2017

Alfalfa Insect Survey (2014F)62R

Comprehensive report on Alberta alfalfa survey 2014-2016

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Introduction

Alfalfa (*Medicago sativa* L.), an introduced plant to North America, is common in Alberta not only as a cultivated crop, but also as a component in managed and unmanaged pasture. Pasture and roadsides can provide corridors that, along with the transport of hay by vehicle and train, help the spread of pest insects into new, hospitable areas. Changes in land-use and climate will initiate changes in species' ranges and potentially number. Therefore, it is important to establish species' ranges and track changes to provide accurate information to growers making management decisions.

As an economically important crop in Alberta, alfalfa, grown for both forage and seed, requires timely decisions for pest control. Chemical and other intensive control measures are infrequently used in cultivated alfalfa forage hay crops due to high economic thresholds for pest species, which means pest control relies heavily on cultural controls. For seed alfalfa control of pests has relied heavily on the use of insecticides. For such practices to work effectively, is it necessary to have up-to-date information on the pest species threatening alfalfa fields.

A species list of insects and mites found in alfalfa fields in Alberta was compiled in 1988 (Harper), but limited information regarding the population and range of pest insect species has been published since that time. Development of integrated pest management plans and justifications for the registration of plant protection products in alfalfa fields are challenging to create when no up-to-date pest population baselines exist. The lack of knowledge available for alfalfa pest insects in Alberta leaves the industry vulnerable.

Due to the importance of alfalfa crops in Alberta, a province wide survey of insect populations in alfalfa fields was conducted from 2014 to 2016. The insect survey will provide information that can be used towards identifying the presence and range of any potential new pest species such as the alfalfa blotch leafminer, documenting population range expansion by known pest species like the alfalfa weevil, and establishing baseline population numbers for alfalfa insects. The results of the alfalfa insect survey will help inform ongoing and future surveillance work, allowing for informed integrated pest management practices.

Alfalfa blotch leafminer

Native North American species of the genus *Liriomyza* (Diptera: Agromyzidae) can be pests of plants in the family Fabaceae, including alfalfa (Harper 1988). Despite alfalfa being a host for at least one species of *Liriomyza* (Harper 1988), *Liriomyza* spp. are not considered to be significant pests for the industry. However, a species within the same family, alfalfa blotch leafminer (ABM), *Agromyza frontella* (Rondani 1874), introduced to North America nearly 50 years ago, can be a significant pest at high numbers.

Though the effects on seed production have not been studied, significant infestations by ABM can cause a reduction in protein content and yield in forage alfalfa (Soroka and Otani 2011). A loss of 11% has been estimated when 30 mines are present per alfalfa stem (Hendrickson *et al.* 1986) and serious economic loss was a fear when this pest first reached Canada. In Ontario during the initial colonization, infestations reached population numbers that required management sprays (Harcourt *et al.* 1987), but ABM is now considered to be controlled by parasitoids (Harcourt *et al.* 1988), throughout much of its known range in North America. The first reported appearance of ABM in Alberta was in 2005 (Meers) in the Southern region, but a survey has yet to be conducted to explore the range of this pest or its parasitoids within Alberta.

Four years after its introduction to North America, the invasive leafminer was identified as *A. frontella*, a European species whose larvae create comma like mines (Spencer and Steyskal 1986), yet confusion exists on-line in the appearance of the mines attributed to this species. The species of fly whose larvae has been feeding within a leaf can often be identified based on the mine appearance (Spencer and Steyskal 1986), which makes it critical that growers and agronomists are able to recognize ABM mines correctly. The mines of ABM are shown to be characterized by a short tail with a large blotch at the midrib of the leaf in both the British (Spencer 1982) and United States (Spencer and Steyskal 1986) manuals for Agromyzidae. A related species, *Agromyza nana* (Meigen 1830), has similar mines, though they lack the "comma" shape and are not associated with the edge of the leaf (Spencer 1982). However, on-line identification keys for British leaf mines attribute the blunter, larger blotch mine to *A. nana* while a long, sinuous mine is given to *A. frontella*. The long, winding mines are the first images to appear when "*A. frontella*" is searched on-line, adding to the potential for misidentification of leaf mines created by ABM in Alberta.

Alfalfa weevil

The alfalfa weevil, *Hypera postica* (Gyllenhal 1813), is an introduced species in North America and a major pest in alfalfa fields. Both the adults and larvae feed on alfalfa foliage, but the larvae do significantly more damage than adult feeding. The adult stage overwinters and produces only one generation per year in Canada; however, eggs can be laid over a long period of time during the growing season.

First reported in Alberta in 1954 (Hobbs *et al.* 1959), the alfalfa weevil's expansion into Canada has not been shown to have been accompanied by an increase in cold hardiness (Peterson 1960). A consistent -18°C lethal limit was found for adults of the alfalfa weevil from Utah and Alberta (Peterson 1960), which indicates the weevil is not adapting to colder winter temperature but establishing in environments that are suitable. Changes in the alfalfa weevil's range within Alberta are likely to be the result of changes in the environment that make it hospitable to the weevil.

Grey Tortrix moth

The British Columbia Ministry of Agriculture issued a pest alert in 2011 for the Grey Tortrix moth (*Cnephasia stephensiana* Doubleday) causing damage in alfalfa stands near Williams Lake and Kersley (Acheampong 2011). By 2013, damage to alfalfa by the Grey Tortrix moth was seen in stands near Sparwood, on the British Columbia side of the Crowsnest Pass (Acheampong and Hueppelsheuser 2013). As the Grey Tortrix moth expands its range through the Rocky Mountains, there is increasing concern that it will establish and begin to damage alfalfa stands in Alberta. Monitoring on the Alberta side of the Crowsnest Pass will determine if populations the Grey Tortrix moth have expanded into Alberta.

Lygus population dynamics

In addition to helping increase the knowledge base for pests in alfalfa fields across Alberta, a paired study on *Lygus* population dynamics between alfalfa and canola (*Brassica* spp.) fields was performed. The study was done to determine if populations of *Lygus* species feeding on alfalfa move into canola fields following alfalfa harvest. Dispersal from harvested alfalfa to adjacent seed alfalfa fields has been observed in insect species including those from the *Lygus* genus

(Schaber *et al.* 1990); however, movement of *Lygus* species from cut alfalfa to canola was not observed in another study based in Alberta and Saskatchewan (Cárcamo *et al.* 2003).

Methods

Field selection

The alfalfa insect survey was conducted province wide in Alberta, collecting from fields in three ecoregions: boreal, parkland and grasslands (Fig. 1). An ecoregion designation was assigned *a posteriori* to the counties (Table 1) and one or two fields were surveyed from each county, each year. In 2014, 150 fields were surveyed (60 boreal, 42 parkland and 48 grassland), 99 fields in 2015 (38 boreal, 26 parkland and 35 grassland) and 109 in 2016 (40 boreal, 33 parkland, 35 grassland). When possible, only forage alfalfa fields were selected for survey and sites were returned to each year for as long as alfalfa was present. Every year the surveys were conducted throughout the month of June, beginning in the Southern region of the province.

Table 1. Division of counties into agro-ecoregions.

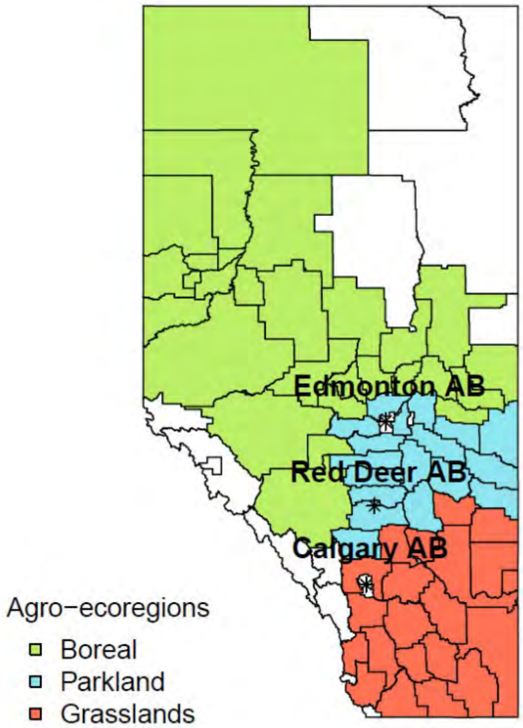


Figure 1. Map of Alberta showing division of counties into 3 agro-ecoregions: boreal, parkland and grasslands.

Ecoregion	County	Ecoregion	County
Boreal	Athabasca	Parkland	Mountain View
Boreal	Barrhead	Parkland	Parkland
Boreal	Big Lakes	Parkland	Ponoka
Boreal	Birch Hills	Parkland	Provost
Boreal	Bonnyville	Parkland	Red Deer
Boreal	Brazeau	Parkland	Stettler
Boreal	Clear Hills	Parkland	Strathcona
Boreal	Fairview	Parkland	Sturgeon
Boreal	Grande Prairie	Parkland	Vermilion River
Boreal	Greenview	Parkland	Wainwright
Boreal	Lac La Biche	Parkland	Wetaskiwin
Boreal	Lac Ste Anne	Grass	Acadia
Boreal	Lesser Slave River	Grass	Cardston
Boreal	Northern Lights	Grass	Cypress
Boreal	Northern Sunrise	Grass	Foothills
Boreal	Peace	Grass	Forty Mile
Boreal	Saddle Hills	Grass	Kneehill
Boreal	Smoky Lake	Grass	Lethbridge
Boreal	Smoky River	Grass	Newell
Boreal	Spirit River	Grass	Paintearth
Boreal	St Paul	Grass	Pincher
Boreal	Thorhild	Grass	Ranchland
Boreal	Two Hills	Grass	Rocky View
Boreal	Westlock	Grass	Special Area 2
Boreal	Yellowhead	Grass	Special Area 3
Parkland	Beaver	Grass	Special Area 4
Parkland	Camrose	Grass	Starland
Parkland	Clearwater	Grass	Taber
Parkland	Flagstaff	Grass	Vulcan
Parkland	Lacombe	Grass	Warner
Parkland	Lamont	Grass	Wheatland
Parkland	Leduc	Grass	Willow Creek
Parkland	Minburn		

Collection

Alfalfa blotch leafminers

At each field site alfalfa stems were collected for damage assessment by alfalfa blotch leafminer. Three stems were collected from 10 different locations in each field for a total of 30 stems per field. Ten of the 30 stems were selected at random and, for each, three measurements were taken: stem length, the number of trifoliates, and the number of mines. The number of mines was the only measure recorded for the remaining 20 stems.

Leaves with mines were cut from the stems and scanned on a flatbed scanner to preserve the appearance of the mines. The mines were grouped based on appearance and assigned to a species using: 1) an on-line UK key (ukflymines.co.uk/Keys/TRIFOLIUM.php), and 2) the British Agromyzidae manual (Spencer 1982). DNA barcode analysis was then used to determine which resource correctly identified the mines to species.

Larvae remaining within mines from 2015 and 2016 were removed and preserved for DNA barcoding. The mtCOI region was amplified and sequenced by the Alberta Plant Health Lab using the LCO1490 and HCO2198 primers. An annealing temperature of 50°C was used for 45" and PCR amplicons were sequenced by MBSU at the University of Alberta. The COI barcodes were compared to those available on the NCBI database and the Barcode of Life Database.

Sweeps

A general collection for insects was performed at each surveyed alfalfa field using a standard 15 inch diameter sweep net with a 3 foot handle. One sweep completed a full 180° motion, moving horizontally to the ground, through the top 2/3 of the canopy. Ten sweeps through the alfalfa canopy were performed at ten locations in each field for a total of 100 sweeps per field. The collected insects were placed into one bag and kept cool until they could be frozen at the Crop Diversification Center, South in Brooks, AB. Each sample was cleaned in the lab to remove any plant debris and then divided into quarters.

