff 1987; Choate 2001).

There are no records of established populations *M. arachidis* in Canada. As of 2014, however, it was recorded in Ontario as an introduced species (Paiero and Marshall 2014). *Marava arachidis* is a cosmopolitan species, often found among stored products (Kamimura *et al.* 2016). Therefore, its presence in Manitoba (Table 1) is not considered abnormal, although collections (in pitfall traps) from a farm compost pile outdoors and away from factories was unusual given other previous records in temperate countries/regions are from indoors (Paiero and Marshall 2014; Matzke and Kocarek 2015). There is one additional record of this species on iNaturalist.ca, from 2012 in Winnipeg.

This species is known to exhibit maternal care (Patel and Habib 1978), so finding both adults and juveniles in the same samples suggests that in-site reproduction may have occurred. We cannot confirm this, since it is unknown how and when they were introduced at this site.

Anisolabididae

There are two records of *Euborellia annulipes* (Lucas), the ring-legged earwig, from Manitoba (Table 1). This species is predominately found along the east and west Coasts of North America, having been introduced to North America prior to 1884 (Langston and Powell 1975), but is also found in heated greenhouses and warehouses (Vickery and Kevan 1986). There is no evidence that this species is established in Manitoba, indoors or out, but it may occasionally be introduced in the same way other earwigs are, through commerce. The specimen collected in 2019, for example, was discovered alive in a package of potting soil mix.

Acknowledgements

We thank Owen Lonsdale for providing the records for earwigs in Manitoba from the Canadian National Collection of Insects, Arachnids and Nematodes (CNC), Agriculture and Agri-Food Canada, Ottawa. We thank the two anonymous reviewers for their suggestions on a previous version of this manuscript.

Table 1. Manitoba earwig records.

Family Identity	Depository	No.	Sex	Location	Lat. (N); Long. (W)	Date	Collector
Anisolabididae *Euborellia annulipes*	WRME[1]	1	♀	Winnipeg	49.81; -97.15	22.ix.1998	W.B. Preston
	WRME	1	♂	Winnipeg	49.82; -97.19	17.xi.2019	S. Storozuk
Forficulidae *Forficula auricularia*	Observed only		Juv.	Winnipeg	49.8456; -97.1282	-.vi.2015	R.J. Lamb
	WRME	1	♂	Winnipeg	49.8456; -97.1282	23.vii.2016	R.J. Lamb
	WRME	1	♀	Winnipeg	49.8456; -97.1282	07.viii.2016	R.J. Lamb
	WRME	1	♂	Winnipeg	49.8456; -97.1282	26.viii.2016	R.J. Lamb
	Observed only		♂	Winnipeg	49.8456; -97.1282	05.viii.2017	R.J. Lamb
	WRME	2	1♀, 1♂	Winnipeg	49.8456; -97.1282	09.ix.2017	R.J. Lamb
	WRME	1	♀	Winnipeg	49.8456; -97.1282	17.vi.2018	R.J. Lamb
	WRME	1	♀	Winnipeg	49.8456; -97.1282	08.viii.2018	R.J. Lamb
	WRME	2	♀	Winnipeg	49.8456; -97.1282	15.viii.2018	R.J. Lamb
	WRME	3	Juv.	Winnipeg	49.8456; -97.1282	09.vi.2018	R.J. Lamb
	WRME	2	Juv.	Winnipeg	49.8456; -97.1282	29.vi.2018	R.J. Lamb
	WRME	1	Juv.	Winnipeg	49.8456; -97.1282	06.vii.2018	R.J. Lamb
	WRME	1	Juv.	Winnipeg	49.8456; -97.1282	13.vii.2018	R.J. Lamb
	Observed only		♂	Winnipeg	49.8456; -97.1282	15.viii.2019	R.J. Lamb
Spongiphoridae *Labia minor*	WRME	1	♂	Aweme	49.71; -99.60	28.vi.1909	E. Criddle
	WRME	1	♂	Aweme	49.71; -99.60	11.ix.1909	S. Criddle
	WRME	1	♀	Aweme	49.71; -99.60	18.ix.1910	N. Criddle
	CNC[2]	2		Aweme	49.71; -99.60	09.vii.1914	N. Criddle
	WRME	1	♀	Winnipeg	49.88; -97.17	10.viii.1924	L. H. Roberts
	CNC	5		Aweme	49.71; -99.60	13.viii.1927	N. Criddle
	WRME	1	♂	Aweme	49.71; -99.60	13.ix.1927	N. Criddle
	WRME	1	♀	Morden	49.18; -98.10	05.viii.1965	
	WRME	1	♂	Morden	49.18; -98.10	13.viii.1965	
	WRME	1	♂	Winnipeg	49.88; -97.17	15.viii.1971	W.B. Preston
	WRME	1	♀	Winnipeg	49.87; -97.16	21.x.1973	W.B. Preston
	WRME	1	♂	Winnipeg	49.88; -97.17	15.viii.1982	I. Wylie-Toal
	WRME	1	♂	10 km SE Beausejour	49.96; -96.64	26.ix.1996	T McKay
	WRME	1	♂	Winnipeg, St. Charles Rifle Range	49.91; -97.34	17-22.iv.1998	D.A. Pollock, J.K. Diehl, R.E. Roughley
	WRME	1	♂	St. Adolphe	49.67; -97.11	10.vi.2001	J.M. Le Gal
	WRME	1	♂	St. Adolphe	49.67; -97.11	24.vi.2001	J.M. Le Gal
	WRME	1	♀	Winnipeg	49.87; -97.16	16.viii.2003	W.B. Preston
	WRME	2	♀	Whitemouth	49.955; -95.955	26.viii.2014	R. Loch
	WRME	2	♀	Whitemouth	49.955; -95.955	26.viii.2014	N. Chubey
	WRME	10	5♀, 5♂	Whitemouth	49.956; -95.954	26.viii.2017	ENTM 3180 class
	WRME	8	2♀, 6♂	Whitemouth	49.956; -95.954	25.viii.2018	ENTM 3180 class
Marava arachidis	WRME	8	4♀, 1♂, 3 Juv.	Grunthal	49.427; -96.797	2.ix.2018	D. Geverink

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Submitted Papers

Microscopic examination of *Lygus lineolaris* (Hemiptera: Miridae) feeding injury to different growth stages of navy beans

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Abstract — Light microscopy was used to study feeding injury to navy beans, *Phaseolus vulgaris* L. (Fabaceae), by fifth instar nymphs and unmated newly-moulted adults of *Lygus lineolaris* (Palisot de Beauvois) (Hemiptera: Miridae). Insects were caged on individual racemes of potted plants at different growth stages. From flowering to early pod set, abortion of pods, flowers or buds was the most common response to feeding injury; this type of injury did not occur at later growth stages. During the seed development growth stage, feeding resulted in exterior diffuse discoloured patches on seed pods and associated interior necrosis of the vascular tissues supplying seeds. At harvest, many of the seeds were shrivelled when racemes were fed upon during the seed development growth stage. Direct seed injury, involving penetration of the testa and loss of cotyledon tissue, was occasionally observed during the seed development growth stage, but was the most frequent injury at the developed seed stage. Harvested seeds that were directly injured exhibited crater-like surface pits fringed by brown pigmented areas. There were no observable differences in the type of injury caused by fifth instar nymphs and the adults at any of the growth stages.

Introduction

Mirid bugs in the genus *Lygus* Hahn are major crop pests worldwide (Tingey and Pillemer 1977). In North America, *Lygus lineolaris* (Palisot de Beauvois) (Hemiptera: Miridae) feeds on plants of more than 385 species (Young 1986), among them *Phaseolus vulgaris* L. (Fabaceae), a species that includes green beans with edible pods and dry edible beans (also known as field beans). *Lygus* feed on meristematic tissues and developing reproductive organs of plants (Strong 1970) by inserting their piercing-sucking mouth parts into the tissues and mechanically or enzymatically destroying cell walls and liberating cell contents (Hori 2000; Backus *et al*. 2007). The cell contents are then digested and consumed through cycles of alternating flushing with saliva and ingestion of the resulting fluids (Strong 1970, Miles 1972; Backus *et al*. 2007). Enzymes in *Lygus* saliva include polygalacturonases, α-amylases, proteases and phenoloxidases (Strong and Kruitwagen 1968; Celorio-Mancera *et al*. 2008; Cooper *et al*. 2013).

Injury by *Lygus*, mostly from feeding on reproductive plant tissues, has been studied macroscopically in apple (Michaud *et al*. 1990), buckwheat (Mostafa 2007) and sunflower (Charlet 2003). There have been light microscopic studies of *Lygus* injury to cotton (King and Cook 1932, Williams and Tugwell 2000), sugar beet and rape (Hori 1971), pumpkin (Hori *et al*. 1987), guayule (Addicott and Romney 1950) and wheat (Wise *et al*. 2000), and light and scanning electron microscopy studies of *L. lineolari*s injury to canola (Butts and Lamb 1990), strawberry (Handley and Pollard 1993a, 1993b), and grape vine (Fleury *et al*. 2006). Macroscopic studies of *Lygus* injury to beans of the genus *Phaseolus* (L. (Fabaceae)) have been carried out on lima beans, *P. lunatus* L. (Baker *et al*. 1946; Bushing and Burton 1974; Elmore 1955), and green beans, *P. vulgaris* L. (Khattat and Stewart 1975). There have been no microscopic studies of *Lygus* injury to *Phaseolus*, and no studies of injury to the field bean types of *P. vulgaris*.

The reproductive organs of *P. vulgaris* are compound racemes, arising in the axil of a trifoliate leaf; three flower buds are located in the leaf axil and at each of two to five nodes along the peduncle of the raceme (Adams 1967; Mauk *et al.* 1984; Sage and Webster 1987). Flowering and pod development occur earlier at the base of the raceme (Sage and Webster 1987). In healthy plants, abortion of buds, flowers or young pods, results in far fewer developed pods than the initial number of buds (Tamas *et al*. 1979; Sage and Webster 1987). Pods are modified leaves, and the two halves of the pod are linked by dorsal and ventral sutures, with the dorsal suture corresponding to the leaf midrib (Woodcock 1935). The vascular supply to developing seeds is the placenta, consisting of two vascular bundles running the length of the pod near the ventral suture; each developing seed is connected to the placenta by the vascular tissue of the funiculus (Woodcock 1935). In healthy pods, considerable numbers of seeds fail to develop, and remain flattened and shrivelled (Harris 1915).

Field beans, including navy beans, are an important crop in Manitoba (Manitoba Pulse and Soybean Growers 2015) and there has been concern about the effect of *Lygus* on this crop (Gavloski 2001–2010). It has been reported that 5–20% of field bean seed can be damaged by *Lygus* (Agriculture and Agri-Food Canada 2005), and processors in Manitoba diagnose blemishes on seeds as insect damage. In Manitoba, >90% of mirids in field bean crops belong to the genus *Lygus* and most of these are *L. lineolaris* (Nagalingam and Holliday 2015). The lack of information about how *L. lineolaris* affects reproductive growth and the quality of seed of field beans impairs diagnosis of *Lygus* injury in the field and accurate assessment of the economic significance of these insects in the crop. Therefore, in this study, we used reflective light microscopy to investigate the feeding injury inflicted by fifth instar nymphs and adults of *L. lineolaris* on reproductive organs of navy beans, *P. vulgaris,* at three different growth stages.

Materials and Methods

Studies were carried out in 2009–2010. Determinate bush-type navy beans of the cultivar 'Envoy' were grown from seed in pots (21 cm diameter, 21 cm height) in a controlled environment room at 23 °C, 70% RH and 16:8 h L:D photoperiod. Pots were filled with horticultural potting mix (Sunshine LA4, Sungro Horticulture Distribution, Inc., Agawam, Massachusetts, United States of America). Two seeds were planted in each pot and, when the first trifoliate leaf opened, plants were thinned to one per pot. Seeds had not received treatment with inoculant or pesticides. Pots were watered every second day, and every two weeks received 0.625 g of NPK 20-20-20 fertilizer in 250 ml of water.

A laboratory colony of *L. lineolaris* was established from over-wintered adults collected each spring from alfalfa fields near Carman, Manitoba. The colony was maintained in a controlled environment chamber at 21 °C, 70% RH and 16:8 h L:D on store-bought broccoli and green beans. First to third instar nymphs were maintained on broccoli pieces in 60 mm diameter polystyrene Petri dishes. Older nymphs and adults were kept in perforated plastic tubs (12 cm diameter, 15 cm height; Bug Tub® (Royal Oak Point NW, Calgary, Alberta, Canada) and provided with green bean (*P. vulgaris*) pods as food and oviposition substrate. Adults were confined with bean pods for 5 days, and then the pods were transferred to 145 mm diameter polystyrene Petri dishes. Thereafter, for one week, the Petri dishes containing the pods were inspected every second day and nymphs that hatched were transferred with a paint brush to the small Petri dishes used for rearing early instar nymphs. The colony was re-established each year to ensure colony vigour.

Injury treatments were made by caging reproductive structures of potted navy bean plants growing in the controlled environment room. Treatments lasted for 5 days during which cages contained either *L. lineolaris* fifth instar nymphs, adults or no insects (controls). Cages (Fig. 1) were fabric sleeve (12 cm diameter, 30 cm long) of 40 thread/cm mesh tergal netting (Fabricland, Winnipeg, Manitoba, Canada) on a wire ring frame. Each cage was supported by attaching it to a wire tomato support frame, the base of which was pushed into the soil of the pot. A single raceme and its subtending trifoliate leaf were inserted into the sleeve cage and the proximal end of the sleeve was secured around the plant stem with a twist tie. The distal end was tightly secured with an elastic band. Both twist ties and elastic bands were covered with adhesive tape to prevent them being dislodged. Insects introduced into infested cages were either fifth instar nymphs within 1 day of moulting from the previous instar, or adults that had completed their final moult within the previous 1–2 days. To avoid injury from oviposition or feeding by young nymphs during the five-day exposure, adults were isolated from the colony as fifth instar nymphs and not allowed to mate; sex of adults was not determined. Injury treatments were made at three plant growth stages (Brown *et al.* 2017), stages present when *L.*

Figure 1. Sleeve cage enclosing raceme of a potted navy bean plant.

lineolaris occurs in navy bean fields in Manitoba (Nagalingam and Holliday 2015), and the number of insects used at each growth stage was chosen to produce injury but not complete destruction of caged plant parts. At growth stages R2–R3 (flowering to early pod set), one nymph or one adult *L. lineolaris* was introduced into each infested cage; there were five replicates of each treatment and of the control. At R4–R5 (mid pod set to early seed fill) three nymphs or three adults were introduced; the treatments and control were replicated six times. At R6–R7 (mid seed fill to early pod maturity) five nymphs or five adults were introduced, and there were three replicates of each treatment and the control.

After the five-day exposure, the insects and cage were removed, and the raceme was detached from the plant and examined under a Leica MS5 stereomicroscope (magnification range 12.6 to 80). Injured plant parts were compared with uninjured parts from control cages, and representative injuries were photographed using a Nikon D5200 digital camera attached to an Olympus SZX16 light microscope. In addition to examination of racemes immediately after exposure to insects, some plants were grown until the stage of commercial seed harvest, and seeds from the previously-caged racemes were examined microscopically as described above.

Results

The use of unmated adults to prevent oviposition injury was successful as there were no eggs or young nymphs seen when sleeve cages were dismantled. Only feeding injuries were evident at the end of the five-day treatment period.

In growth stages R2–R3, buds, flowers and small pods are present (Brown *et al.* 2017). At the end of the five-day exposure, injuries to pods caused by feeding of either adults and nymphs were characterized by brown spots, about 1 mm in diameter, centred at the feeding puncture (Fig. 2A). In some cases, the exterior surface of injured pods was irregular because of swelling at feeding sites (Fig. 2B). In other cases, “split lesions” (Painter 1930) in the epidermis occurred at feeding sites (Figs. 2C–E). Split lesions on the peduncle were found mainly in internode regions but usually close to a node, and often resulted in constriction or breakage (Fig. 2D). On pods, split lesions were elongated areas of torn epidermal tissue (Fig. 2E). The most frequent response to feeding injury during the R2–R3 growth stages was abortion of buds, flowers, and pods (Fig. 2F). This abortion injury was readily distinguishable from stem breakage at a feeding site. Abortions occurred in uninfested controls, but were more frequent when racemes were caged with *Lygus*. *Lygus*-induced abortion of pods was associated with brown necrotic lesions inside the pod (Fig 2G). Injuries caused by feeding by nymphs (Figs. 2A–C, G) showed no observable differences from those resulting from adult feeding (Figs. 2D–F).

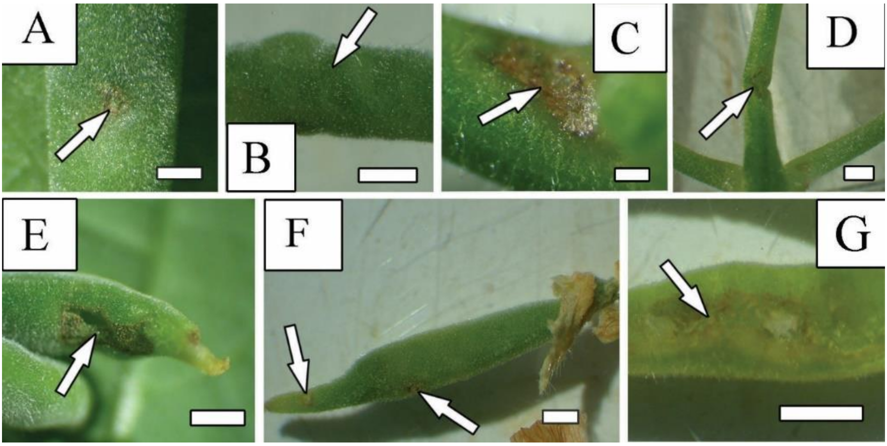

Figure 2. Injuries caused by *Lygus lineolaris* during feeding on the R2–R3 growth stages of navy beans; scale bars = 1 mm. (A) Necrotic spot (arrow) on pod surface at the site of nymphal feeding; (B) pod showing swellings (arrow) at sites of nymphal feeding; (C) discoloured area and split lesion (arrow) on peduncle of the raceme resulting from nymphal feeding; (D) split lesion (arrow) on peduncle following adult feeding; (E) split lesion (arrow) on pod following feeding by an adult; (F) pod aborted following feeding by an adult showing location of feeding sites (arrows); (G) aborted bean pod sectioned longitudinally to show inner discolouration following nymphal feeding.

In the R4–R5 growth stages, pods contained seeds that ranged in stage from just initiated to fully developed. At the end of the five-day exposure, external pod injury in the R4–R5 growth stage took the form of indistinct brownish areas, which were mainly near the ventral suture (Fig. 3A). Stylet entry points near the ventral suture were associated with brown necrotic lesions in the placental region of the seed pod (Fig. 3B); frequently this necrosis also involved the funiculus supplying the developing seed (Fig. 3C). Neither adults nor nymphs showed any preference for specific seed positions within the pod when funiculus injuries were evaluated immediately after exposure to insects.

Direct injury to developing seeds was also observed in the R4–R5 stages, and affected 3% of developing seeds exposed to feeding by three nymphs per raceme, and 7% of seeds

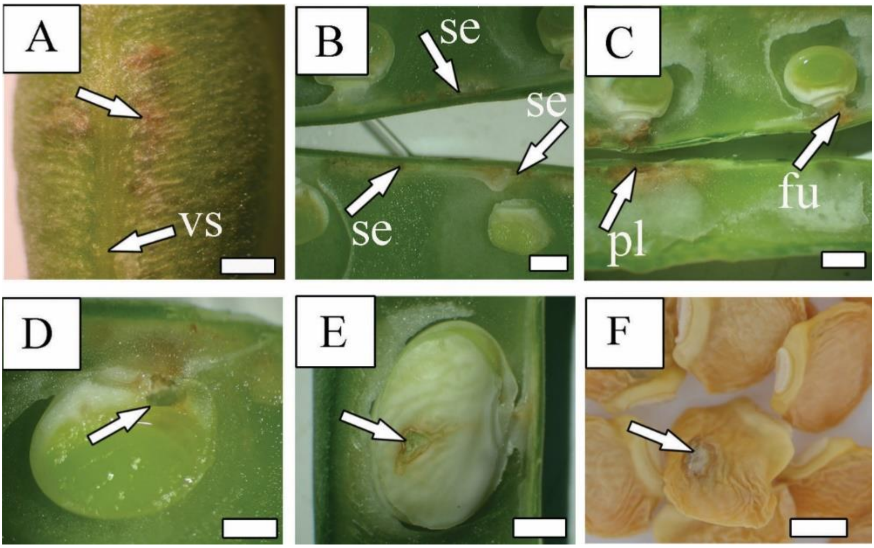

Figure 3. Injuries caused by *Lygus lineolaris* during feeding on the R4–R5 growth stages of navy beans; scale bars = 1 mm. (A) External discolouration (arrow) near the ventral suture (vs) following nymphal feeding; (B) longitudinal section of a pod showing necrosis of the placental region (brown discolouration) and stylet entry points (se) following nymphal feeding; (C) necrosis of the placental region (pl) and funiculus (fu) regions following adult feeding; (D) direct seed injury (arrow) from adult feeding, that penetrated through the testa into the cotyledon of a young developing seed; (E) direct seed injury (arrow) to an older developing seed following nymphal feeding; (F) shrivelled seeds at harvest maturity, one of which has a scar (arrow) from direct seed injury, following feeding injury by nymphs at the R4–R5 stage.

exposed to three adults per raceme. In direct seed injury, the testa was penetrated and a cavity was evident in the underlying cotyledon (Fig. 3D). In the early stages of seed development, there was little change in pigmentation, but in older seeds, the testa bordering the injury became brown (Fig. 3E). Unlike earlier growth stages, no pod abortion resulted from feeding in the R4–R5 stage. Like earlier stages, the nature of injury in response to feeding by nymphs (Figs. 3A, B, E) and adults (Figs. 3C, D) did not differ.

When seeds from the R4–R5 treatments were examined at the time of seed harvest, many of them were shrivelled (Fig. 3F). The majority of shrivelled seeds showed no signs of direct injury, but some shrivelled seeds did have scars indicating that they had been directly injured. Exposure to nymphs resulted in 94% of seeds being shrivelled at harvest, compared with 70% of seeds in the adult treatment and 37% in controls.

At the R6–R7 stages, bean pods contain fully developed and filling seeds (Brown *et al.* 2017). At the end of the five-day exposure, most injury at these stages was direct injury to the seed, and this did not appear to be fundamentally different from the seed injury in the R4–R5 stage. Exposure to five nymphs per raceme resulted in 37% of seeds being directly injured, whereas 26% of seeds exhibited direct injury when exposed to five adults per raceme. Injury at the R6–R7 stages was more visible because, in more mature seeds, there was greater pigmentation of the testa bordering the injury site (Fig. 4A). The injury was not localized on any particular part of the seed, and more than one injury on a seed was frequently observed. At the site of feeding, the testa was perforated and there was a cavity in the tissues of the cotyledon (Fig. 4B). In most cases, stylets were inserted through the pod wall and the feeding site on the seed was close to the pod penetration point (Fig. 4C); pod penetration points included the dorsal and ventral sutures and sides of the pod. When seeds injured during the R6–R7 growth stages were examined at the normal time of harvest, lesions were crater-like pits and frequently had surrounding concentric raised brown ridges (Fig. 4D), No pod abortion was observed at the R6–R7 growth stages, and no differences were observed between the type of injury from nymphs (Fig. 4B, C, D) and adults (Fig. 4A).

Discussion

The cultivar 'Envoy' was used in this study because the uniformly white seed coat facilitates detection of injury to the seed: the cultivar is the check cultivar with which the performance of other cultivars is compared in Manitoba variety trials. We chose the five-day duration for feeding injury treatments to provide the maximum duration of exposure to a specific insect stage, without transition to a following stage. At the end of the injury treatment at the temperatures of this study, the fifth instar nymphs would be almost ready to moult to adults, and female *L. lineolaris* would be about to begin oviposition (Bariola 1969; Ugine 2012). It is unwise to assume that our results apply to all ages of nymphs and adult *L. lineolaris* as, in *Lygus hesperus* (Knight), feeding behaviour is dependent on nymphal instar (Cooper and Spurgeon 2013) and reproductive status of adults (Cooper and Spurgeon 2011).