A random quarter of each sweep sample was selected and the insects were identified, counted and vialed. Select insects were identified to species (e.g. alfalfa and *Sitona* weevils) (Table 2) while others were identified to family (e.g. lacewings) (Table 3) or to order (e.g. mites) (Table 4). The results for most insect groups are presented terms of ¼ of the total sample; however, larger insects were tallied for the entire 100 sweep sample, including: Orthoptera, Lepidoptera, ladybird beetles, bees, lacewings, spiders and harvestmen. Results are graphed by average regional abundance based only on collection numbers from sites that were repeated all three years. Maps created to display population numbers and ranges use collection numbers across all sites visited.

Table 2. Insects groups from alfalfa sweeps across Alberta with members identified to species and tallied. Highlighted insects are evaluated as main pests of alfalfa.

Insects	Coleoptera	Hemiptera	Diptera
	Other beetles Beetle larvae	Other bugs	Other flies
Family	Soft-winged flower beetles (Melyridae) Blister beetles (Meloidae) Ground beetles (Carabidae) Click beetles (Elateridae)	Leafhoppers (Cicadellidae) Spittlebug (Cercopoidae) Other aphids (Aphididae) Minute pirate bugs (Anthocoridae) Damsel bugs (Nabidae)	Syrphid flies (Syrphidae)
Species	Alfalfa weevil (Hypera postica) Sitona (S. lineatus & S. cylindricollis) Ladybird beetles	Alfalfa plant bug (Adelphocoris lineolatus) Lygus bugs (4 species) Pea aphid (Acyrthosiphon pisum) Spotted alfalfa aphid (*Therioaphis maculata*) Twice-stabbed stink bug (Cosmopepla lintneriana)	Alfalfa blotch leaf-miner (*Agromyza frontella*)

Table 3. Insect groups from the alfalfa sweeps across Alberta with members identified only to family and tallied.

Insects	Thysanoptera	Hymenoptera	Orthoptera	Lepidoptera	Neuroptera
		Wasps Sawfly larvae	Grasshoppers	Adults Caterpillars	
Family	Phlaeothripidae Aeolothripidae Thripidae	Bees (Apoidea: Anthophila)	Katydids (Tettigonioidea)		Lacewings (Chrysopidae)

Table 4. Other arthropod groups from alfalfa sweeps across Alberta.

Other	Acari	Collembola	Araneae	Opiliones
	Mites	Globular (Symphypleona) Long (Entomobryomorpha)		Harvestmen
Family			Web builders (5 families) Ambush (2 families) Active hunting (3 families)	

Alfalfa weevil

Suspect alfalfa weevil larvae from sites outside of the expected southern range were sent for DNA barcoding to confirm identification. The barcoding was done by the Alberta Plant Health Lab t the Crop Diversification Centre, North, Edmonton AB, using one of two primer sets to amplify the mitochondrial DNA (mtDNA) COI gene region. The universal COI Folmer primers, LCO1490 (5'-ggtcaacaaatcatcccgatattgg-3') and HCO2198 (5'-taaacttcagggtgaccaaaaaatca-3'), and tailed versions, LCO1490_t1 (5'-tgtaaaacgacggccagtggtcaacaaatcataaagatattgg-3') and HCO2198_t1 (5'-caggaaacagctatgactaaacttcagggtgaccaaaaaatca-3'), were chosen and an annealing temperature of 50°C for 45" was used during polymerase chain reaction (PCR). The amplicons from the barcoding PCRs were sequenced by MBSU at the University of Alberta.

A positive control for the alfalfa weevil was an adult collected from Willow Creek, AB within the known range of the species. Alfalfa weevil sequences available on the National Center for Biotechnology Information (NCBI) website were also used for comparison to confirm species identification. Positive identification through DNA barcoding is usually found when sequences variation is below 4%.

Sites where the alfalfa weevil was found outside of the expected range in 2015 were returned to and surveyed in 2016. Additional sites were surveyed around the initial sites to determine the extent of the pest's spread in these new areas. Distance from the initial sites varied with a range from 13 to 25 km.

Grey Tortrix moth

As a follow up to the B.C. reports on the Grey Tortrix moth, roadside alfalfa plants were visually surveyed for evidence of the Grey Tortrix moth at ten locations between the British Columbia and Alberta border, to the junction of Highway 3 and Highway 22. The surveyed area covered a distance of 40 kilometers. At each surveyed location, 10 plants were visually examined for evidence of feeding and the presence of larvae. The survey was carried out in 2014 and 2016.

Paired *Lygus* study

Sweeps were performed at paired canola and alfalfa fields in the foothills area of Alberta, between Calgary and Red Deer. Each set of paired fields chosen were located across a road or had a common border. The close proximity of the fields was selected to allow accurate documentation of any lygus bug movement between fields before and after alfalfa harvest. The fields were visited once a week for four to five weeks. During each visit, two collections of 25 sweeps were performed for a total of 50 sweeps in each of the canola and alfalfa fields. The sweep samples were collected into separate bags, taken back to the lab and frozen before identification. The lygus bugs, adults and nymphs, from each sample were counted and identified to species or nymphal stage.

As there were no set harvest times, field pairs were given *a posteriori* designations as either “cut” for field pairs where the alfalfa was harvested during the survey or “uncut” for pairs where the alfalfa remained unharvested. The “cut” fields were grouped based on the number of collection periods prior to the alfalfa harvest. Comparisons between alfalfa fields and canola fields were done based only on “cut” groups with four field pairs.

Results and Discussion

Alfalfa blotch leafminer

Two distinctive mine shapes were found on alfalfa leaves in Alberta, a long, serpentine mine (Fig. 2A) and a blunt, comma shaped mine that was either associated with the leaf edge (Fig. 2B) or free from it (Fig. 2C). Tentative species assignment using the on-line UK key identified the sinuous mines as *A. frontella* and the comma-like mines as *A. nana*; however, identification using the British Agromyzidae manual (Spencer 1982) assigned the comma-like mines associated with the leaf edges (Fig. 2B) to *A. frontella*, the free standing mines (Fig. 2C) to *A. nana* and the sinuous mines (Fig. 2A) were labeled as “other”.

Through DNA barcode analysis, all larvae removed from the short, blunt mines (Fig. 2B and 2C) were confirmed to be a single species, *A. frontella*. The DNA results agree with the original identification of the invasive species as *A. frontella* and confirm only one species of Agromyzidae has been introduced. The winding, serpentine mines (Fig. 2A) were found to belong to a native leaf miner, *Liriomyza fricki* Spencer, whose adults were common in alfalfa fields, but the instances of its mines were much lower than those of *A. frontella* (Fig. 3).

Figure 2. Representative images of the distinct leaf mines collected from Alberta alfalfa fields over the 3 year (2014-2016) survey.

Despite the first reported incidence of ABM in Alberta occurring in 2005 (Meers), the survey found the range of this species to be across all agro-ecoregions of Alberta based on adults collected in sweeps (discussed in the Sweeps section below) and leaf mines (Fig. 3). The highest incidence of leaf mines, by both *A. frontella* (3506) and *L. fricki* (101), occurred in 2014. Despite the high number of mines in the boreal and parkland agro-ecoregions in 2014 (Fig. 3), events of 30 mines on a single stem were rare. Instances of 30 mines per single stem were seen in only three counties: one stem from Leduc, one from Mackenzie and two stems from Northern Lights. By 2016, the numbers of leaf mines had dropped significantly in both *A. frontella* and *L. fricki* (Fig. 3) for a total of 29 mines and 7 mines respectively.

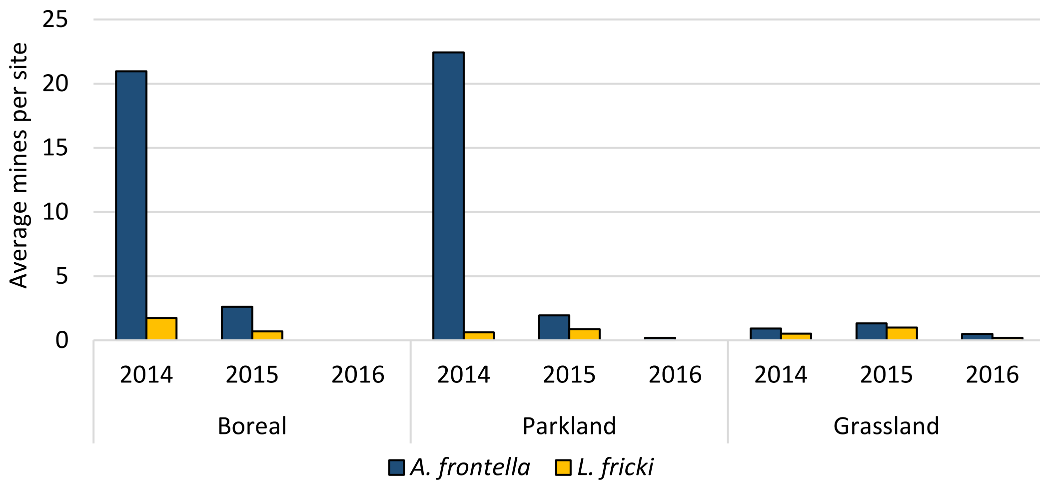
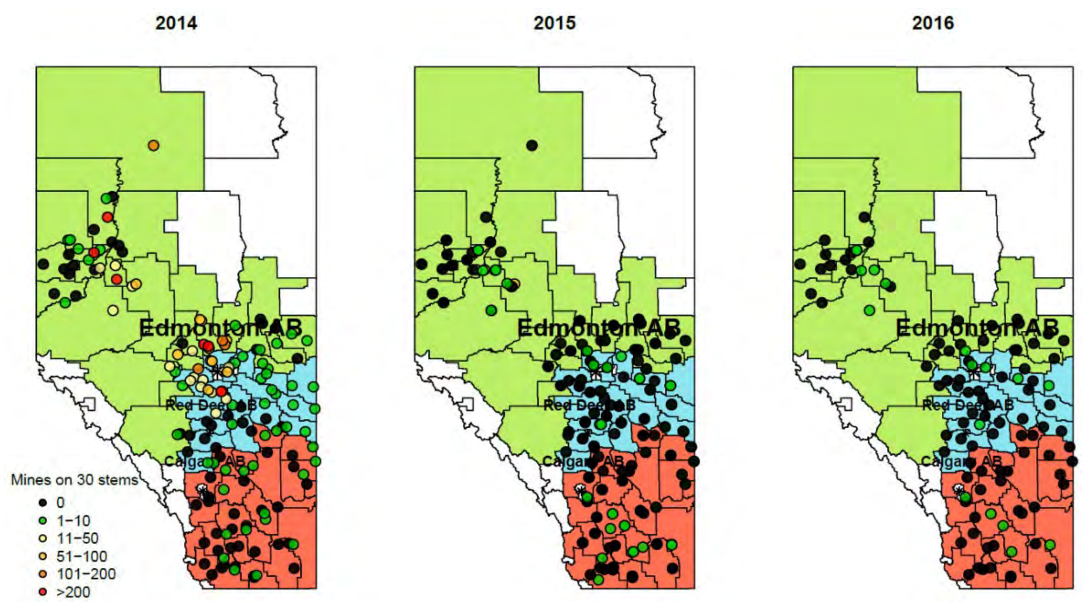


Figure 3. Average number of leaf mines by *A. frontella* and *L. fricki* per 30 stems collected from fields over the 3 year survey (2014-2016) in each agro-ecoregion.

The dramatic change in *A. frontella* mine number may be influenced in part by changes in the environment, particularly the soil moisture. The soil moisture can influence the survival of ABM because it pupates shallowly in the soil (Therrien and McNeil 1985). The modeled soil moisture in pastures (Alberta Agriculture and Forestry, Weatherdata.ca) in mid-May of each year shows a decrease over the three year survey (Fig. 4), which may have contributed to decreasing pupal survival. However, life tables created in Ontario during the initial invasion of ABM in that area, revealed population trends were most influenced by larval mortality while they were still within the mine (Harcourt *et al.* 1987).