In this study, brown discoloured lesions were found both externally and internally in navy bean reproductive organs, regardless of growth stage. The exterior 1 mm diameter brown spots we observed appeared to surround individual stylet penetration points, whereas diffuse brown areas on the surface of pods, were probably the result of multiple low-volume injections of saliva, as described for *L. hesperus* (Backus *et al*. 2007). Brown colouration was also evident at interior feeding locations, including the sites of placental and funiculus injury. Hori (2000) suggested that oxidation of phenols by phenoloxidases

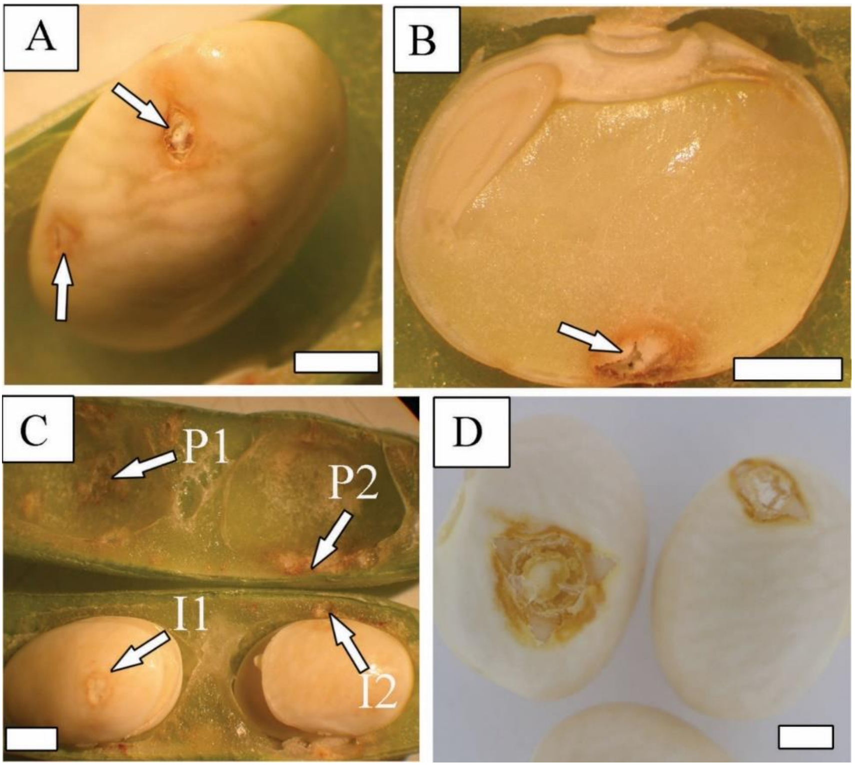

Figure 4. Injuries caused by *Lygus lineolaris* during feeding on the R6–R7 growth stages of navy beans; scale bars = 1mm. (A) Direct injury to seed (arrows) following adult feeding; (B) longitudinal section of a seed showing injury to cotyledon (arrow) following nymphal feeding; (C) corresponding halves of pod joined at the dorsal suture, showing pod penetrations points (P1 and P2) and corresponding seed injury sites (I1 and I2) following nymphal feeding; (D) seed pits on mature harvested seeds following nymphal feeding at the R6–R7 growth stages.

is responsible for the brown-pigmentation following feeding by Heteroptera. In plants, activation of the phenol-phenoloxidase system is a general response to wounding, and so the brown pigmentation could be the plant's response to cellular destruction by the stylets or saliva of *Lygus* (Hori 2000), or be the result of the phenoloxidases that are minor components of *Lygus* saliva (Cooper *et al*. 2013).

Tissue swelling and split lesions resulted from *Lygus* feeding in the R2–R3 stage. Split lesions on stems are characteristic injuries from *Lygus* feeding on cotton (King and Cook 1932), poplar (Sapio *et al*. 1982) and Douglas-fir (Schowalter *et al.* 1986). Swellings are the result of cell hypertrophy, and interior swelling may strain the epidermis sufficiently to cause it to split (Painter 1930; King and Cook 1932). The hypertrophy probably results from disruption of the plant's hormonal system by *Lygus* feeding (Tingey and Pillemer 1977; Hori 2000), as there is no evidence that *Lygus* saliva contains plant hormones (Strong 1970).

Abortion of reproductive structures in response to *Lygus* feeding has been reported in several leguminous crops including alfalfa (Sorensen 1939), soybeans (Broersma and Luckmann 1970), Lima beans (Baker *et al*. 1946), snap beans (Fisher *et al.* 1946), and green beans (Khattat and Stewart 1975). In our study, abortion of reproductive organs occurred only at the R2–R3 growth stages, and in soybeans, Lima beans and green beans there is a similar restriction to early stages of raceme development (Baker *et al*. 1946; Broersma and Luckmann 1970; Khattat and Stewart 1975).

Abscission resulting in abortion may be a response to reduced flow of auxins from the pod (Osborne 1989; Ofir *et al.* 1993), or be a response to reduced photosynthate sink activity of the pod (Binnie and Clifford 1999). We observed that in cages with insects, aborted pods had internal lesions. Such lesions could, as hypothesized by Strong (1970) and Tingey and Pillemer (1977), lower the levels of auxins released by the pods, but could also reduce the pod's sink activity. In either mechanism, *Lygus* feeding is interfering with the normal regulation of abscission in the raceme, a process that occurs only during a critical period within 5 days of anthesis (Sage and Webster 1987). Our finding that pod abortion did not occur in later growth stages supports the hypothesis that the elevated levels of abortion were not a direct response to *Lygus* feeding, but rather a consequence of that feeding modifying the plant's normal system of regulation of abscission during the critical period.

Necrosis of the vascular tissues in the placental and funiculus regions in pods at the R4–R5 stage occurred only in cages with *Lygus*. Developing seeds within pods receive minerals and photosynthates through these vascular tissues, and shortage of these resources results in abortion and collapse of fertilized ovules (Adams 1967). Hence, injury to the vascular tissues supplying nutrients is the most likely cause of shrivelling of seeds, which was very frequent at pod maturity when *Lygus* feeding had occurred at the R4–R5 stages. Seed shrivelling in response to *Lygus* feeding also occurs in Lima beans, *P. lunatus* (Baker *et al.* 1946). In *P. vulgaris*, shrivelling of seed is a normal phenomenon in healthy pods, where the frequency of undeveloped seeds may exceed 90% for the basal seed position in the pod and be 10–30% in more distal positions (Harris 1915; Nakamura 1988).

Direct injury to seeds was prevalent in the R6–R7 stages and infrequent at the R4–R5 stages. The central pit of the lesions is likely to be the result of physical and enzymatic destruction of the cells of the testa and underlying cotyledon; the surrounding pigmentation probably arises from the oxidation of phenols through the plant's wound response (Hori 2000) or by salivary enzymes (Cooper *et al.* 2013). Such blemishes on seeds could make beans unsuitable for canning (United States Department of Agriculture 2001); ≥1% of blemished seed in a sample for grading results in grade reduction in Canada (Canadian Grain Commission 2019). Similar seed pitting occurs in Lima bean when *Lygus* feed on developing seeds (Baker *et al.* 1946; Elmore 1955).

Field diagnosis of *Lygus* injury and implications for economic loss

This study has identified the symptoms of *Lygus* injury to navy bean racemes that are observable within a few days of that injury occurring. Knowledge of these symptoms can allow for more accurate diagnosis of *Lygus* injury during field scouting in field beans. However, the presence of *Lygus* or of the injury they have caused does not necessarily predict economic loss.

Early in the growing season, *Lygus* adults are detectable in low numbers in field beans at growth stages up to R3 (Nagalingam and Holliday 2015). Although *Lygus* feeding induces abscission of reproductive structures at these growth stages, detached buds, flowers or small pods are not diagnostic of *Lygus* injury because of the prevalence of abscission of reproductive structures in healthy plants. Reliable signs of *Lygus* injury up to the R3 growth stage include brown pigmented feeding spots and associated tissue swelling or split lesions. However, it is not clear whether *Lygus* injury at these early growth stages causes economic loss. Plants of *P. vulgaris* respond to removal of early flowers by setting pods from later flowers (Binnie and Clifford 1981) and respond to removal of early pods by reduced frequency of abortion of later-developing pods (Tamas *et al.* 1979). Thus, the plant may compensate partially or completely for loss of some reproductive structures due to *Lygus* injury.

Following the arrival of *Lygus* adults, a generation of nymphs develops in field beans but, probably because of low sampling efficiency, only low numbers are detected in sweep net samples during the R4–R5 growth stages (Nagalingam and Holliday 2015). At these growth stages, funiculus and placental injury are characteristic, and external examination of developing pods for discolouration near the ventral suture, followed by internal examination for brown lesions near the vascular tissues, provides a reliable indicator of *Lygus* injury. The resulting shrivelling of seed is not definitive because many seeds fail to fill in the absence of *Lygus* (Harris 1915). Plants may compensate for *Lygus*-induced seed shrivelling. Seed filling occurs within an environment regulated by nutrient competition (Adams 1967) and a relatively high proportion of seeds fail to fill (Harris 1915; Nakamura 1988); *Lygus*-induced removal of some seeds from the competition could allow filling of unaffected seeds that would otherwise fail to fill. It is difficult to assess whether *Lygus*-induced seed shrivelling increases the proportion of shrivelled seed at harvest, as shrivelled seed is likely to be under-represented in harvested samples following threshing and cleaning.

Late in the growing season, there are peaks of sweep net catches of nymphs and adults that occur at R6–R7 (Nagalingam and Holliday 2015). At these growth stages, pods with exterior penetration points and containing seeds with direct injury to the testa are diagnostic for *Lygus* feeding. Reduced grade of seeds because of seed pitting is likely to lead to economic loss for bean producers. Retrospective assessments of *Lygus* injury based on harvested seed can clearly show evidence of direct *Lygus* injury to seeds, which produces seed pits.

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STUDIES IN THE BIOLOGY OF NORTH AMERICAN ACRIDIDAE DEVELOPMENT AND HABITS

Norman Criddle

PREAMBLE TO PUBLICATION OF THE ORIGINAL MANUSCRIPT

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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, ALKALlNE 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 acrididians 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*] *confusus* 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.

75th Annual Meeting ENTOMOLOGICAL SOCIETY OF MANITOBA, Inc.

October 25, 2019
Dept. Biological Sciences, 201 Biological Sciences Building
50 Sifton Road
University of Manitoba
Winnipeg, Manitoba

and

October 26, 2019
Department of Entomology Rm 219
12 Dafoe Rd., University of Manitoba
Winnipeg, Manitoba

Abstracts

KEYNOTE ADDRESS

INSECT BEHAVIOUR: A CONTEXTUAL JOURNEY.

Bernard D. Roitberg, Biological Sciences, Simon Fraser University, Burnaby, BC, V5A 1S6.

I will provide a brief introduction to behaviour, in the broad sense (my definition does not require movement). I will then discuss the evolution of labile traits, focusing on behavioural traits. I will argue that the ability to predict the expression of such traits (e.g. aggression), in order to understand how such traits evolve, depends upon the context (e.g. hunger state) in which they are expressed. I will use some examples from our work ((i)

defence of nests by bees, (ii) willingness to oviposit on poor quality hosts by parasitoids and (iii) the evolution of diet breadth in community context) and others, to make my point. I will also demonstrate, using examples, how theoretical constructs (mathematical models) provide great tools for explicitly including context to make predictions. I will focus more on concepts than details.

SYMPOSIUM

Insects Behave!

HOW ECOLOGY OF THE LANDSCAPE SHAPES BLOOD-FEEDING BEHAVIOUR PATTERNS OF MOSQUITOES.

Robert Anderson, Department of Biology, University of Winnipeg, Winnipeg, Manitoba, R3B 2E9.

Blood is a very nearly-perfect nutritional resource for those insects that are adapted to acquire it because of the high quality protein, salts, water and other components of metabolic utility. Mosquito species are often classified as host specialists, which makes them particularly important as vectors of blood pathogens with narrow host possibilities. Some mosquito species are truly selective about the blood sources they exploit with respect to sensory response to particular host cues but other species arrive at an apparently narrow blood host range as a result of host availability and opportunity to feed. Differing opportunities due to changes in blood host species in the immediate vicinity can produce apparently anomalous results. Several Manitoba species of mosquitoes with different proclivities for host specialization will be reviewed with respect to published, blood-feeding data since 1980 and the respective roles they play in pathogen transmission cycles.

THE NEEDLE IN THE HAYSTACK: SEARCHING FOR SPERM COMPETITION GENES.