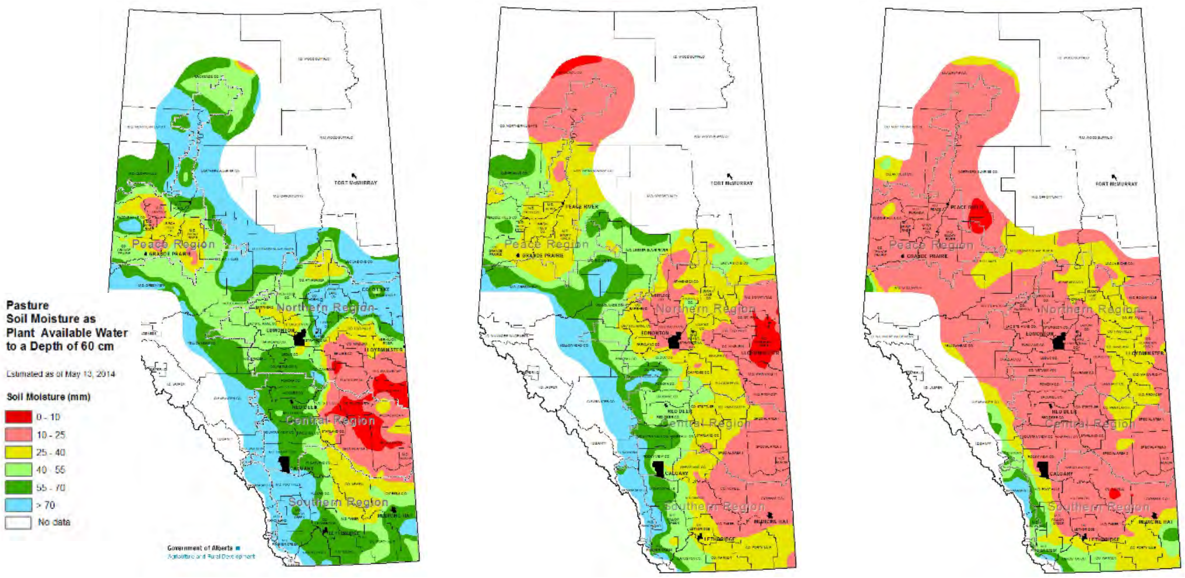


Figure 4. Maps of Alberta displaying the location and number of alfalfa blotch leafminer mines (top row) over the 3 year survey (2014-2016) and the soil moisture across the province (bottom row) in mid-May of each year. Soil moisture modeled by Alberta Agriculture and Forestry.

Occupied mines of the alfalfa blotch leafminer collected from the southern grasslands agro-ecoregion in 2016 were incubated and two different species of parasitoid emerged. Parasitism rate in ABM was observed to be high in the South region in 2008 (Meers). High parasitism rates by native and introduced parasitoids is likely an important factor in the control of ABM populations below an economic threshold.

Sweeps

A total of 63 fields were repeated across all three years of the survey (23 boreal, 16 parkland and 24 grassland). The grasslands had the largest abundance of insects throughout all survey years while the lowest abundance was seen in the boreal region (Fig. 5). The initial year of the survey, 2014, saw the lowest abundance of insects in all agro-ecoregions (Fig. 5). A significant increase in the average insect abundance was seen between 2014 and 2015 in the parkland ($p<0.05$) and grassland ($p<0.05$) agro-ecoregions and numbers continued to increase in these regions into 2016 (Fig. 5); however, the highest insect abundance in the boreal agro-ecoregion occurred in 2015 due to a high number of grasshoppers that year.

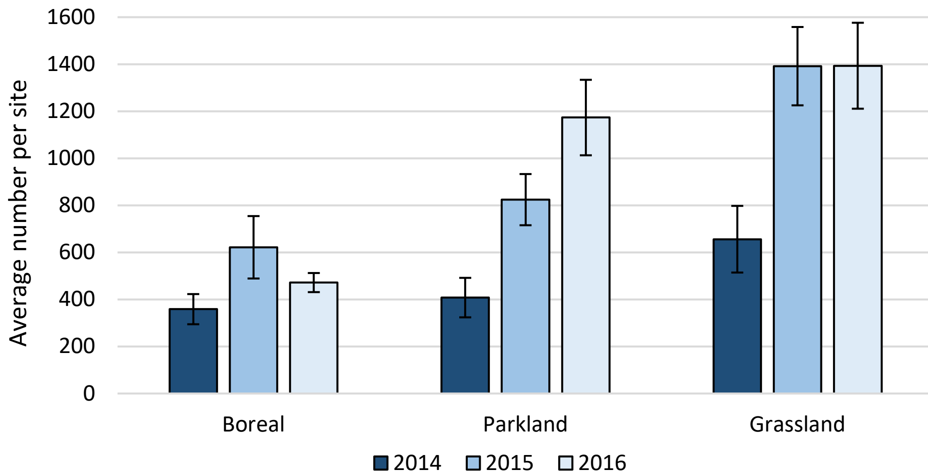


Figure 5. The average insect abundance (+S.E.) is shown for the 3 agro-ecoregions of Alberta over the 3 year (2014-2016) alfalfa survey.

Pest insects

Main pests of alfalfa

In terms of absolute number, collections of alfalfa weevil, lygus bugs, pea aphids and spotted alfalfa aphids more than doubled from 2014 and 2016, with the largest abundance of alfalfa weevil and lygus in 2015, and aphids in 2016. The opposite was true for the alfalfa blotch leafminer and the alfalfa plant bug, for which the highest abundance was seen in 2014 and decreased over the course of the survey. The variation in abundance of each pest insects over the three years differs among the agro-ecoregions (Fig. 6), indicating regional specific influences on pest numbers. The grassland region had the highest abundance of main pest insects (Table 2) every years (Fig. 6), largely due to the high numbers of alfalfa weevil. The alfalfa weevil is the dominant pest in the grasslands agro-ecoregion and its range has been expanding in the parkland.

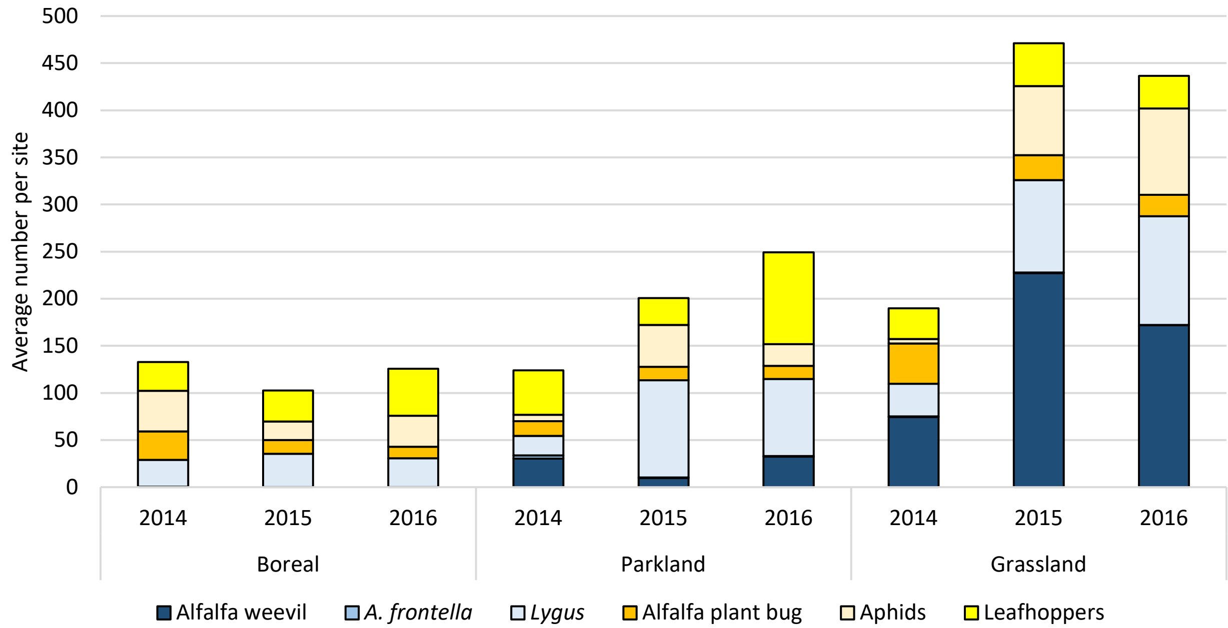


Figure 6. The average abundance of main pest insects per year of the alfalfa survey (2014-2016) in all 3 agro-ecoregions of Alberta.

Alfalfa weevil

Alfalfa weevil is found primarily in the grasslands agro-ecoregion where numbers tend to be high (Fig. 7). The largest number of larvae collected in 2014 was 1028 from Willow Creek, in 2015 a Willow Creek site had 3005 and in 2016 a field from Mountain View, a county in the parkland region, had 1993 larvae. The economic threshold for alfalfa weevil is based on larval numbers and, for 12% loss in forage alfalfa, it is set at 40 larvae per 180° sweep (Aasen and Bjorge 2009) or 1000 larvae in 25 sweeps. The grasslands had the most sites that were estimated to exceed the economic threshold, with two fields in 2014, three in 2015 and one in 2016 along with a single parkland site that year. Populations in the grasslands appear to peak in the second year while the average number is lowest that year in the parklands (Fig. 7). Despite the low average density of alfalfa weevil in the parkland region, the range of the alfalfa weevil expanded in this agro-ecoregion over the course of the survey. Alfalfa weevils were found at 7 fields in the parkland agro-ecoregion in 2014, 10 in 2015 and at a total of 20 fields in 2016.

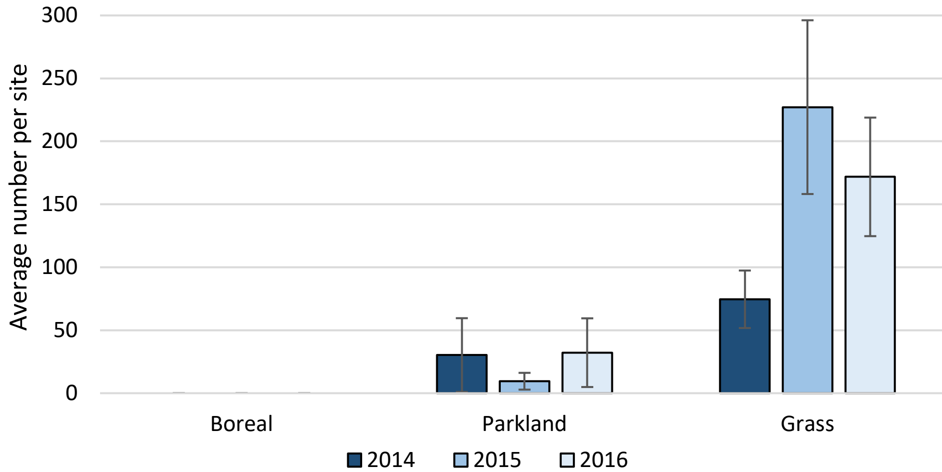


Figure 7. Change in average abundance (+S.E) of the alfalfa weevil, adults and larvae combined, over the 3 year survey (2014-2016) in each agro-ecoregion.

In 2015, continuous range expansion of the alfalfa weevil occurred in to the north-west in Lacombe, where 3 larvae were collected, and the north-east in Wainwright, where an adult and eight larvae were found (Fig. 8). During the last year of the survey, higher numbers were recovered from both of the initial 2015 sites and expansion was observed into three more counties: Ponoka, Flagstaff and Vermilion River (Fig. 8). Additional collection in Wainwright County in 2016 revealed the presence of four larvae 25 km north-west of the initial Wainwright site.

In 2015, an adult and larvae of alfalfa weevil were found in Sturgeon County, just north of Edmonton. Rather than a continuous range expansion like that seen further south, the Sturgeon population was isolated (Fig. 8). Subsequent collection at the site in 2016 found a single alfalfa weevil larva, but no alfalfa weevil was found at locations 13 km north-west of the site nor 25 km east. However, an alfalfa weevil larva was also found in Parkland County in 2016, expanding the isolated population to two counties (Fig. 8).