A. Civetta, Department of Biology, University of Winnipeg, Winnipeg, Manitoba, Canada, R3B 2E9.

The elaborate traits used by males to attract females during mating behaviour rituals or to outcompete other males for access to copulation have long been known as examples of sexual selection. More recently, sperm competition has become recognized as a form of postcopulatory sexual selection that can influence the evolution of primary sexual traits, sperm cells, and sex-related genes. Some details about mechanisms of sperm competition have been disentangled using approaches such as sperm tracking and *in vitro* manipulations of sperm and accessory glands fluids. However, we still lack a precise knowledge about the underlying genetics that influences sperm competitive ability. This limits our knowledge of molecular characteristics or processes, such as tissue of expression, gene networks and pleiotropism, and biochemical attributes, that might be relevant to sperm competition. Equally important, knowing the identity of the genes involved will result in a better understanding of how sperm competition might contribute to the speciation process and to gain valuable insights in the evolutionary dynamics of differential sperm competitive ability. Classical genetic approaches have encountered difficulties in identifying gene loci influencing sperm competitiveness. Despite the clearly polygenic basis underlying the phenotype, gene variant association studies have identified some interesting candidate genes. With advances in *in vitro* tracking and manipulations, and the use of approaches that incorporate gene perturbation, I propose that we are better positioned to identify genes linked to sperm competitiveness and to incorporate detail phenotypic characterization that will improve gene functional annotations.

SOCIAL IMMUNITY: BREEDING FOR BEHAVIOURAL MECHANISMS TO COMBAT PARASITES AND PATHOGENS IN HONEY BEES.

R. W. Currie[1] and BeeOmics Consortium[2]. [1]Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2; [2]York University, Universities of British Columbia, Alberta, Manitoba, Laval, Vancouver, Canada.

Honey bees are eusocial insects with large colony populations that make them susceptible to a wide range of parasites and pathogens. One of the more economically serious parasites is the mite, *Varroa destructor*, that feeds on both immature and adult bees workers. To help deal with these mites, bees utilize “social immunity” that involves either a sequence of hygienic behaviours that allow them to detect and remove brood infected with mites or self- and group-grooming behaviours to remove mites from adult bees. The mechanisms through which bees perceive and react to these parasites at the individual and colony level using these behavioural mechanisms will be discussed in this seminar.

HOW DO WE PROTECT AND MANAGE AN ENDANDERED INSECT WITH LITTLE KNOWLEDGE OF ITS BEHAVIOUR AND BIOLOGY?

Richard Westwood, Department of Biology, University of Winnipeg, Manitoba, R3B 2E9, Canada.

The Poweshiek skipperling (PS) (*Oarisma poweshiek*) is a critically endangered grassland butterfly with less than ~200 individuals remaining in Canada and the United States. PS was a locally common butterfly distributed widely in the north central United States and southern Manitoba up until the early 2000's when the first warnings of its rapid population decline became evident. While common in collections over the last 130 years little was known about its biology and behaviour and it had never been reared in captivity. The speed of its demise has prompted an international group of researchers and conservation managers to take action to save the species. Beginning in 2005 a step wise program was implemented for the Canadian population to better understand PS biology and ecology, habitat requirements and the impact of management activities on its long term survival. A similar program was established for the lone remaining population in Michigan. A series of studies in Canada have provided us with considerable information to help address the impending extirpation of PS. The need to learn about and understand important biological and behavoural characteristics of this species is now critical to conserving the only two populations left in the world. The progress of the biological and ecology research conducted in Canada is presented and the requirements for future research are discussed.

SUBMITTED PAPERS

DOES LANDSCAPE STRUCTURE INFLUENCE PREDATION ON CEREAL LEAF BEETLE IN WHEAT FIELDS?

Alejandro C Costamagna[1], Arash Kheirodin[1,2], Héctor A. Cárcamo[2] and Barbara Sharanowski[3]. [1]Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2, [2]Agriculture and Agri-Food Canada, Lethbridge Research Centre, Lethbridge, Alberta, Canada, T1J 4B1, and [3]Department of Biology, University of Central Florida, Orlando, Florida, USA, 32816.

The cereal leaf beetle (CLB) is an invasive pest expanding its range in the Canadian Prairies. *Tetrastichus julis* (Hymenoptera: Eulophidae), a specialist parasitoid, was introduced from Europe in the USA and is being relocated throughout the Canadian Prairies. Most research has focused on this parasitoid and there is little knowledge on the impacts of generalist predators on CLB. In this study, we assessed the role of landscape complexity in predation levels on immatures stages of CLB in Alberta. Early in the season, we assessed predation using sentinel CLB egg cards in 18 wheat fields in May 2014 and 2015. Later in the season (when CLB larvae is the dominant stage), we assessed predation on CLB by collecting generalist predators in 26 wheat fields during July 2014 and 2015 and conducting molecular gut content analysis to detect CLB DNA using newly developed DNA primers. Fields were located within a wide range of agricultural landscapes characterized based on the percentage of the seminatural habitats (including pasture, native and cultivated grassland, and riparian vegetation) and percentage of cultivated area in proximity to the fields sampled. Egg predation increased with proportion of wooded areas, alfalfa, canola, and non-cereal crops, but decreased with habitat and crop diversity. Percentage of predators positive for CLB DNA increased with CLB abundance and proportion of canola in the landscape, but decreased with habitat diversity, proportion of pasture and non-cereal crops. These results show significant, but site-dependent landscape impacts of predation on CLB.

INTERACTIONS BETWEEN EXOTIC AND NATIVE LADY BEETLE SPECIES STABILIZE COMMUNITY ABUNDANCE.

Robert J. Lamb, Jordan A. Bannerman, and Alejandro C. Costamagna, Department of Entomology, University of Manitoba, Winnipeg, Canada, R3T 2N2.

A 23-year time-series of abundance for a community of 13 lady beetle species (Coccinellidae) was used to investigate factors that affect community stability. The community exhibited remarkable stability: no overall trend in abundance was detected; temporal variability was low. Population Variability (PV) = 0.33 on a scale from 0 to 1, and declined to 0.16 in the last 8 years. This high level of stability occurred at the same time as exotic lady beetles invaded and disrupted the stability of native species. PV for hypothetical communities of pairs of lady beetle species (with randomly generated annual abundances within the naturally observed range) increased linearly with the correlation coefficients between individual populations, illustrating a “portfolio effect”. PV for the real community and negative correlation between the abundance of exotics and natives fit this linear relationship precisely, although in this case the correlation coefficient reflected competition and resurgence by natives when exotic populations declined. The three most abundant species, and negative correlations in their abundance, explained much of the low population variability. Stability of the dominant species, an exotic, increased over 23 years, stabilizing the community over time. Competition between exotic and native lady beetles stabilized the abundance of this community, but the effect may not last if populations of native species continue to decline.

SEASONAL AND DIURNAL PATTERNS OF PREDATION IN COLONIES OF A NATIVE APHID.

Patricia A. MacKay and Robert J. Lamb, Department of Entomology, University of Manitoba, Winnipeg, Canada, R3T 2N2.

Data are presented for several years of abundance, prevalence and mean intensity of the aphid *Uroleucon rudbeckiae* on *Rudbeckia laciniata* in Manitoba, and for 10 years of data on the natural enemies attacking this species. Sampling was entirely non-destructive with photographic confirmation of predation. Predators were not usually identified to species, but classified into eight higher taxonomic groups, most containing several species. Listed from highest to lowest frequency, they were: parasitoids, hover flies, spiders, midges, lacewings, lady beetles, mites, and true bugs. For the months of June, July, August and September, the prevalence of predation was similar, as was the mean number of taxa in the colonies. Parasitism peaked in mid-season. Spiders were equally abundant throughout the sampling period. Hover flies and midges were most common in the first half of the sampling period. Lady beetles and lacewings occurred primarily in June and September. Based on twice-daily assessments, predation events occurred equally during the day and night. There were no significant differences among months, however the trend in number of larvae and adults predated during the day increased from June to August before declining in September, while nocturnal predation was uniform throughout the sampling period. The presence of exclusively nocturnal predators was not documented, although, if present, exclusively nocturnal predators replaced rather than adding to the impact of predators observed during the day. These data will be used to assess the importance of predation in determining the stability of aphid population dynamics.

STATUS AND BEHAVIOUR OF ENDANGERED MOTTLED DUSKYWING (*ERYNNIS MARTIALIS*) IN MANITOBA.

Justis Henault and Richard Westwood, Department of Biology, University of Winnipeg, Winnipeg, Manitoba, Canada, R3B 2E9.

There have been several historic surveys with descriptions of potential suitable habitat in southeastern Manitoba for the endangered Mottled Duskywing (*Erynnis martialis*) to determine its status in this province. Our objectives were to assess the current size of the population in Manitoba, provide a more detailed understanding of critical habitat for this species, to document the immature stages of Mottled Duskywing, determine host plants and the flight season. We developed descriptions of preferred habitat, located host plants and documented reliance on specific critical habitat provided by commercial forestry management activities. Jack pine forests located on sandy beach ridges with the host plant New Jersey Tea (*Ceanothus americanus*) provide suitable habitat for the butterfly in Manitoba. We found Mottled Duskywing was present in a few historic locations and new locations in Sandilands Provincial Forest but was not observed in Northwest Angle Provincial Forest or Whiteshell Provincial Park. This research increases our understanding of the ecology of this butterfly in Manitoba and provides guidance on future management activities.

DO CONSPECIFIC DAMAGE-RELEASED ALARM CUES AFFECT THE CASE CONSTRUCTION BEHAVIOUR OF CADDISFLY, *LIMNEPHILUS SP.*, (TRICHOPTERA: LIMNEPHILIDAE) LARVAE?

M. O. Ajiboye[1], D. P. Chivers[1], and M. C. O. Ferrari[2], [1]Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, S7N 5E2. [2]Department of Biomedical Sciences, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, S7N 5B4.

Defense against predation is essential for the survival of prey. The portable case of an actively foraging caddisfly larva is generally agreed to have evolved as a defense against predators. Larvae of many caddisfly species use various materials present in their environment to construct transportable cases using self-secreted silk to bind them together. Aquatic prey use chemical cues to detect their predators. Caddisfly larvae inhabit most freshwater habitats, and caddisfly larvae are able produce and perceive chemical cues that affect their case construction behaviour. We examined the case construction behaviour of caddisfly larvae, *Limnephilus* sp., in response to conspecific damage-released alarm cues. Exposure to alarm cues elicited no effect on the case construction behaviour of *Limnephilus* sp. larvae. There was no significant difference between the construction time, length of the cases, number of sticks added to the case, number of stones used in constructing the case, and the mass of the cases when compared to the control group. Conspecific, damage-released alarm cues, although predator-related chemical cues, are not strong enough to affect the case construction behaviour of *Limnephilus* sp. larvae.

USING CONFIRMATORY PATH ANALYSIS TO UNRAVEL THE PATHS BETWEEN LANDSCAPE, PREDATORS AND SOYBEAN APHIDS.

C. Almdal and A. C. Costamagna, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2.

Aphis glycines Matsumura (Hemiptera: Aphididae) is an invasive species and major pest of soybean in North America. Determining the impact of surrounding landscape on aphidophagous predators and aphid suppression are important steps towards finding preventative measures for the control of *Aphis glycines* in the future. Previous work has demonstrated that a higher proportion of cereals and a lower proportion of canola in the landscape contribute to *Aphis glycines* suppression during low aphid years in Manitoba. The objective of this study was to determine the impact of landscape composition and configuration on aphidophagous predators and aphids in soybean. Predator exclusion experiments were set up in 23 soybean fields for a period of 2 weeks in July–August 2017 (12) and 2018 (11), to determine the level of aphid suppression with varying landscape compositions and configurations. Aphid counts were conducted weekly on experimental and field plants. Generalist predators were collected weekly by sweep net sampling. Bi-directional malaise traps were set up between soybean and the neighboring habitat (canola, wheat, alfalfa, or woody vegetation) to quantify predator movement between fields. Habitats within a 2 km radius from the focal soybean field were mapped. We predicted landscapes with higher diversity and edge density will promote predator abundances and greater aphid suppression. Confirmatory path analysis was used to determine the importance of different landscape parameters on predator abundances and aphid suppression, and to determine the link between predator abundance and aphid population size.

TOWARD A BETTER UNDERSTANDING OF THE MEXICAN *LASIOGLOSSUM* (*DIALICTUS*): FIRST LOOK AT SOME NEW TAXA.

Joel Gardner[1], Jason Gibbs[2], and Michael Branstetter[2], [1]Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2, [2]USDA-ARS-PWA Pollinating Insect-Biology, Management, Systematics Research, Department of Biology, Utah State University, Logan, Utah, USA, 84322.

The Mexican *Lasioglossum* (*Dialictus*) fauna is sorely understudied and in need of revision. Of the 302 currently recognized species of *Dialictus* in mainland North and

Central America, only 31 are recorded from Mexico, most of which were described from the United States and since discovered south of the border. To help fill this knowledge gap, a revision of the *Dialictus* of western North America is underway, including Canada, the United States, and Nearctic Mexico. Selected provisional new species and new records are presented, and the designation of a new subgenus is suggested based on a preliminary new phylogeny.

THE BEES' NEEDS: ARE HUMAN-INDUCED LANDSCAPE DISTURBANCES IMPACTING WILD BEE DIVERSITY IN SOUTHERN MANITOBA?

Emily J. Hanuschuk and Jason Gibbs, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2.

Wild bee diversity and the effects of anthropogenic landscape disturbances on bee communities remains poorly understood in southern Manitoba. This study aims to quantify the effect of disturbance on wild bee abundance, richness and diversity using a statistical modeling approach. Bees were collected passively at 32 sites of varying disturbance intensities using blue vane traps and coloured bee bowls, and additionally actively collected using air nets at half of these sites, between May and August, 2018. A sample size of 10 443 bees was obtained. Preliminary results will be presented. This study is being conducted in collaboration with Agriculture and Agri-Food Canada as part of a larger ongoing study on native pollinator potential in Manitoba.

ADULT STABLE FLY (*STOMOXYS CALCITRANS,* L.) PHENOLOGY AND POPULATION DYNAMICS ON SOUTHERN MANITOBA DAIRY FARMS.

Gina Karam and Kateryn Rochon, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2.

The stable fly (*Stomoxys calcitrans,* L.) is one of the most important livestock pests in North America. Fly bites are painful and host energy is diverted to avoidance behaviours, reducing weight gain and decreasing milk yields in dairy cattle. Environmental conditions such as temperature, precipitation and substrate suitability vary throughout fly season, which affects emergence and reproduction. Six Coroplast® sticky traps were deployed weekly at three dairy farms from 17 June to 21 October in 2017 (n=53,540 flies) and May 23 to October 3 in 2018 (n=42,585). In 2017, stable flies were first trapped on June 17 and population distribution was unimodal with the highest population recorded between July 14-27. In 2018, stable flies were first captured on June 6 and population distribution was bimodal with peaks in July 24-August 2 and August 30-September 6. The sex ratio

was determined and used to uncover trap biases, and changes over time. Females from sticky traps were dissected to examine ovarian development (stage 0-4, uniparous and multiparous), which was used to determine changes in age structure over the season. Relationships between adult abundance and environmental conditions over time were analyzed using multiple linear regression models and ANOVA, revealing relative humidity, maximum air temperature, or soil temperature as the strongest predictors of fly abundance, but the parameters changed between years. Few studies on stable fly biology have occurred in in Manitoba. Understanding stable fly population dynamics provides critical information on phenology, and can help predict outbreaks and lead to strategic management plans.

INFLUENCE OF MANAGEMENT STRATEGY ON WILD BEES IN THE TALL GRASS PRAIRIE ECOSYSTEM.

Reid Miller, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2.

The tall grass prairie (TGP) ecosystem occupies less than 0.05% of its former range in Manitoba. Current management strategies designed to mimic historical disturbances include prescribed fires and cattle grazing. The effects that these strategies have on invertebrate communities that depend on TGP, along with the associated ecological functions that they provide, are insufficiently studied. For my study, the diversity and abundance of insect pollinators was analysed to elucidate the effects that current management policies are having on these beneficial insects in the TGP ecosystem. To study the effect that fire and grazing are having on the diversity and abundance of pollinators in a TGP ecosystem, sites were chosen representing three treatments: 1) burned 2) grazed, and 3) no disturbance. Native bees were captured using bee bowls and blue vane traps. Here I report on my bee data, my landscape characteristic data, and announce several new exciting finds in the beetle side of my project.

MANAGING DUTCH ELM DISEASE: PRIORITIZED REMOVAL OF INFECTED AMERICAN ELM TREES.

Matthew Russell and Richard Westwood, Department of Biology, University of Winnipeg, Manitoba, Canada, R3B 2E9.

The introduction of Dutch elm disease (DED), *Ophiostoma novo-ulmi*, to Manitoba in 1975 has resulted in provincial legislation and control programs that have until recently limited American elm tree loss to approximately 2.5% per year. However, recently DED incidence has increased and began surpassing the financial resources of the City of Winnipeg to manage the disease adequately. Preliminary research has suggested that a large proportion of the disease vector, the Native Elm Bark Beetle (NEBB, *Hylurgopinus rufipes*), may be contained within relatively few trees in city neighbourhoods. Prioritized removal of infected trees containing high NEBB densities prior to beetle emergence from diseased trees could remove a significant proportion of the vector population transmitting DED to healthy trees. We examined methods to identify American elm trees on Winnipeg boulevards with high NEBB densities prior to beetle emergence in the fall. Analyzing internal and external disease symptoms we link the observable rate of change in canopy features with internal beetle densities. Successful identification of high density NEBB elm trees earlier in the summer season could facilitate their rapid removal before vector dispersal and may result in a decrease in DED incidence.

ARTIFICIAL DIET FOR THE REARING OF *ARCHANARA NEURICA* (LEPIDOPTERA: NOCTUIDAE), A POTENTIAL BIOCONTROL AGENT OF EUROPEAN COMMON REED.

Vincent A.D. Hervet[1], Sandra M Smith[2], and Robert S. Bourchier[3], [1]Agriculture and Agri-Food-Canada, University of Manitoba, 96 Dafoe Road, Winnipeg, Manitoba, Canada, R3T 5V6, [2]University of Toronto, 33 Willcocks Street, Toronto, Ontario, Canada, M5S 3B3, [3]Agriculture and Agri-Food-Canada, 5403 1st Avenue South, Lethbridge, Alberta, Canada, T1J 4B1.

Archanara neurica is a European moth species that has been approved for release in Canada for the biological control of the invasive European common reed (*Phragmites australis* subsp. *australis*). A key step in the successful establishment of any weed biocontrol agent is the ability to mass-rear the agents for release. Current rearing methods for *Archanara neurica* are very labor intensive, requiring hand-transferring of larvae between multiple *Phragmites* stems to achieve successful pupation. To facilitate rearing of *A. neurica*, we tested four artificial-diet recipes: 1) the McMorran Lepidoptera diet, and the McMorran diet supplemented with either 2) dried *Phragmites* shoots, 3) fresh *Phragmites* stems and leaves, or 4) fresh growing tips of stems. Plant material was added to the base diet because we expected it to be required to stimulate feeding. *Archanara neurica* was successfully reared from egg to adult and the adults produced viable eggs on all diets. Contrary to our expectations the best results were obtained on base McMorran diet for all parameters of fitness measured (survival, development times of larvae and pupae, pupal mass and length) compared to the plant-supplemented diets. The McMorran diet can now be used to replace or complement labour intensive rearing of *Archanara neurica* on *Phragmites*.

RADIOFREQUENCY-ELECTROMAGNETIC FIELDS FROM WIRELESS 5G TECHNOLOGY AND POSSIBLE EFFECTS ON INSECTS: KNOWLEDGE GAPS.

Margaret Friesen, 43 Rutgers Bay, Winnipeg, Manitoba, Canada, R3T 3C9.

There are serious concerns about the decline of insects worldwide. Responsible "drivers" such as habitat loss, pesticides and changing climate, have been proposed. Radiofrequency-electromagnetic fields (RF-EMF) can affect the physiology and behaviour of insects *e.g.*, fruit flies and bees. New wireless 5G technology includes mm waves, along with longer wavelengths used for 2G, 3G and 4G for smart phones and other wireless devices. Mm waves penetrate materials more poorly than longer waves, so at full deployment, a dense network of small cellular antennas, along with additional large cellular towers, are required. This, along with the proposed transmission of 5G from space satellites, will lead to unprecedented exposure to RF-EMF radiation globally. Most studies showing adverse effects of RF on insects are laboratory based. One field study found that electromagnetic radiation from mobile telecommunication antennas affected the abundance and composition of wild pollinators. I will synthesize the current science on biological effects of RF on insects, including the work of the European-based EKLIPSE project, and summarize knowledge gaps of RF-insect research. Included will be what we can learn from other taxa about non-thermal effects of ambient RF radiation, including on DNA, circadian clocks, cryptochrome, oxidative stress, and voltage-gated calcium channels. Based on insect model computer simulation, increased absorbed power from 5G wavelengths could result in excessive heating of the exoskeleton. I make the case that RF radiation, if not a driver, should be considered a possible contributor to stress on insects making them more susceptible to other stressors.

LARVAL FEEDING BEHAVIOUR AND HOST PLANT PREFERENCE OF ENDANGERED POWESHIEK SKIPPERLING (*OARISMA POWESHIEK*) IN MANITOBA.

Justis Henault and Richard Westwood, Department of Biology, University of Winnipeg, Winnipeg, Manitoba, Canada, R3B 2E9.

We investigated biological and structural factors within larval microhabitats of the endangered Poweshiek Skippering (PS) (*Oarisma poweshiek*) in Manitoba. This butterfly is endemic to endangered tall grass prairie ecosystems in North America and remaining populations are only found at the Tall Grass Prairie Preserve (TGPP) in Manitoba, and several remnant tall grass prairie fens in Michigan, United States. The destruction of habitat has caused the majority of PS decline and a comprehensive understanding of PS adult and larvae requirements in remaining habitat are necessary to keep remaining populations extant. We found that Poweshiek Skipperling adults feed on specific nectar plants and larvae feed on certain host plants. Specific diversity and abundance of nectar plants are required by adults while larvae need access to multiple host plants and specific shelter requirements in tall grass prairie microhabitats. Female egg laying activities were documented and the larval actual host plant species identified for Manitoba. Larvae remain in close proximity to host plants where the initial egg was laid. Larval microhabitats require specific physical characteristics including appropriate soil moisture which supports a suitable structure and diversity of host plants during the 11-month larval development period. This information is essential to help local and for international conservation experts to develop techniques that increase the quality of remaining habitat, prioritize suitable tall grass prairie that can support reintroduction of PS and successfully protect this species from extinction.

POSTERS

GYNANDROMORPHY IN BEES: POSSIBLE CAUSES AND FIVE NEW CASES FROM SOUTHERN MANITOBA.

Emily J. Hanuschuk and Jason Gibbs, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada. R3T 2N2.

Some insects can be both male and female. These rare specimens are known as ‘gynanders’. We know that gynanders exists, but what causes them to occur? This poster reveals five new *Lasioglossum* Curtis gynandromorphic specimens from Manitoba caught in 2018 using passive sampling methods, and underlines the current hypotheses regarding their existence.

EVIDENCE OF SOCIAL BEHAVIOUR IN *LASSIOGLOSSUM VERSANS* LOCATED IN ALGONQUIN PARK, ONTARIO.

Katherine Morgan, and Jason Gibbs, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2.

The sweat bee genus *Lasioglossum* displays a wider variety of social systems than any other insect genus. Both solitary and social nesting are known to occur. However, few species have had their nesting biology studied. Our objectives were to: 1) determine if museum specimens could be used to indirectly infer social status of sweat bees and 2) assess the social status of *L. versans*. The phylogenetic placement of *L. versans* makes it of interest for studies of social evolution. Seventy females collected from May to August were measured and dissected to assess ovarial development. There was no correlation between body size and ovarial development. However, there was a clear temporal pattern in ovarial development such that eggs were small or absent after July 15. Bees without developed eggs had signs of wing wear equal to or greater than females with eggs. We surmise that these were workers and not recently emerged females. We conclude hat *L. versans* is a social species without distinct castes.

LANDSCAPE SIMPLIFICATION AND ITS EFFECTS ON BEE BODY SIZE.

Phoenix Nakagawa, Emily Hanuschuk, and Jason Gibbs, Department of Entomology, University of Manitoba, Winnipeg, Manitoba, Canada, R3T 2N2.

Most bees are mass provisioners; each egg is laid on a single food provision made primarily of pollen and nectar. Adult bee size is determined by the amount of these provisions. Habitat loss and agricultural intensification reduce floral resources available to bees. Two potential responses to reduced food availability are to feed fewer offspring or to produce smaller ones. The effects of landscape on bee size have not been well studied. We measured the intertegular distance (ITD) of 166 bee species collected across different levels of agricultural disturbance in southern Manitoba. ITD is highly correlated with bee dry weight. We collected large sample sizes (80–544 individuals) of 22 bee species across four bee families (Apidae, Colletidae, Halictidae, and Megachilidae) and nine genera. We analyzed the data to see if 1) bee communities in disturbed habitats were biased towards smaller species and 2) populations of individual species are smaller in disturbed habitats.

EFFICACY OF DELTAGARD® ON MOSQUITO POPULATIONS IN WINNIPEG, MANITOBA AND A REVIEW OF MANITOBA MOSQUITO SPECIES IN AVAILABLE IDENTIFICATION KEYS.