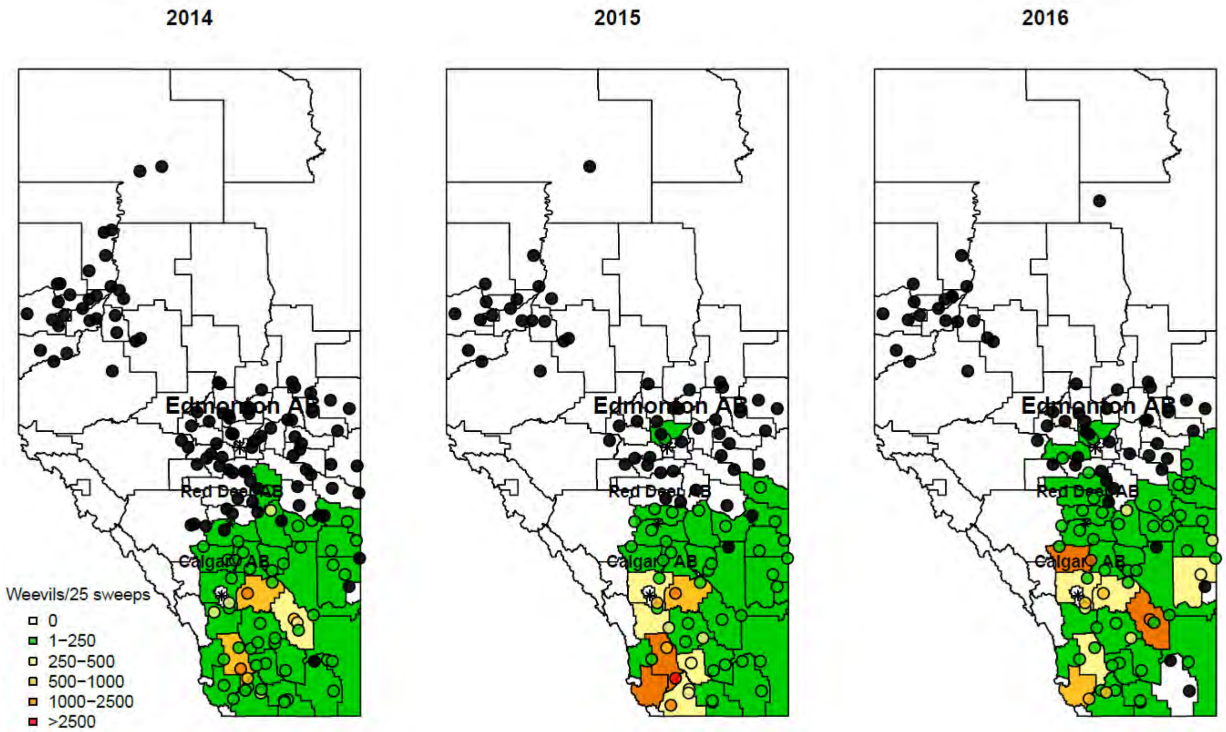


Figure 8. Maps of Alberta displaying the location and number of alfalfa weevils collected per 25 sweeps over the 3 year survey (2014-2016).

Species identification to *H. postica* was confirmed for the adults and larvae found in Sturgeon, Parkland, Flagstaff, Wainwright and Vermilion River through DNA barcoding. Barcoding on one larva from Vermilion River resulted in a poor quality DNA sequence. The resulting COI sequence appears to be two sequences overlaid, one with low confidence match with *H. postica* and the other to the genus *Bathyplectes*. The *Bathyplectes* genus contains species that are known parasitoids of *H. postica* larvae. The *H. postica* larva was likely parasitized by a *Bathyplectes* larva when it was collected and sent for sequencing, resulting in the amplification of both insects' COI region and a messy sequence. The sequence match to *Bathyplectes,* despite the low confidence, suggests that the parasitoid may be moving with the pest.

The presence of larval alfalfa weevils outside the expected range indicates that the weevils are actively breeding in the area rather than errant, migrating adults explaining our collection. Subsequent collections of both adults and larvae in the same locations the following year indicate the weevils have survived overwintering in these new areas and the populations are likely to be establishing. Comparison of the winter temperatures from 2014 through 2016 suggest that range expansion of the alfalfa weevil may be the result of the recent warmer winters.

Barcoding on larvae resembling *H. postica* from Greenview County in 2015 and Smoky Lake in 2016 identified the larvae as the species *Hypera trivittata* (Say 1831). *Hypera trivittata* has previously been collected in Alberta and while larvae were once collected off of veiny pea (*Lathyrus venosus*) little else is known about its ecology (Titus 1911). It is unlikely to be a pest of alfalfa, but due to its similarity to the alfalfa weevil, it may cause confusion as the range of the alfalfa weevil expands. In counties nearby to the alfalfa weevil range expansion, any adults and larvae resembling the alfalfa weevil should be submitted for identification. Confirmation is key to accurately track changes in the alfalfa weevil's range, which will allow the appropriate management tools to be used.

Alfalfa blotch leafminer adults

The confirmation of a single species of *Agromyza* leafminer, the alfalfa blotch leafminer (*A. frontella*), as responsible for the comma-like mines found across Alberta in alfalfa fields, allowed for the adult *Agromyza* collected in sweep samples to be identified to this species. Adults of the ABM were most abundant in 2014 in the parkland agro-ecoregion (Fig. 9), but numbers, like those of the leaf mines, in this agro-ecoregion dropped significantly ($p<0.05$) by 2015. Over the three year survey, the adult numbers in the grasslands agro-ecoregion remained relative constant while those in the boreal decreased (Fig. 9), mirroring the trend seen in leaf mine number (Fig. 3).

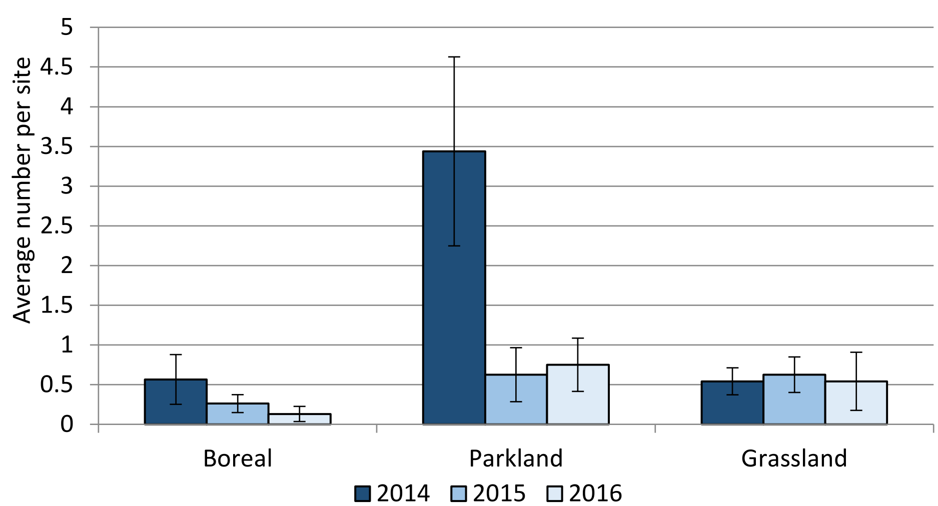


Figure 9. Average number (+S.E) of *A. frontella* adults per site over the 3 year survey (2014-2016) in each agro-ecoregion of Alberta.

Lygus spp.

Lygus bugs overwinter as adults and emerge in the spring to breed and lay eggs (Aasen and Bjorge 2009). A significant increase was seen in the average number of nymphs collected in both the parkland and grassland regions between 2014 and 2015 (Fig. 10). Over the three years, adult numbers increased in all three regions, but adult numbers were always well below those of nymphs (Fig. 10) likely due to overlap between the timing of the survey and nymphal emergence in fields. When nymphs and adult numbers are combined, the size of *Lygus* bug populations increased over the survey (Fig. 11).

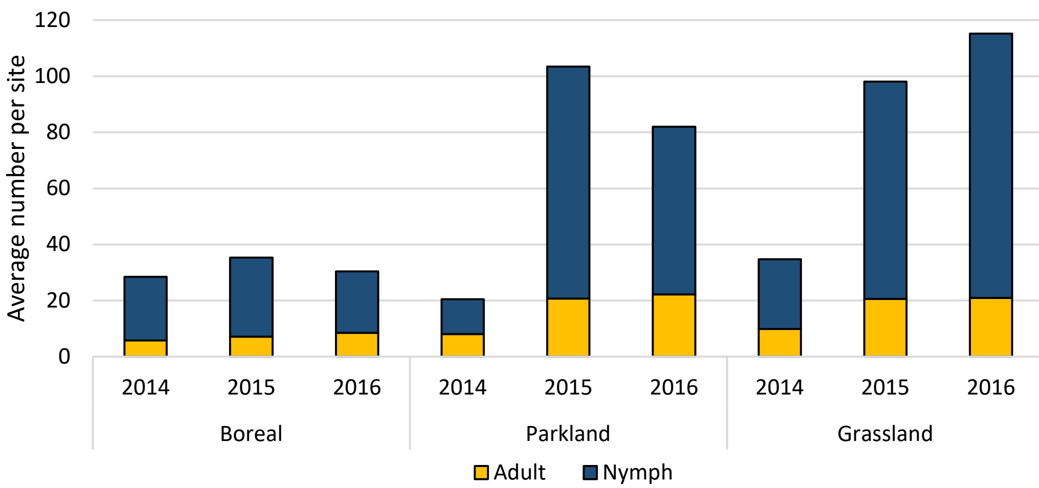


Figure #. Change in the average abundance of adult and nymph lygus bugs over the 3 year alfalfa survey (2014-2016) in each agro-ecoregion

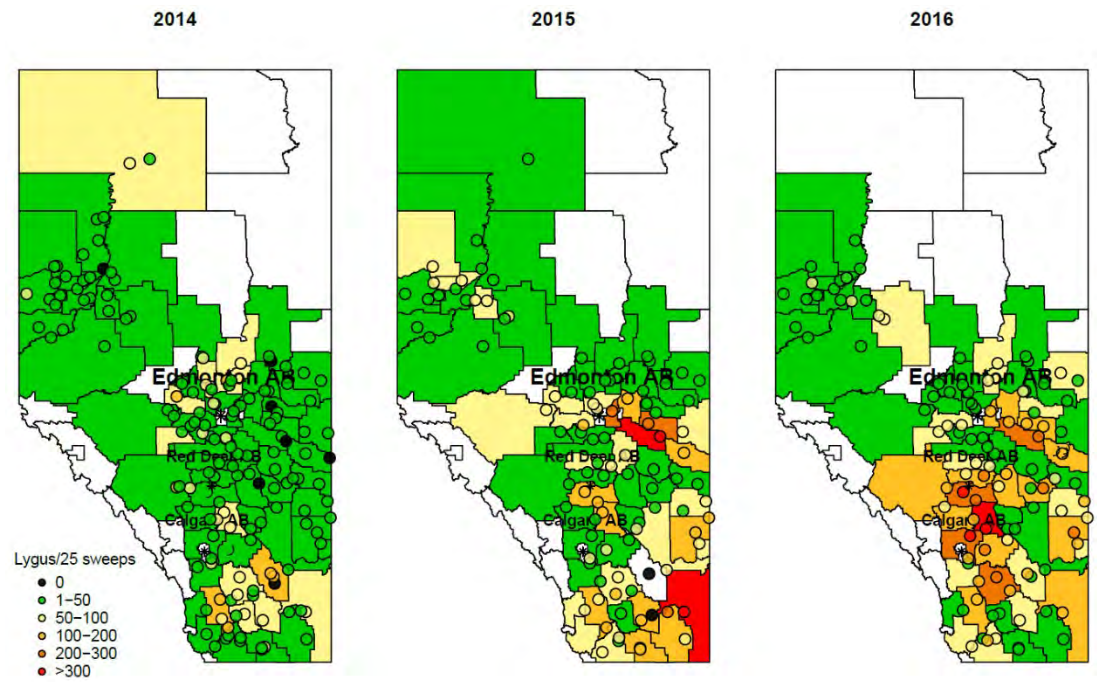


Figure 11. Maps of Alberta displaying the location and number of *Lygus* collected per 25 sweeps over the 3 year survey (2014-2016).