Jennifer Pawluk, Department of Bioscience, University of Winnipeg, Winnipeg, Manitoba, Canada, R3B 2E9.

The purpose of this study is to evaluate the efficacy of DeltaGard® (active ingredient: Deltamethrin) for adult mosquito control in Winnipeg by experimental analysis and monitoring for potential changes in mosquito fauna. I will test the effects of DeltaGard on adult mortality for control efforts in Winnipeg. Emergence of large numbers of adult mosquitoes in Winnipeg may trigger nuisance threshold criteria for the use of DeltaGard by truck-mounted equipment in parts or the entire city. I will be comparing the lethal effects of DeltaGard to adjacent control sites before, during, and after application and considering the spatial extent of control from aerosol swaths. This will be done by comparing mosquito trap numbers in CO_2-baited CDC traps placed within areas treated and areas not treated. In 2019, mosquito trap counts did not reach sufficient levels for the Insect Control Branch to adulticide citywide. DeltaGard was applied in a limited manner to cemeteries and parks. Initial efforts at evaluation provided a learning experience for conducting more rigorous and larger scale evaluations in subsequent mosquito seasons, assuming suitable conditions for widespread, threshold adult mosquito numbers. Samples of mosquito populations from several sites in Manitoba are also being identified and counted. A comparison of trapped and identified mosquitoes with the species list in Wood, Dang and Ellis (1979) will be used to create a dichotomous key for mosquito species specific to Manitoba. This will make catch, identification, and species monitoring more efficient by not considering species never found in Manitoba.

EFFECTS OF TEMPERATURE ON THE FEEDING RATES OF THE FLEA BEETLES, *PHYLLOTRETA STRIOLATA* AND *PHYLLOTRETA CRUCIFERAE*, (COLEOPTERA: CHRYSOMELIDAE) ON UNTREATED CANOLA (BRASSICACEAE).

Shayla Woodland, **Denice Geverink**, and Alejandro C. Costamagna, Department of Entomology, University of Manitoba, Winnipeg, Canada, R3T 2N2.

Understanding how temperature affects the feeding behavior of significant economic pests, such as flea beetles, is essential to aid canola growers in scouting techniques that support pest control. Past studies have noted that flea beetles move and feed slowly and tend to not fly below temperatures of 14℃, while feeding increases on warmer days. The objective of this project was to determine how temperature affects consumption of canola (*Brassica napus*) by the two most common species of flea beetles, *Phyllotreta striolata* and *P. cruciferae* (Coleoptera: Chrysomelidae), where consumption was measured by the surface area of missing plant tissue per beetle. After 48-hour exposure to flea beetles, photos were taken of the damaged canola and flea beetle pits and missing tissue coloured in. An image pixel histogram was formed via colour distance analysis (R 3.4.2) to determine the proportion of plant tissue damaged. We have found that flea beetles are more likely to feed on the abaxial side of canola cotyledons and there is an increase in damage as temperature is increased, indicating higher feeding rates. We found similar consumption rates for both species studied.

The Entomological Society of Manitoba Wishes to Thank the Following Sponsors for Their Generous Support of the 75th Annual Meeting

Bayer CropScience Canada, Inc.

Canadian Centre for Mosquito Management, Inc.

Canola Council of Canada

City of Winnipeg Insect Pest Control

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Orkin Canada Corporation

Poulin's Pest Control

The Entomological Society of Manitoba 75th Annual Business Meeting

26 October 2019, 1:00 PM
219 Animal Science Building
University of Manitoba

Attendance

President	Erica Smith
President-elect	Alejandro Costamagna
Past President, Scrutineer	Mahmood Iranpour
Regional Director (ESC)	Kateryn Rochon
Treasurer	Kathy Cano
Proceedings Editor	Terry Galloway
Secretary	Sarah Semmler
Common Names	Jason Gibbs
Endowment Fund	Richard Westwood
Scientific Program	Jeffrey Marcus
Newsletter	Marjorie Smith/Kateryn Rochon
Youth Encouragement	Emily Hanuschuk
Social Committee	Gina Karam
Scholarships and Awards	Desirée Vanderwel
Webpage and Archives	Jordan Bannerman
Scrutineer	John Gavloski

Alberto Civetta	Crystal Almdal
Rob Currie	Kyle Bobiwash
Robert Lamb	Byron Van Nest
Neil Holliday	Kelsey Jones
Rob Anderson	Vincent Hervet
Pat Mackay	Bob Wrigley
Robbin Linsday	Riley LeBlanc
Katherine Morgan	Michael LeBlanc
Megan Cowell	

Regrets

Fundraising	Ian Wise

1 **Acceptance of Agenda**
Motion: to accept the Agenda (**Appendix A**) – R. Currie/K. Rochon .... Carried

2 **Acceptance of the Minutes of the Last Annual Business Meeting (20 October 2018)**
Motion: to accept the Minutes of the 74th Business Meeting – R. Lamb/N. Holliday .... Carried

3 **Business Arising from the Minutes**
No new business.

4 **Reports – Executive**
Motion: to receive the reports – K. Rochon/D. Vanderwel......................... Carried

Appendix B – President

Presented by E. Smith.

– Thanks were given to J. Marcus and the Scientific Committee for and excellent meeting.

– J. Bannerman added [in response to report] that the ESM website is still hosted under Paul Fields, but that the change isn't time sensitive yet.

Appendix C – Treasurer

Presented by K. Cano.

– The accounts haven't been audited in a long time, but the statements are reviewed with members. K. Cano reviewed this year's accounts with R. Westwood and I. Wise.

– Donations have decreases, so new sources of funding are being sought.

– Previous meeting costs [in report] reflect speakers, travel costs etc., so the costs differ between meetings.

R. Currie – are the 2019 costs predicted?

K. Cano – no, they are actual. I have eliminated some of the items from the previous report as the amounts are typically the same each year. I'm not using any predictions.

– E. Hanuschuk will be asking for Youth Encouragement funds from the current and previous year; the money was not spent in the previous year. Usually receive $200 annually.

NOTE: Errors were found in the Treasurers Report following the meeting. The attached report is the corrected document.

Appendix D – Regional Director to the ESC

Presented by K. Rochon.

– There is a new section in the ESC bulletin called News from the Regions.

– Submission do not have to come from ESC members.

– MB has been well represented and we are encouraged to maintain that presence.

– Trying to increase awareness of the annual Insect Appreciation Day – more mentions and partnerships.

– The grant from the ESC to begin the Provincial Insect Emblem campaign has been confirmed.

– K. Rochon will be sending emails regarding ESC membership status. The emails will be intended to determine the reasoning behind having a membership with one society over another. They will help gather information for the ESC.

J. Bannerman – the ESC bulletin is aiming to share more news from Provincial societies, intended to hear what's going on, or share information. The Blog on the ESC webpage can also be used to post insect-related articles. It's a good platform for a wider audience.

N. Holliday – We've been trying to get Canada's Coolest Insects on the ESC blog. The posts would also appear in the bulletin. Photos and content are aimed at a general audience. Could produce one on each Society's emblem [look to Bob Wrigley]. A way to highlight each Society.

Appendix E – Editor of the *Proceedings*

Presented by T. Galloway.

– Vol. 75 is a landmark issue – submissions for manuscripts wanted.

– the *Proceedings* are great for specific MB research and new records.

Appendix F – Membership

Presented by S. Semmler.

5 **Reports – Committees**

Appendix G – Endowment Fund

Presented by R. Westwood.

– Have five investments, with two coming due. Continue to have one come due each year and renewed.

– Investments go back to the Society.

– Change in amount? Direction on changes can be sent to the Treasurer.

M. Smith – Can we increase the Endowment Fund?

R. Westwood – the Executive would have to be apprised of any changes.

N. Holliday – We have a good account, so could consider increasing investments.

P. Mackay – Remembers that in 2016, there had been an agreement to add $1000 each year as they came due.

K. Cano – Did increase last year, but now have two due. Will make a recommendation to the Executive to top them up.

Action Item: K. Cano to recommend an increase in investments to the Executive.

Scientific Program (No Report Submitted)

Presented by J. Marcus.

– Thanked the members of the Scientific Program committee and beyond. Appreciated their efforts and felt that the meeting was very successful.

Appendix H – Newsletter

Presented by M. Smith.

– The thirds newsletter will be slightly late.

- Gave special mention to J. Gavloski, B. Wrigley, and T. Lawton to providing great content.

– Finished last year as co-editor, editing now provided by K. Rochon.

– Noted that the newsletter is not a journal and that it's intended to share what members are up to.

– M. Smith has been working on the newsletter since 2004.

E. Smith – formal thanks given to M. Smith for many years of dedication to the newsletter.

K. Smith – volunteered to be a co-editor of the newsletter.

Action Item: Kelsey Smith to contact M. Smith to get started as a volunteer co-editor.

Appendix I - Youth Encouragement/Public Education

Presented by E. Hanuschuk.

– Had 11 outreach events so far.

– Is the only person on the committee, would like more committee members to come out on a regular basis. Will provide training to volunteers.

K. Cano – There are funds available for travel costs etc.

E. Smith – Interested members should speak to E. Hanuschuk after the meeting.

K. Rochon – Could get more "non-university" volunteers if all members are made aware of the requests.

S. Semmler – Can send requests for assistance to the membership if notified of the need.

K. Rochon – Would introduce more people to leading outreach and support more opportunities for members in general.

Social (No Report Submitted)

Presented by M. Iranpour.

– Newly appointed so beginning to get comfortable with the role.

– Seeking another member of the committee to assist with activities.

Appendix J – Scholarships and Awards

Presented by D. Vanderwel.

– Allowing the submission of a CV with award applications worked very well.

– Special mention to 15 years of support from Orkin. They increased their award amount to $300 without prompting.

– The names of previous recipients are now available on the website.

Appendix K – Fundraising

I. Wise absent. Presented by E. Smith.

P. Mackay – Are the amounts provided by Orkin separate?

K. Cano – Yes, one amount goes to the scholarship and another to support the AGM.

Appendix L – Web Page and Archives

Presented by J. Bannerman.

– All of the information on the previous ESM webpage is now available on the new.

– D. Vanderwel provided the list of previous recipients to be posted on Awards page.

– Have created a new Youth Encouragement and Outreach page.

– Information such as ESM news and available student positions could be posted on the webpage.

Action Item: The Executive has been asked to draft an intro paragraph for the ESM website.

N. Holliday – [RE archives] Gave a talk on Criddle. The content came from personal notes and grasshopper surveys from 1931 – the grasshoppers were hand-coloured. These exist in the ESM archives. Have discussed published the last of the Criddle manuscripts with with T. Galloway. Think they should be in the

Provincial archives where they are safer and better accessed. Suggested moving these documents to the Province.

R. Anderson – are they deteriorating?

N. Holliday – the condition isn't good, some are hand-written and others are typed copies. His wife has volunteered to copy some. They are fragile.

J. Bannerman – Can't they be scanned to maintain the records? Could be posted on the website server or on a higher quality of paper.

S. Semmler – Discussed this at a previous meeting. Found that the format of the pages made it difficult to scan some of the items.

J. Gibbs – supports digitizing the documents.

T. Galloway –found three slide boxers of grasshopper eggs from the Criddle surveys. Would like to keep this material in the museum collection. Some would require photographs.

– Some could be brought to the archives in the library, may have better equipment to handle them.

Motion: Have Society members (N. Holliday, T. Galloway, J. Bannerman) deal with the Criddle material in the archives and report any new accommodations to the Executive.

Moved by P. Mackay. Seconded by J. Gibbs..Carried

Appendix M – Common Names

Presented by J. Gibbs.

– Send suggestions for insects requiring common names to the Common Names Committee.

6 **Appendix N - Election Results**

Presented by J. Gavloski.

President Elect..Jeffrey Marcus
Member-at-large...Jason Gibbs

Motion to destroy the electronic files.

Moved by P. Mackay. Seconded by T. Galloway ....Carried

P. Mackay – Claimed that she and R. Lamb had issued with voting due to a shared email address. Possible that Survey Monkey restricted voting by IP address but not device? Could lead to multiple votes.

Action Item: R. Currie will look into the platform used by the University faculty voting system.

Action Item: E. Smith with look for a program that provides a code for each user.

S. Semmler – Survey Monkey offers enhanced functions for a fee, which could be considered for next year.

7 **New Business**

a) Executive considering making Member-at-Large position a two-year term

- suggested staggering position with two people at once, but doesn't solve the problem of finding people to fil the role.

-Need to have a call for nominations specifically

S. Semmler – emails were sent to the membership asking for nominees, included a description of the role.

P. Mackay – May not always need t have two names. Past President can put one name forward, perhaps a new member.

M. Cowell – Two year terms may eliminate some nominations; the length may be intimidating.

A. Costamagna – Could have the option of being renewable. Could increase the time available to learn about the Society.

R. Anderson – There doesn't appear to be rule that you cannot let a name stand for another term.

J. Gavloski – should leave the determination with the Executive for today, determine if there needs to be a bylaw change [read section of bylaw pertaining to election of Member-at-large to room].

T. Galloway – Not hearing anything against staying for a second term.

K. Rochon – why the reluctance to change the bylaws? Just needs some revision.

R. Anderson – Would just need to give notice of changes to the membership.

Action Item: Executive to determine length of term for Member-at-Large, and to determine if changes to the bylaw would be required.

b) Creation of new "Student Service Award" – M. Iranpour and D. Vanderwel

– intended to reward student effort and assist students in being competitive in the job market – something to build up a resume.

SAMPLE APPLICATION?

R. Anderson – Could have a separate award for long-standing members vs. students. Cash for student, but other acknowledgement for working members.

D. Vanderwel – So difficult to choose who to nominate. Some people have a long list of contributions. Suggested a "Years of Service" award each year as an alternative.

P. Mackay – Already have a distinction of Honourary Member. Not just for years of service, but other actions as well.

M. Smith – Many of us work for the ESM without expecting acknowledgement, happy to provide this service.

Motion: that the draft Student Service Award be accepted.

Moved by B. Lamb. Seconded by R. Currie.. Carried.

8 **Moment of Silence for Deceased Members This Year**

– John Guthrie, deceased 7 May 2018.

9 **Transfer of Office** – E. Smith transferred her role as President to A. Costamagna.

10 **Other Business**

No other business to discuss.

11 **Adjournment** – 2:46 p.m. *Motion*: to adjourn meeting – R. Currie/M. Colwell .... Carried

APPENDICES

APPENDIX A

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.

Agenda of the Entomological Society of Manitoba
75th Annual General Meeting
Saturday, 26 October 2019, 1:00 PM
219 Animal Science Building, University of Manitoba

1. Acceptance of Agenda

2. Acceptance of the Minutes of the last Annual Meeting (20th October, 2018)

3. Business Arising from the Minutes

4. Reports of the Executive
   President – Erica Smith
   Treasurer – Kathy Cano
   Regional Director to the ESC – Kateryn Rochon
   Editor of the Proceedings – Terry Galloway
   Membership – Sarah Semmler

5. Committee Reportsd
   Endowment Fund – Richard Westwood
   Scientific Program – Jeffery Marcus
   Newsletter – Marjorie Smith/Kateryn Rochon
   Youth Encouragement/Public Education – Emily Hanuschuk
   Social – Mahmood Iranpour
   Scholarship and Awards – Desirée Vanderwel
   Fundraising – Ian Wise
   Archives and Web Page – Jordan Bannerman
   Common Names – Jason Gibbs

6. Election Results – Scrutineer: John Gavloski

7. New Business
   a) Executive considering making Member-at-Large position a 2-year term

b) Creation of new "Student Service Award" – Mahmood Iranpour

8. Moment of Silence for Deceased Members
   a) John Guthrie

9. Transfer of Office

10. Other Business

11. Adjournment

APPENDIX B

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.

President's Report to the Membership

Annual Business Meeting - 26 October, 2019

There were three meetings of the Executive Committee of the Entomological Society of Manitoba in 2018/19:

First Executive Meeting – 12 February, 2019 – Entomology Library, University of Manitoba

– Issues regarding the financial statements brought up at the AGM were discussed, particularly those regarding the maintenance of our charitable status. K. Cano agreed to meet with the president to discuss the findings and results at a later date.

– J. Bannerman presented the new website and brought up the issue of domain hosting as the site is currently hosted through someone's staff page. The Executive agreed that it would be appropriate for the ESM to have its own domain. J. Bannerman indicated this hinged on being able to use a credit card to pay for the online service. The Executive agreed to implement measures to procure a credit card for Society use.

– The Executive recommended the creation of a Financial Committee to ease the burden of checking records and dealing with banking statements. K. Cano agreed to seek volunteers.

– S. Semmler suggested that Manitoba should have an official Provincial Insect and is spearheading a Committee.

Second Executive Meeting – 8 April, 2019 – Entomology Library, University of Manitoba

– A report from the Finance Chair assured the Executive that the ESM charitable status was not in jeopardy. Regarding issuance of a credit card, the bank requested a copy of the borrowing by-laws. As the Society does not have the topic of "borrowing" in its by-laws, the Executive suggested the drafting of a letter signed by all members of the Executive to be offered in lieu of creating a new by-law. The Finance Chair also reported the successful formation of a Finance Committee.
– Discussion regarding a proposal to obtain monies from the Entomological Society of Canada to support the newly formed Provincial Insect Committee took place, resulting in S. Semmler and K. Rochon volunteering to put together a proposal.
– K. Rochon indicated that she had accepted the role of Co-Editor of the Newsletter in response to a call for assistance from the Editor.
– The Executive welcomed the new Youth Encouragement and Public Education Chair, Emily Hanuschuk. E. Hanuschuk outlined her plans for the new year and agreed to design a banner to be used at outreach events.
– The Scholarships and Awards Chair, D. Vanderwel presented new criteria for award applications. The Executive voted in favour of the changes to be implemented immediately to give students time to apply before the AGM.

Third Executive Meeting – 9 October, 2019 – Entomology Library, University of Manitoba

– Meeting was called largely to make sure all members of the Executive were ready for the upcoming meeting.
– Action item from the last meeting regarding the Member-at-Large position was revisited due to difficulty finding volunteers to run for the position. The Executive agreed that a 2-year term could be beneficial, but felt that the membership needed to vote as there are positives and negatives to each side of the debate.
– The Executive welcomed the new Social Chair, Mahmood Iranpour.
– An action item from the AGM was revisited, namely the creation of a new award. The President suggested that, M. Iranpour, work together with D. Vanderwel to produce a description and criteria to be presented at the AGM.

I thank the Committee Chairs for all their hard work and dedication. If not for them, the Society would cease to function. This year has been a time of learning, growth and opportunity. I thank the membership for allowing me to represent the ESM as President. I have enjoyed my year of service and look forward to working with the Executive next year in my new role.

Erica Smith 26 October, 2019

APPENDIX C

ENTOMOLOGICAL SOCIETY OF MANITOBA INC.

Treasurer's Report

No report.

APPENDIX D

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.

Report of the ESC Regional Director
Entomological Society of Manitoba

The Entomological Society of Canada (ESC) held its Annual General Meeting jointly with the Acadian Entomological Society (AES) and the Canadian Society for Ecology & Evolution (CSEE) in Fredericton, NB on August 18–21. The theme for this year's meeting was "Naturally connected". The ESC's new President is Dr. Gail Anderson (Simon Fraser University).

Continuing its commitment to stronger relationships with regional societies, the ESC has released a new logo which can be viewed on the ESC's website at www.esc-sec.ca . The ESC logo is placed centrally with lines radiating to the logos of the seven affiliated regional societies surrounding it. The logo was presented at the annual meeting, and I presented it to the ESM membership in the latest edition of the newsletter (vol. 45.2).

The ESC recognized the need for better communication with the regional societies. To this end, a new section titled "News from the Regions" was added to the *Bulletin*, ESC's quarterly publication, to bring ESC members the latest news on all regional societies. Manitoba has been well featured in the past year, and I encourage all ESM members to send me any local entomological news they would like to share with ESC membership. The current *Bulletin* and archives are freely available to all on the ESC's website: http://esc-sec.ca/publications/bulletin/.

This year marked the launch of the first annual National Insect Appreciation Day (NAIAD) on June 8, 2019, a day to celebrate all things 6- and 8-legged. Events were organized nation-wide to share our fascination with insects. The ESC encourages all regional societies to take advantage of this annual National Insect Appreciation Day to raise awareness about insects through organizing public talks, workshops, displays, or other events to engage the public. The ESC hopes that NAIAD can become a regular fixture in educational programmes in schools, daycares, and museums, and an opportunity to positively feature entomology in the media.

Along these lines, the ESM was the recipient of a $1,000 Public Encouragement Grant from the ESC. This grant will go toward the establishment of Manitoba's Provincial Insect Emblem.

Lastly, the ESC now offers a new membership category: Entomology Enthusiast. This new membership category is aimed at "persons engaged in entomological pursuits as amateurs (*e.g.*, collects and/or studies insects as a pastime), and who do not derive a significant amount of their income from entomological activity, such as entomologist instructors/researchers (university or college), government researchers and extension personnel or students enrolled in a graduate program in entomology". Membership dues are set at 50% of regular membership, and provides all the advantages of being an ESC member, including access to publications and archives.

Kateryn Rochon
Regional Director (Manitoba), Entomological Society of Canada

APPENDIX E

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.

Report of the *Proceedings* Editor
Entomological Society of Manitoba

Volume 74 (2018) of the *Proceedings of the Entomological Society of Manitoba* was produced exclusively in electronic format. It has been sent by the Secretary, Sarah Semmler, to all members of the ESM with electronic access and posted on the ESM website by Jordan Bannerman. Volume 74 is 52 numbered pages in length, containing one submitted paper on new records for the brown marmorated stink bug in the province (including one excellent colour image), abstracts from the Annual Meeting of the Entomological Society of Manitoba held in the Freshwater Institute on 19 October, 2018, and Minutes and Committee Reports from the 74th Annual Business Meeting held in Room 219 Animal Science/Entomology Building on the University of Manitoba campus on 20 October, 2018.

I encourage everyone to submit Scientific Notes as well as full Scientific Papers. The *Proceedings* is an excellent place to publish new distribution records and faunal lists for insects and related arthropods in Manitoba as well as the results of entomological endeavours of all sorts. I have one submitted paper and pledges from several people to submit a variety of very interesting papers, which I hope will appear in the 2019 *Proceedings*. All submitted manuscripts are peer-reviewed; all published papers are available as PDF reprints on the web. Thanks very much to Jordan Bannerman for posting Volume 74, taking over from Rob Currie. Issues of the *Proceedings* are fully accessible using on-line search engines. There are no page charges to authors for published manuscripts, and with our electronic format, colour images can be included in manuscripts. In theory, there are no practical limits on manuscript length. There are no formal instructions for authors, other than to adopt manuscript format consistent with previously published papers. All issues of the *Proceedings* are freely available to entomologists around the world. If you have something of relevance to entomology in Manitoba, I encourage you to consider submitting it to the *Proceedings*. Thanks this year to Sarah Semmler for providing me with committee reports, Robbin Lindsay who submitted the abstracts, Kateryn Rochon who provided valuable technical assistance when I ran into seemingly insurmountable format issues, and Carol Galloway who cast her discriminating eye on the *Proceedings* before it was finalized.

Terry Galloway
Proceedings Editor
26 October, 2019

APPENDIX F

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.
Report on Membership by the Secretary

The Entomological Society of Manitoba currently has 79 members. Our membership is composed of 18 student status, 56 regular members, and 5 lifetime members.

For comparison, we had 89 listed members in 2017–2018. However, only 52 of the 89 members had been recorded as paying dues in that year. The roster has been fully updated and all members are in good standing – I am confident that we now have an accurate representation of our membership.

Our members will continue to be notified by email when it is time for renewal.

I encourage our members to notify me, or a member of the Board, of insect related events/activities that would be of interest to our membership. I can also assist with these events by sharing calls for volunteers.

Please continue to encourage students and colleagues to join, and thank you for continuing to support the ESM.

Sarah Semmler
Secretary

APPENDIX G

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.
Report of the Endowment Fund Board for 2018-2019

A summary of investments and projected interest income for the fiscal year is attached (Table 1). Interest generated by the Endowment Fund provides a basis for funding the Society activities. The Endowment Fund principal is $46,000. There were no transactions during the fiscal year in the Endowment Fund.

Richard Westwood
Kathy Cano, Treasurer

Endowment Fund Guaranteed Investment Certificates

Table 1: Account information as of October 23, 2019.

Certificate No.	Principal $	Interest Rate (%)	Maturity Date (Purchase Date)	Annual Interest $	Total Interest at time of maturity ($)
900055611-0016	9,000.00	2.1	12/12/2019** (Dec 12 2012)	189	1323.00
900055611-0017	9,000.00	2	11/17/2019* (Nov 17, 2014)	180	900.00
900055611-0018	9,000.00	2	19-Nov-20 (Nov 19, 2015)	180	900.00
900055611-0019	10,000.00	1.73	2-Dec-21 (Dec 2 , 2016)	173	865.00
900055611-0020	9,000.00	2.25	10-Nov-22 (Nov 10, 2017)	202.5	1012.50
Total	**$46,000.00**			**$924.50**	

* Will be renewed to come due in 2023

** Will be renewed to come due in 202

APPENDIX H

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.