The adult lygus specimens were identified to four main species: *Lygus lineolaris* (Palisot de Beauvois), *L. keltoni* (Schwartz and Foottit), *L. borealis* (Kelton) and *L. elisus* (Van Duzee). Though *L. borealis* was found to be the dominant species in Saskatchewan alfalfa fields from mid-June to early July (Braun *et al.* 2001), *L. borealis* was not found to be dominant in any agro-ecoregions during the Alberta survey (Fig. 12). In fact, while *L. borealis* was more abundant than *L. elisus* in the grasslands agro-ecoregions, it was often less abundant than *L. elisus* in the boreal (Fig. 12).

Throughout all three years of the survey, *Lygus keltoni*, a species not found in Saskatchewan (Braun *et al.* 2001), and *L. lineolaris* were the most numerous species. The average number of *L. lineolaris* at each site increased significantly over the three year survey in the parkland ($p<0.05$) and grasslands ($p<0.05$) ecoregions, but remained relatively consistent in the boreal region (Fig. 12). In contrast, the average number of *L. keltoni* per site increased in all agro-ecoregions (Fig. 12), but no increase was significant due to the large variation in number among sites. The boreal ecoregion has the lowest number of lygus bugs, but the species diversity was equal to that in the grasslands.

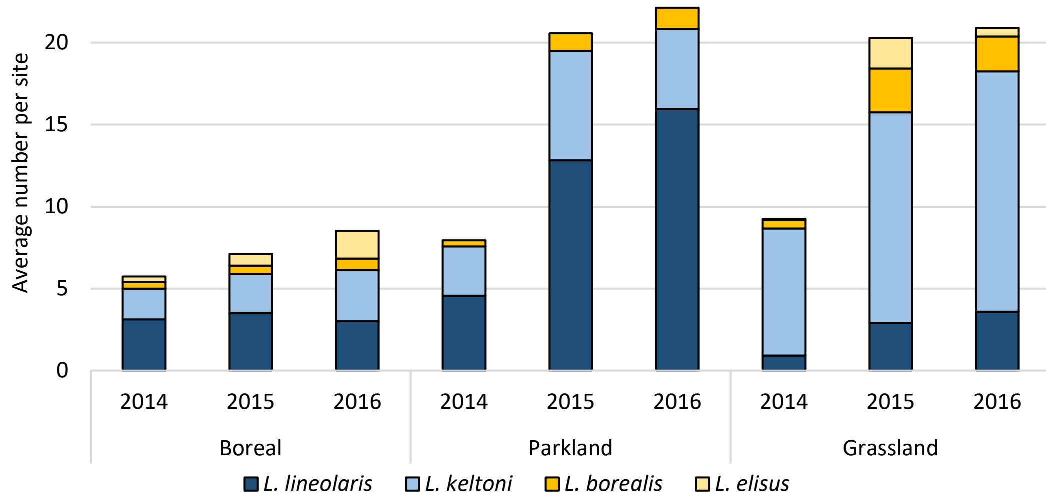


Figure 12. Variation in the species abundance of lygus bugs over the 3 year alfalfa survey (2014-2016) in each agro-ecoregion.

The lygus species assemblage in alfalfa fields varies among the agro-ecoregions of Alberta. In alfalfa fields from the grasslands agro-ecoregion, *L. keltoni* was found to dominate the species assemblage (Fig. 13), a result that is consistent with the dominant species found in canola in Alberta grasslands (Cárcamo *et al.* 2002). Also consistent with results from Alberta canola fields (Cárcamo *et al.* 2002) was the identification of *L. lineolaris* as the predominant species in alfalfa fields from the parkland and boreal ecoregions (Fig. 13). However, *L. keltoni*, while not the dominant species, makes up a large proportion of adult lygus bugs caught in alfalfa in the boreal region (Fig. 13), which was not seen in canola fields from this region (Cárcamo *et al.* 2002). The boreal species assemblage in alfalfa was seen to be variable over the three year survey, with *L. lineolaris* proportionally the most dominant species (Fig. 13), but variation in dominance at individual sites among *L. lineolaris*, *L. keltoni* and *L. elisus* (Fig. 14).

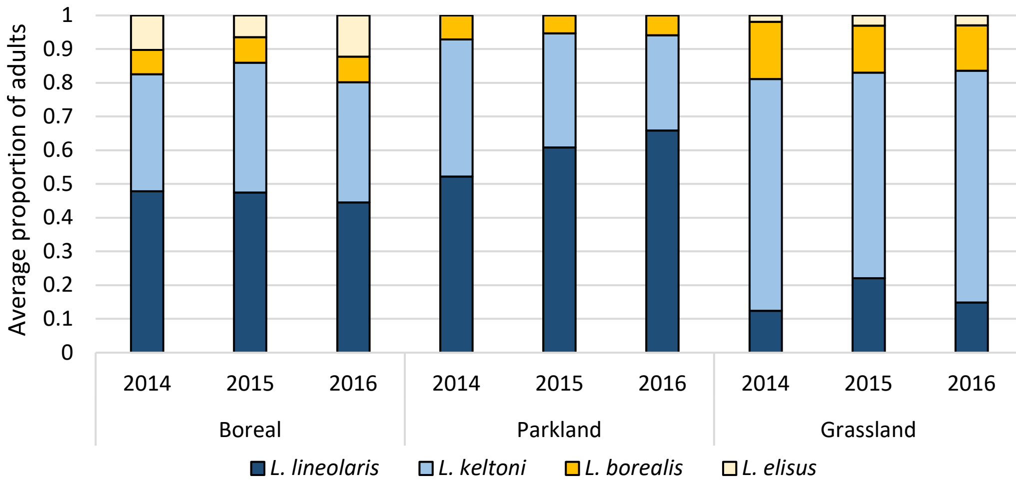


Figure 13. Variation in the species composition of lygus bugs over the 3 year alfalfa survey (2014-2016) in each agro-ecoregion.

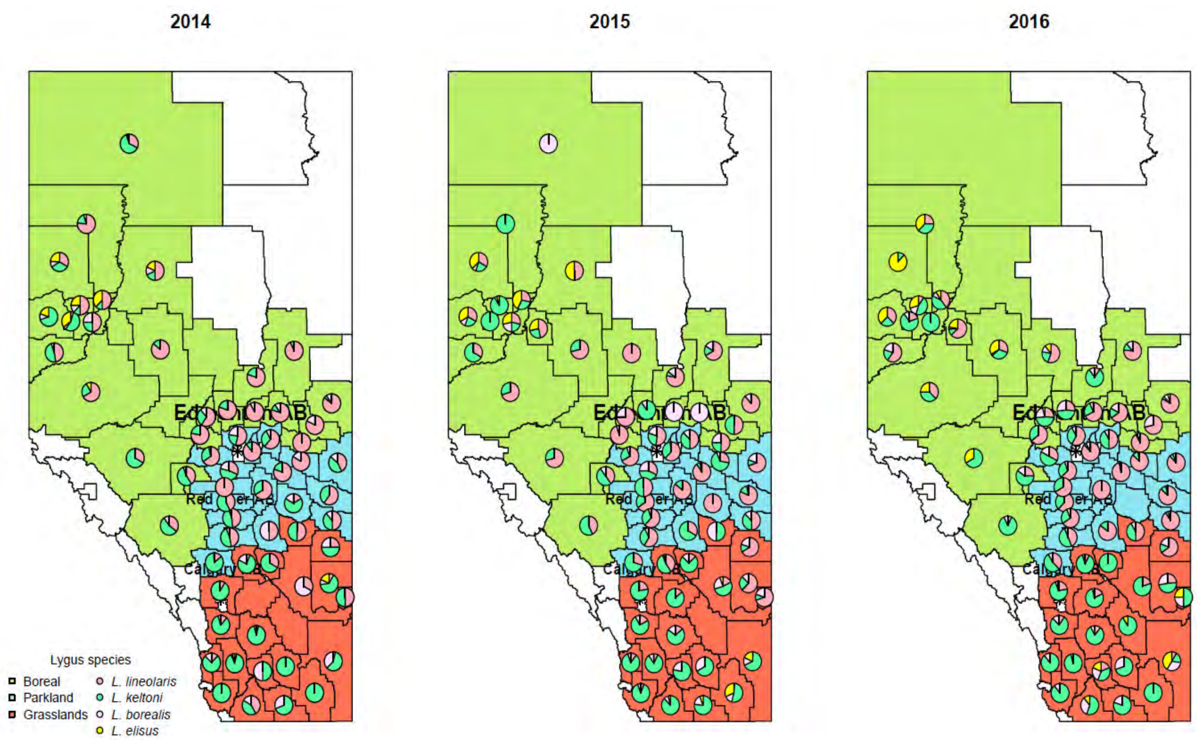


Figure 14. Maps of Alberta, with the 3 agro-ecoregions defined, displaying the average composition of *Lygus* spp. in each county over the 3 year survey (2014-2016).

The *L. elisus* specimens collected in the boreal agro-ecoregion vary in appearance from those found in the grasslands region. While those in the grasslands are light in color and often have two spots on the mesoscutum (Fig. 15A), *L. elisus* in the boreal region are darker and seldom have spots (Fig. 15B). The absence of this species in alfalfa fields in the parkland agro-ecoregion

(Fig. 14) suggests the populations in the boreal and the grasslands may be relatively isolated from each other. The physical variation may indicate the misidentification of two species as one or may be the result of regional variation.

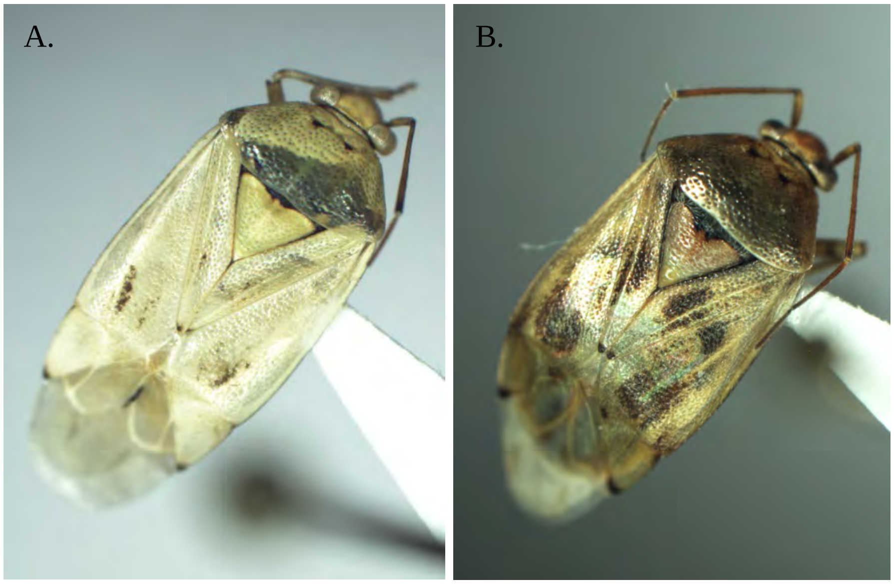


Figure 15. Colour variation observed between *L. elisus* found in (A) the grasslands, and (B) the boreal agro-ecoregions over the three year (2014-2016) alfalfa survey in Alberta.

In addition to the color variation in *L. elisus*, a few light colored lygus bugs were collected across the province that caused confusion during identification, but were ultimately identified as *L. keltoni*. Species confirmation cannot be done through genetic analyses at this time, due to uncertainty in species' boundaries within the *Lygus* genus (Roehrdanz and Wichmann 2015). Therefore, specimens representing the different color variations will be sent to an expert for study.