Entomological Society of Manitoba
Report of the Newsletter Committee

The Newsletter Committee produced two issues of Volume 45 of the ESM Newsletter in the past year. Issue 45.1 was published in May 2019, and issue 45.2 in September 2019. The issues were distributed via e-mail. Issue 45.3 will be published in January 2020.

The budget of the ESM Newsletter committee is expected to be minimal in future fiscal years because of the use of e-mail to distribute issues.

Many thanks to Jordon Bannerman, who was Co-Editor of the ESM Newsletter from 2014 to 2018. This past spring, Kateryn Rochon joined the Newsletter Committee as Co-Editor, and is doing all the formatting of the articles and the Newsletter.

Thank you to those members who have contributed articles to the Newsletter. We encourage all ESM Members to contribute items of interest to the membership.

Marjorie Smith
Kateryn Rochon
Co-Editors, ESM Newsletter Committee

APPENDIX I

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.

Youth Encouragement and Public Outreach Committee
November 2018 – October 2019

This year, the YEPOC was involved in 11 outreach activities (see table below). The highest-reaching of these was Science Rendezvous, which pulled in a crowd of about 5000 people. Science Rendezvous is a free science festival that aims to educate the general public and spark interest in many different scientific fields. This year, our departmental booth included Madagascar hissing cockroaches, a honey bee observation hive, and lots of fun facts and trivia about insects. Besides this event, an additional 425 people benefited from our program. Most were students aged 8-18 residing in the

Winnipeg area. We reached these students through in-class presentations and insect demonstrations. Joel Gardner also led a bumble bee survey at Fort Whyte on four separate weekends during the summer. He was able to get the general public involved in capturing and releasing bumble bees, and taught them about bees during this time. In general, events were requested through email to the committee chairperson (Emily Hanuschuk). The YEPOC webpage was updated this year to include current details about the program and pictures of past events. Note: there are additional events occurring on 27 October (beekeeping workshop at Fort Whyte Alive led by Derek) and 28 October (classroom presentation led by Emily and Denice).

Date	Presenter(s)	Event	Audience (approx.)	Ages
14-Nov-18	Emily Hanuschuk and Gina Karam	Ag Canada Take your Kids to Work Day	17	Grade 9
10-Dec-18	Gina	Miles Macdonnell Collegiate	40	Grade 9 (25), grade 12 (15)
18-Apr-19	Emily, Crystal Almdal and Derek Micholson	École Robert Browning School visit	120	Grades 2-5
22-Apr-19	Derek	Beekeeping demo at Fort Whyte Alive		Public
30-Apr-19	Emily and Reid Miller	MPUE department visit	50	Grade 6
11-May-19	Emily, Lavanya Ganesan, Joel Gardner, Jade Tanner	Science Rendezvous	5000	Public
31-May-19	Katherine Morgan	Winkler Discovery Water Festival	50	Grade 4
30-Jul-19	Emily, Denice Geverink	Transcona Jaycee's Daycare Centre	38	Grades 1-6
13-Jul-19, 27-Jul-19, 10-Aug-19, 17-Aug-19	Joel, Emily (twice)	Bumblebee survey at Fort Whyte Alive	40	Public
20-Sep-19	Emily, Joel, Steve Robinson	Amber Trails School	30	Grades 1 and 2
10-Oct-19	Michael Killewald	Agriculture days at Kelburn Farm	40	Grade 11

Total – 5425 Presented by Emily Hanuschuk

APPENDIX J

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.

Report of the ESM Student Awards and ESM Scholarship Committee

The ESM Student Awards and ESM Scholarship Committee revised the application process for the ESM Graduate Student Scholarship, in response to feedback from various stakeholders. The revised version was used this year, and seemed to be well received. The date of application for all scholarships and awards was also set to be the same every year (October 1) for continuity.

A short description of each award and a list of previous years' award winners were prepared for posting on the ESM web-site.

The value of the Orkin Award was raised to $300 by Orkin Canada Corporation, effective this year. Orkin has supported students with this award since 2003! The award was first created in 1986 as the SWAT Award, and after SWAT joined Orkin it was called the SWAT-Orkin Award. The changed to the Orkin Award in 2012.

ESM Annual Scientific Meeting Student Competition: The student competition at the 75th Annual Meeting of the ESM was judged by Kyle Bobiwash, Erica Smith, and Byron Van Nest (Chair). The quality of the presentations was very high, making it a difficult decision for the judges. Emily Hanuschuk was the winner of the oral presentation competition. There were no entries for the poster competition.

Students also applied for the three scholarships and awards offered by the ESM: the ESM Student Achievement Award, the Orkin Student Award, and the ESM Graduate Student Scholarship. The committee deciding these awards was comprised of Jeffrey Marcus, Taz Stuart, and Désirée Vanderwel (Chair). There was an exceptionally strong crop of applicants/nominees this year, which made the work of the committee very difficult. The committee would like to thank the referees who participated in the process: your input was invaluable.

ESM Student Achievement Award: Awarded to a student who is in or recently completed a Bachelor's degree program. This award recognizes students who have shown exceptional interest in entomology as evidenced by their insect collections, insect photography, published articles of entomological interest, insect experiments and/or outstanding contributions during summer employment.

This year's winner of the Entomological Society of Manitoba Student Achievement award is Shayla Storozuk (University of Manitoba), who will soon graduate with a B.Sc. in Biological Sciences, with a major in Ecology and Environmental Science and a minor in Entomology. Shayla is an academically gifted student, and was the top student in many of the Entomology courses in which she enrolled. Her aquatic insect collection was of exceptional quality. Shayla also has extensive Entomology-related work experience through summer jobs with the City of Winnipeg (Insect Control Branch), the Costamagna research lab. According to her nominators, Shayla has exceptional attention to detail, creative problem-solving skills, and an "unmatched work ethic".

Orkin Student Award: This award is designed to foster and encourage student interest in general Entomology including natural methods of insect pest control and the proper use of insecticides. Candidates must have a demonstrated interest in entomology, superior scholastic ability, high research potential, originality and industriousness in their university courses and/or summer work.

This year's winner of the Orkin award is Jennifer Pawluk (Biology, University of Winnipeg). During her undergraduate program, Jennifer took courses involving insect-borne pathogens, and medical and veterinary entomology, and completed a Directed Studies course on the history of insecticide use for adult mosquito control in Winnipeg (supervised by Dr. Rob Anderson). Jenifer gained research experience working in the lab of Dr. Rob Anderson as an undergrad, and gained an interest in mosquito control. She has just started a Masters program, investigating new and effective ways of controlling and monitoring mosquitoes in the City of Winnipeg. Her nominator predicts a bright future in Entomology ahead of her.

The ESM Graduate Scholarship: This scholarship is awarded to students in a M.Sc. or Ph.D. program related to entomology at the University of Manitoba, University of Winnipeg or University of Brandon. Students must be enrolled in their graduate program for at least 12 months prior to Oct 1 of the award year. This award recognizes superior scholastic ability, high research potential, and excellent communication skills.

The 2018 Scholarship winner is Justis Henault (University of Winnipeg). Justis has been enrolled as Master's student in Bioscience, Technology and Public Policy since 2017, and is supervised by Dr. Richard Westwood. Justis earned his B.Sc. (Honours, Biology) in 2017, earning the Gold Medal for Achievement in a Major. Justis' research focusses on investigating biological and structural factors within microhabitats of endangered Poweshiek Skippering (*Oarisma poweshiek*) larvae that influence survival in Manitoba. Poweshiek skipperling is the most critically endangered butterfly in Manitoba, and Manitoba is the site of the only remaining population in Canada. Justis has several manuscripts almost ready for submission for publication in peer-reviewed journals. He is an active communicator, and has made several conference presentations at local, national and international scientific meetings. He has also participated in many workshops, and has been involved in various volunteer outreach activities, working towards the preservation of endangered species and public education. His referees comment that Justis has demonstrated "incredible potential at this stage of early career his development": we wish him continued success as he completes his M.Sc. and moves towards the next phase of his career.

Respectfully,
ESM Student Awards and ESM Scholarship Committee
Jeffrey Marcus
Taz Stuart
Désirée Vanderwel (Chair)

APPENDIX K

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.

Report of the Fundraising Committee, 2019

The Entomological Society of Manitoba received a total $1225 in donations this past year from eight sponsors. The sponsors were Orkin Canada Corporation, Poulin's Pest Control, the City of Winnipeg Insect Pest Control, Canola Council of Canada, Bayer Cropscience Canada, Gilles Lambert Pest Control, North/South Consultants, and the Canadian Centre for Mosquito Management. A notable sponsor from past years, the Canadian Grain Commission, has greatly reduced its funding after a leadership change. Dow AgroSciences Canada also did not donate following a corporate merger and a change in contact.

Ian Wise
Fundraising Committee

APPENDIX L

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.

ESM Website/Archivist Report – 2018-2019

Upon appointment in October 2018, I developed and launched a new ESM website (https://home.cc.umanitoba.ca/~fieldspg/index.html), which is still currently hosted on Paul Fields UofM web space, but it can be moved in the future if necessary (though there would be an ongoing cost to the Society at that point). New additions to the page include a redeveloped youth encouragement and public outreach page (https://home.cc.umanitoba.ca/~fieldspg/education.html) and a page devoted to highlighting the affiliations between our provincial and national entomological societies (https://home.cc.umanitoba.ca/~fieldspg/links.html). Other duties have included posting documents associated with the 2019 AGM to the website and updating various student award documents as required.

In the next year I would like to have the board develop a new introductory paragraph describing the society and its history for the homepage and to build and maintain a list of former winners of the various ESM student awards on the awards page.

Other archival material relevant to the Society is maintained in a filing cabinet in a room located within 008 in the Animal Science/Entomology building basement. No new additions have been made since I assumed the archivist duties.

Jordan Bannerman, ESM Webmaster and Archivist

APPENDIX M

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.

Report of the Common Names of Insects Committee, 2019

1) **Common names proposed and accepted by ESC**
Latin name: ***Drosophila suzukii*** (Matsumura, 1931)
Order and family: Diptera, Drosophilidae
Accepted English name: spotted-wing drosophila
Accepted French name: drosophile à ailes tachetées
Suggested French name: moucheron asiatique, drosophile japonaise ou drosophile à ailes tachetées
Reason for suggestion: *Drosophila suzukii* is a serious pest of small fruit crops, including, but not limited to cherries, strawberries, raspberries, and blueberries. It was introduced from Asia and has rapidly spread across North America. This species is the focus of a great deal of active research in both North America and Europe (where it is also introduced) due to its severe economic impact. The distinctive wing spots of the male are the basis of the common name, which is often abbreviated to 'SWD'.
Additional notes. Spotted-wing drosophila is also the official common name used by the Entomological Society of America. A Google Scholar search for '*Drosophila suzukii'* resulted in >660 results in 2018 alone. 580 records for the same time period used spotted wing drosophila (hyphenated or not).

2) **Possible suggestions**

Some bees of conservation interest were informally proposed, but there is an active application for Canadian bumble bees and several years ago, Cory Sheffield was working on a list of common names for all Canadian bees (that list would be out-of-date by now) and may conflict with some other common names for *Epeolus* proposed in Zookeys by Onuferko (2018). I may follow up with some specific non-bumble bee suggestions. It may be worth checking COSEWIC applications to formalize common names of species of conservation concern. For example, Poweshiek skipperling is not formally recognized by ESC.

Suggestions are welcome. Jason Gibbs, Chair

APPENDIX N

ENTOMOLOGICAL SOCIETY OF MANITOBA, INC.

Election Report

Elections closed October 1, 2018 for the Entomological Society of Manitoba offices of President-Elect and Member-at-Large. There were 76 ballots issues, 53 ballots returned, and one spoiled ballots.

The successful candidate for President-Elect is **Jeff Marcus**.
The successful candidate for Member-at-Large is **Jason Gibbs**.

This was the second year using an electronic voting process. All votes were done through Survey Monkey this year. Responses are anonymous. The source of the vote is not visible or collected. Survey Monkey is also set to only allow one vote per respondent.

We thank all candidates for their willingness to participate in the election. Formal announcement and commencement of terms will be at and after the ESM Annual Business Meeting, respectively.

John Gavloski, Chair
Scrutineer Committee

ENTOMOLOGICAL SOCIETY OF MANITOBA

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