Alfalfa plant bug

Alfalfa plant bug is most numerous in the grasslands agro-ecoregion, but numbers decreased across all agro-ecoregions over the three year survey (Fig. 16). In every year of the survey, more alfalfa plant bug nymphs were collected than adults (Fig. 16), the majority of which were late stage nymphs. The largest number of nymphs was collected in 2014, with a provincial total of 3143, followed by a significant drop in number at boreal and grassland sites by 2015 (Fig. 16). Adult numbers were highest in 2015 (Fig. 16), with a total of 310 across the province, whereas less than 60 were collected in the other two years.

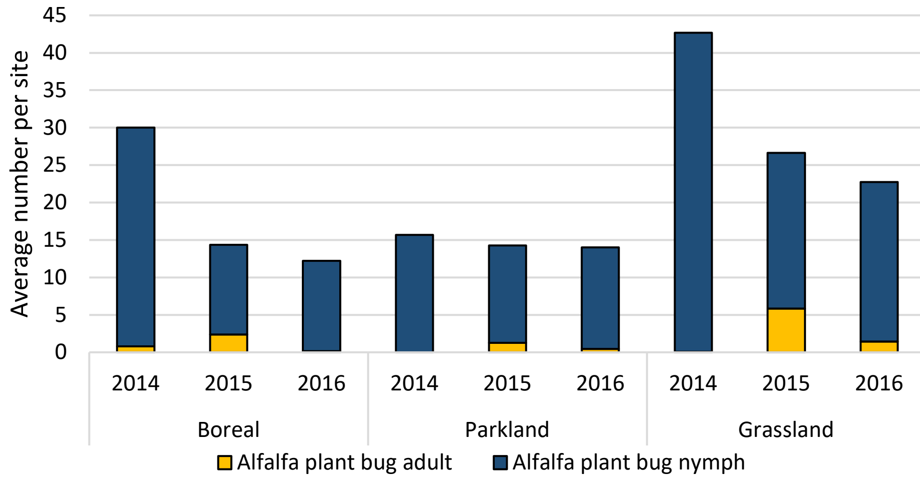


Figure 16. Average abundance of the alfalfa plant bug, over the 3 year survey (2014-2016) in each agro-ecoregion of Alberta.

The alfalfa plant bug, unlike lygus bug, has one generation per year in Alberta, with a rare second generation if the weather permits (Aasen and Bjorge 2009). It is the egg stage of the alfalfa plant bug that overwinters, which means nymphs are seen in fields before the adults. The appropriate timing of surveys for the alfalfa plant bug is critical as thresholds are set for the late stage, 4^{th} and 5^{th}, instar nymphs. The Alberta Forage manual suggests a threshold of four late stage instars per 180° sweep (Aasen and Bjorge 2009). Based on the limited number of early instar nymphs collected, our survey dates likely overlapped with the development of the later nymphal instars and the newly emerging adults. Using the set economic threshold (Aasen and Bjorge 2009), six fields in 2014 were found to have significant numbers of alfalfa plant bug (≥100/25 sweeps), one in 2015 and four in 2016 (Fig. 17).

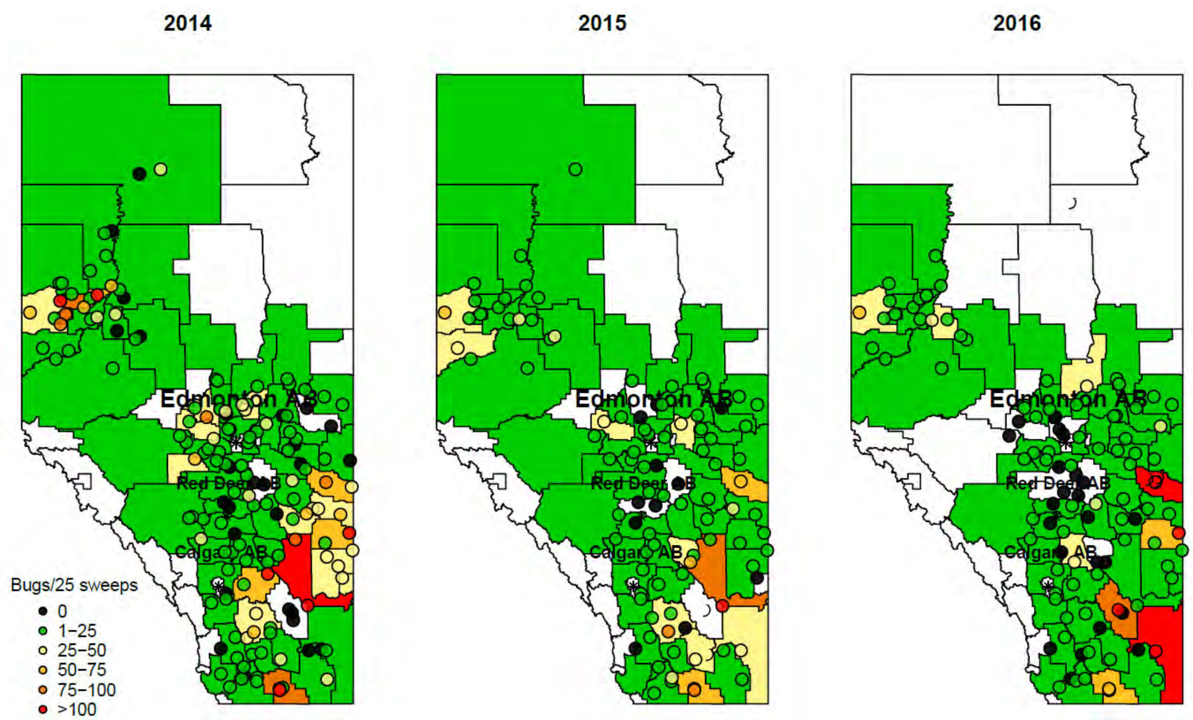


Figure 17. Maps of Alberta displaying the location and number of alfalfa plant bug collected per 25 sweeps over the 3 year survey (2014-2016).

Aphids

Pea aphid and spotted alfalfa aphid populations, under the right conditions, can build-up quickly and do significant damage to alfalfa fields. Though both aphids encourage the growth of sooty molds, due to the honeydew they excrete, the saliva of the spotted alfalfa aphid causes necrosis (Madhusudhan and Miles 1998). This toxin in spotted alfalfa aphid saliva can interfere with plant growth and development, making the spotted alfalfa aphid a greater concern than the pea aphid.

The absolute numbers of pea aphid and spotted alfalfa aphid increased over the three survey years (Fig. 18 and 19). From 2014 to 2016, the absolute number of the pea aphid increased from 5728 collected across the province to 9462, while the number of spotted alfalfa aphids increased from 201 to 1643. The increase in aphid numbers is due largely to expanding populations in the grasslands agro-ecoregion.

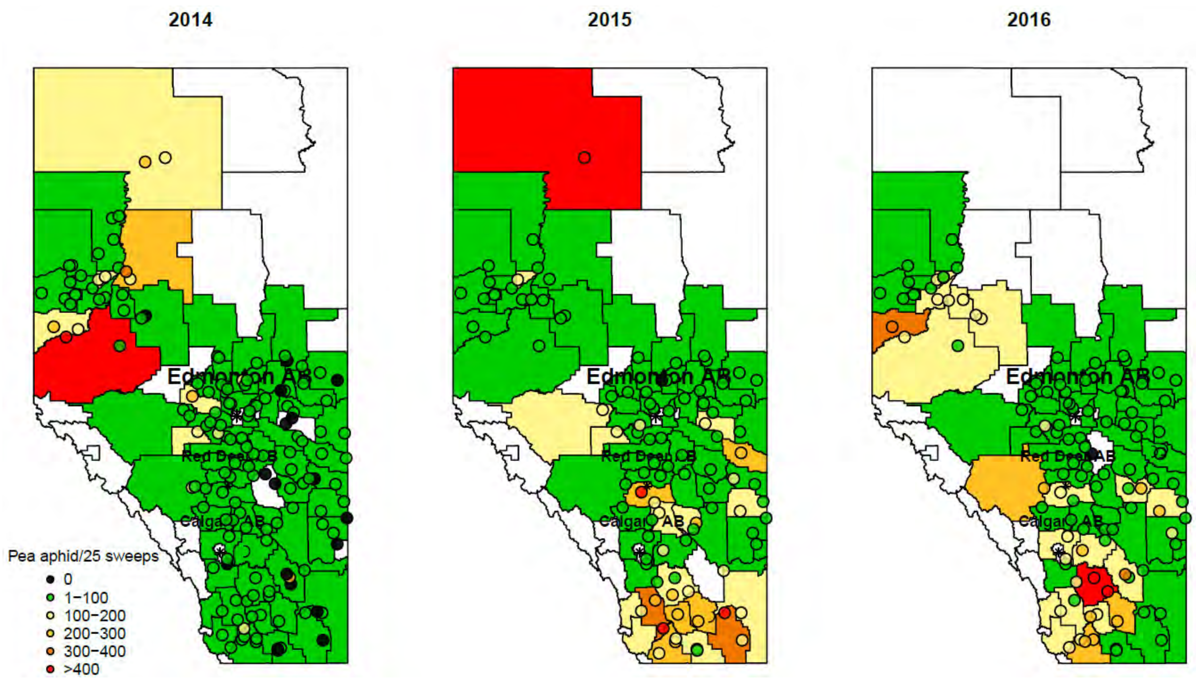


Figure 18. Maps of Alberta displaying the location and number of pea aphid collected per 25 sweeps over the 3 year survey (2014-2016).

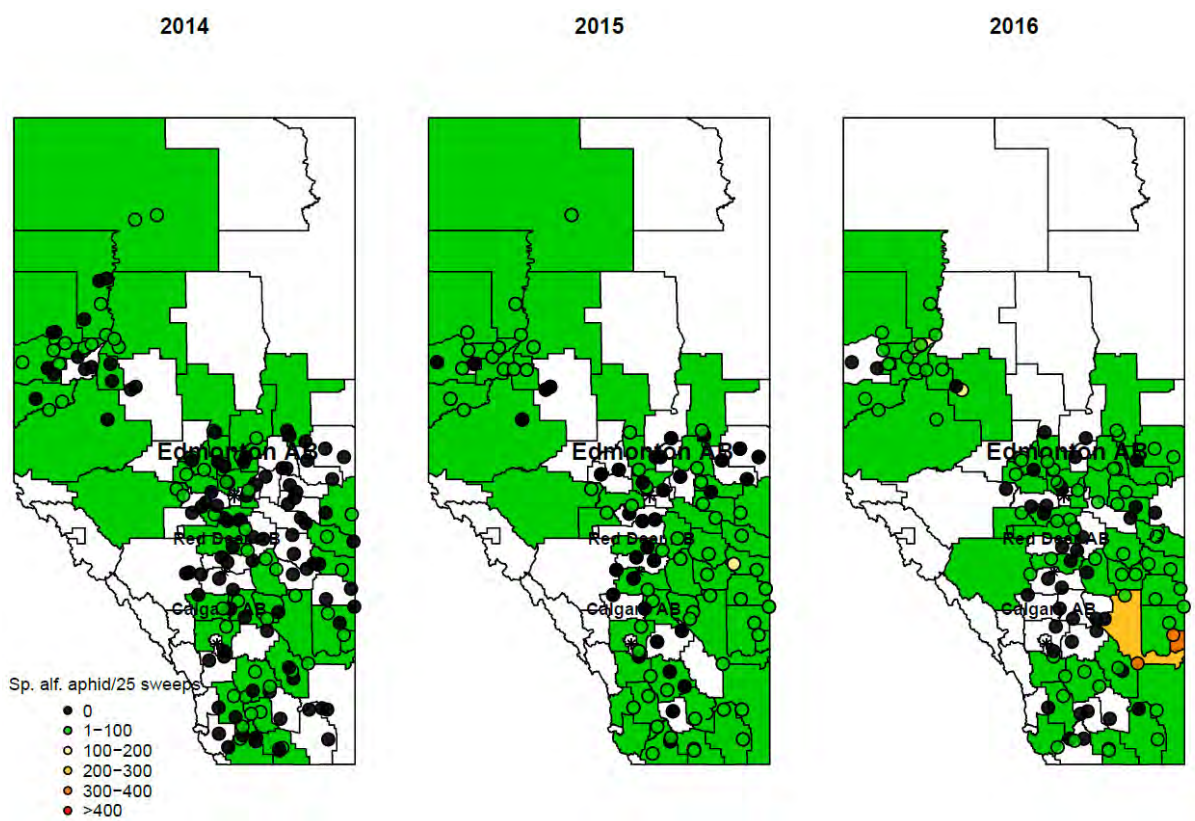


Figure 19. Maps of Alberta displaying the location and number of spotted alfalfa aphid collected per 25 sweeps over the 3 year survey (2014-2016).

The population trends of the two aphid species were similar in the grasslands and parkland ecoregions where numbers inscreased significantly between 2014 and 2015, but not between 2015 and 2016 (Fig. 20 and 21). While the average number of pea aphids per site did not vary significantly among the years in the boreal ecoregion (Fig. 20), the average number of spotted alfalfa aphid increased significantly in this region from 2014 to 2016 (Fig. 21). First reported in Alberta in 1981, populations of the spotted alfalfa aphid remained low seven years after its introduction (Harper 1988). Unfortunately, as no actual population numbers were reported by Harper (1988) and no province wide surveys have been conducted in recent time, it difficult to determine if the increase in spotted alfalfa aphid numbers indicates a growing risk to alfalfa production in Alberta or if it is simply an artifact of population fluctuations. However, the population numbers recorded from this survey may be used for comparison in future years to determine a baseline population for the spotted alfalfa aphid and help growers make decisions regarding planting aphid-resistant varieties.

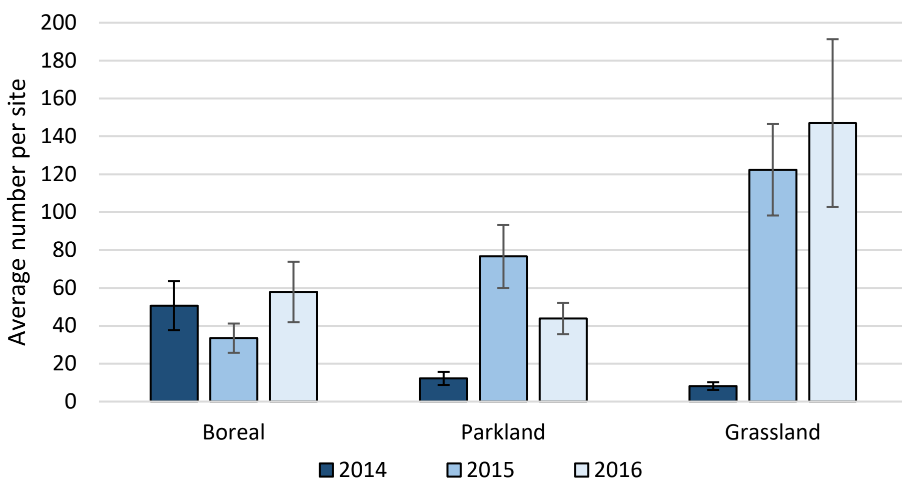


Figure 20. Change in average abundance (+S.E) of the pea aphid over the 3 year survey (2014-2016) in each agro-ecoregion.

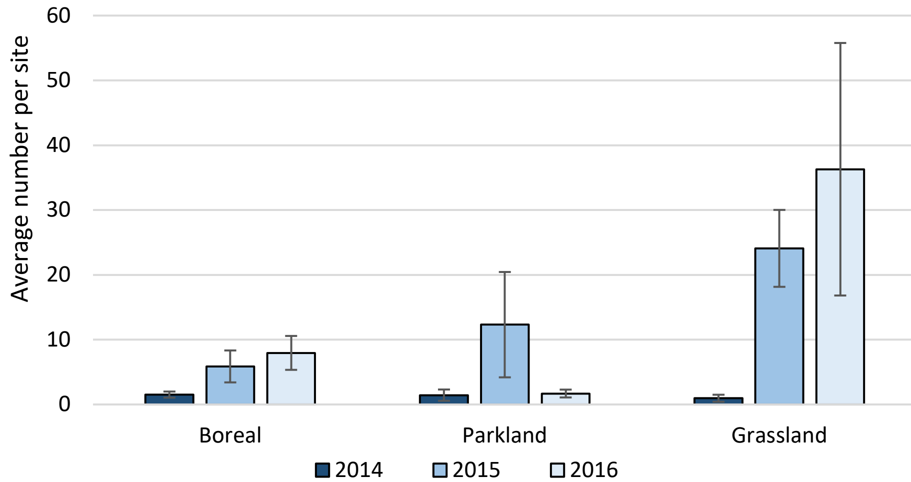


Figure 21. Change in average abundance (+S.E) of the spotted alfalfa aphid over the 3 year survey (2014-2016) in each agro-ecoregion.

Spittlebugs and leafhoppers

Spittlebugs, also known as froghoppers, are most easily recognized by the froth they create around egg masses and the nymphs. Spittlebugs are generally minor pests of alfalfa and relatively low numbers of them were found throughout the three year survey (Fig. 22). In 2016, the lowest numbers of spittlebugs were seen across all agro-ecoregions (Fig. 22), potentially due to a dry spring.

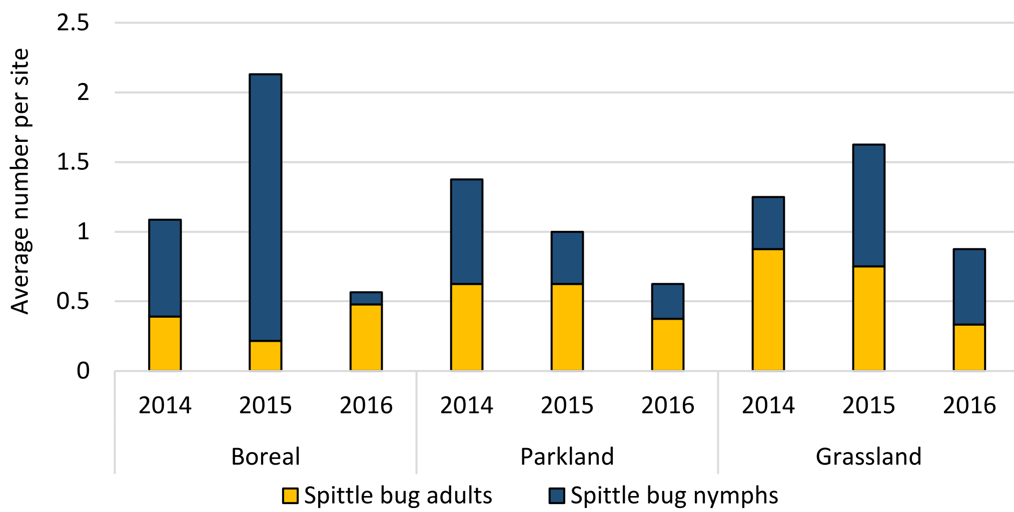


Figure 22. Change in average abundance of spittle bugs over the 3 year survey (2014-2016) in each agro-ecoregion of Alberta.

Leafhoppers inject plants with a toxin during feeding and are, therefore, considered to be a major pest of alfalfa in high numbers, especially the potato leafhopper. Leafhopper numbers did not vary significantly over the survey in any of the agro-ecoregions (Fig. 23). In 2016, the leafhopper count at a site in the Municipal District of Provost reached 841, while no sites in any other county reached over 300 leafhoppers during the survey.

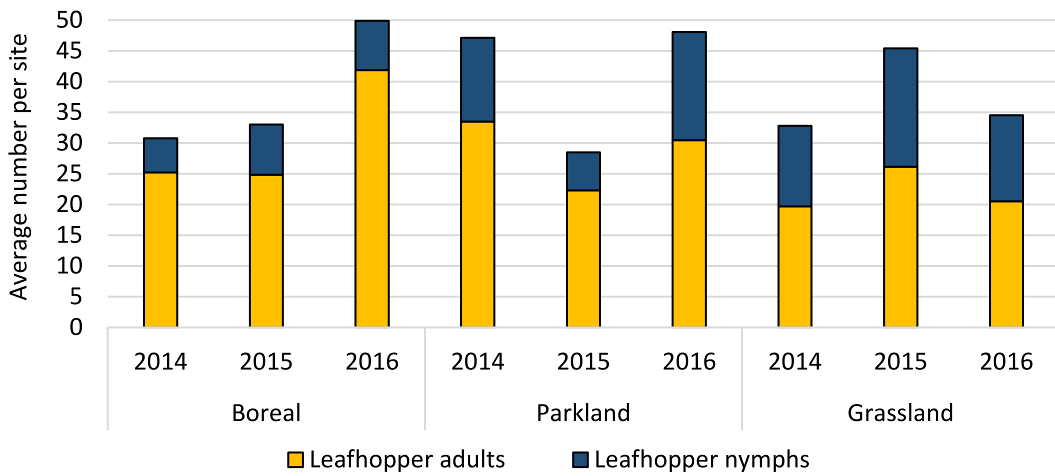


Figure 23. Change in average abundance of leafhoppers over the 3 year survey (2014-2016) in each agro-ecoregion of Alberta.

An adult female wasp of the Dryinidae genus *Gonatopus* Ljungh, parasitoids of leafhoppers and spittle bugs, was found in sweeps from two sites in 2015 and another three adults were collected in 2016. They have modified forelegs (Fig. 24A) that allow them to grasp onto a host, in this case either a spittle bug or leafhopper, and lay an egg. The larvae develop in sacs that protrude from the host's body. These larval sacs were observed protruding from the bodies of leafhoppers and spittlebugs (Fig. 24B) in every agro-ecoregion. The widespread appearance of parasitoid sacs indicates they are an established natural parasitoid, though the family is not reported in the 1988 list of alfalfa insects (Harper).

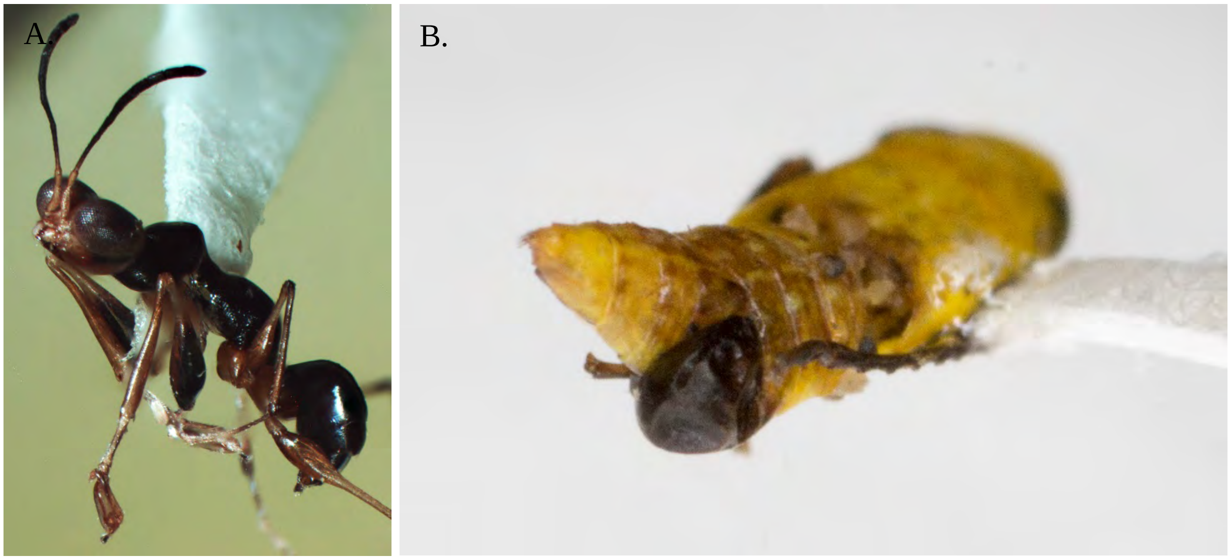


Figure 24. The parasitic Dryinidae wasp (*Gonatopus* sp.) has modified forelegs (A) for grasping onto hosts and the larvae develop in protruding sacs, on the host's abdomen (B).

The *Gonatopus* parasitoid is not available commercially and, the observed parasitoid sacs occurred in low frequency across the province. The number of parasitoid sacs has a positive but weak correlation with the number of leafhoppers, making it difficult to determine how significantly this parasitoid contributes to biocontrol of leafhoppers and spittle bugs. Dissections of the host pest would be required to get a more accurate estimate of parasitism by this wasp.

Minor pests of alfalfa

Low numbers of black grass bugs (*Labops* spp.), green grass bugs (*Stenodema* spp.), false chinch bugs (*Nysius* spp.) and various stink bugs (Pentatomidae) were collected every year; however, as none of these insects are considered to do significant damage to alfalfa (Harper 1988), they will not be discussed further. *Sitona* weevils and thrips were identified to species and will be discussed briefly, while discussion of springtails, mites, Orthoptera and Lepidoptera will be minimal due to taxonomic identification going no further than order.

Sitona weevils

The *Sitona* weevils collected were identified in 2015 and 2016 to one of three species: the pea leaf weevil (*S. lineatus* L.), the sweet clover weevil (*S. cylindricollis* Fåhraeus) or the clover root curculio (*S. hispidulus* Fabricus). Both *S. lineatus* and *S. cylindricollis* will feed on alfalfa, the adults on the foliage and growing points while the larvae feed on the roots' nitrogen fixing nodules; however, neither species completes their lifecycle on alfalfa plants. Only alfalfa fields in the seedling stage are at risk of serious damage if the number of feeding pea leaf weevil adults are sufficiently high.

The sweet clover weevil was the most prominent species (Fig. 25) in alfalfa fields across Alberta while pea leaf weevil was found at only a few sites and never in great number (Fig. 26). No more than one pea leaf weevil was collected at any site in 2015 (Fig. 27). In 2016, the highest numbers of pea leaf weevil, ranging from 4 to 14, were seen in Cardston, Lethbridge and Taber (Fig. 27). Adults were also being collected in counties on the edges of the pea leaf weevil's northern range: Parkland, Wainwright and Minburn in 2015, and Clearwater, Parkland and Sturgeon in 2016 (Fig. 27).

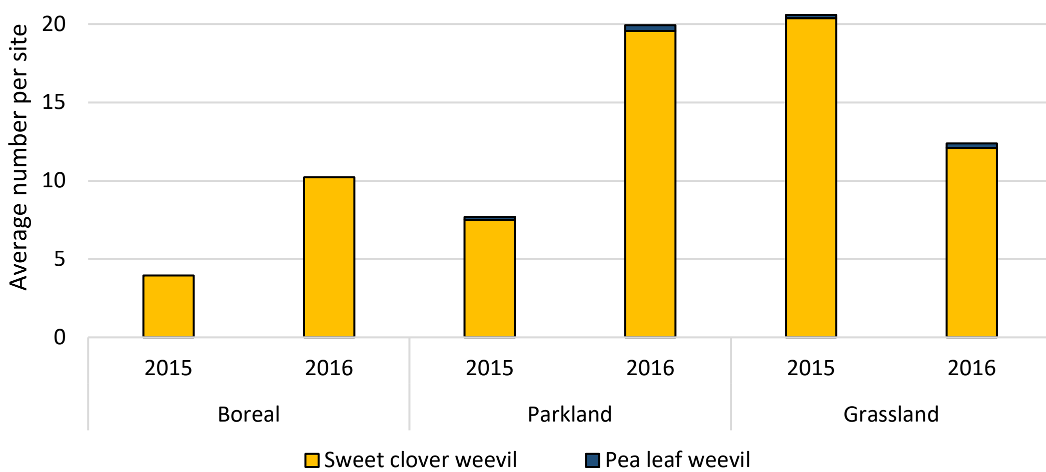


Figure 25. Change in average abundance of *Sitona* weevils over the 3 year alfalfa survey (2014-2016) in each agro-ecoregion.

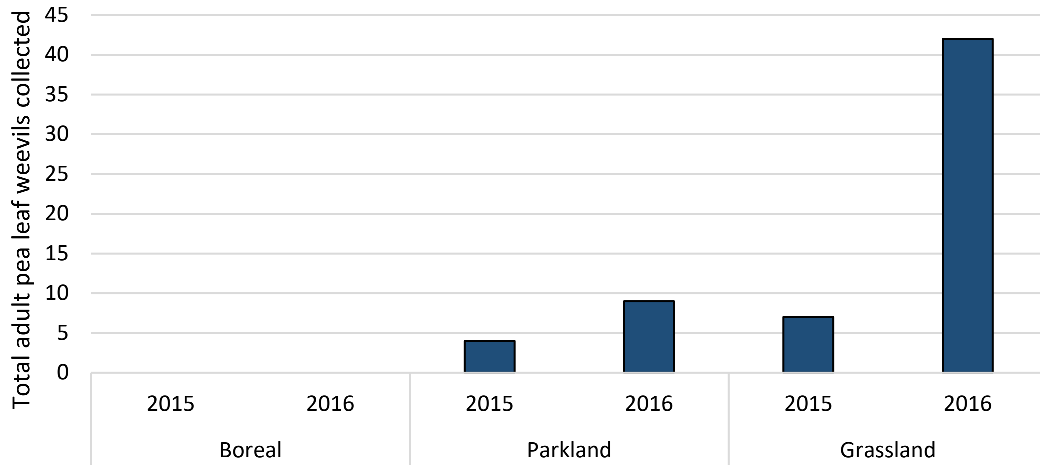


Figure 26. Absolute number of pea leaf weevil (*S. lineatus*) collected per year of the alfalfa survey (2014-2016) in each agro-ecoregion.

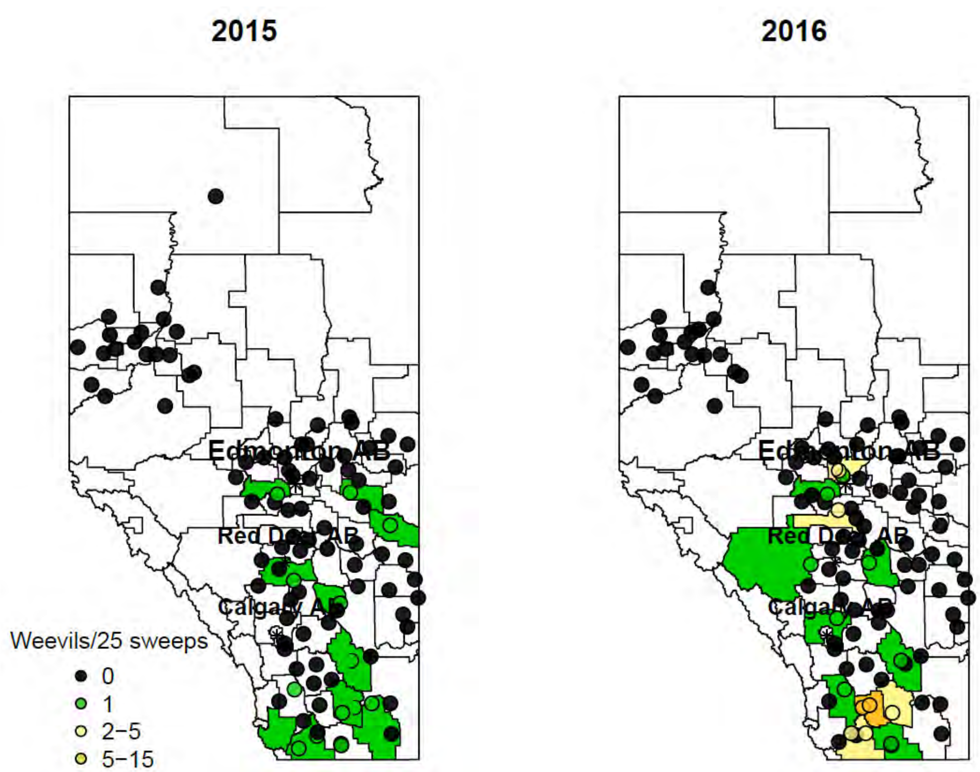


Figure 27. Maps of Alberta displaying the location and number of pea leaf weevil collected per 25 sweeps over 2 years of the survey (2015-2016).

The clover root curculio does complete its lifecycle on alfalfa plants and, as such, is of greater economic concern than the other two species. Clover root curculio has previously been found only in southern Alberta and this limited distribution is supported by our collections (Fig. 28). Collected only in Southern counties, the numbers were low in 2015, 4 in total, but 42 were collected in 2016. The 2016 numbers are due to larger populations at two sites, one in Cardston County with 30 adults and another in Lethbridge County with 10 (Fig. 28). The clover root curculio should be followed in the future to assess its population in southern Alberta.

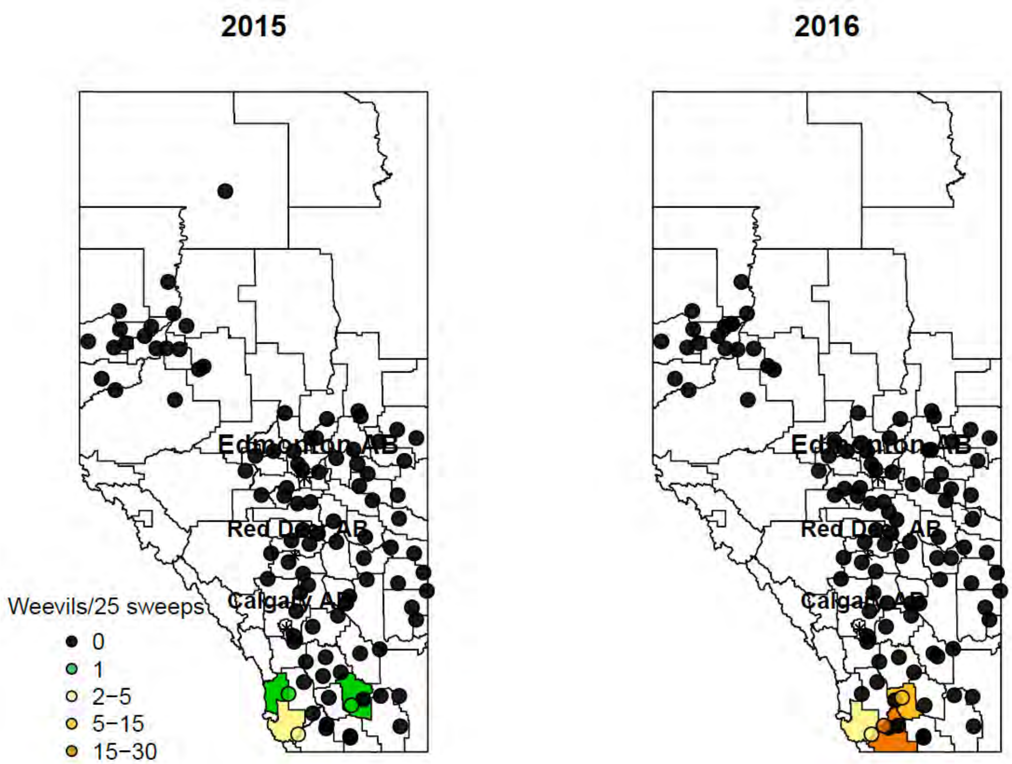


Figure 28. Maps of Alberta displaying the location and number of clover root curculio collected per 25 sweeps over 2 years of the survey (2015-2016).

Thrips, springtails and mites

Thrips were one of the most abundant insect groups, with their numbers increasing in every agro-ecoregion over the course of the survey (Fig. 29) and reaching a total abundance of 28, 275 in 2016. Thrips were most abundant in the grasslands ecoregion and least in the boreal (Fig. 29), likely due to the warmer, drier climate of the grasslands (Aasen and Bjorge 2009). Subsets of thrips were identified from the agro-ecoregions and the majority of thrips were determined to belong to the family Thripidae. Though members of the Thripidae family are pests (e.g. *Frankliniella occidentalis*), thrips tend not to be managed, instead their numbers are usually kept in check by predators (Aasen and Bjorge 2009).

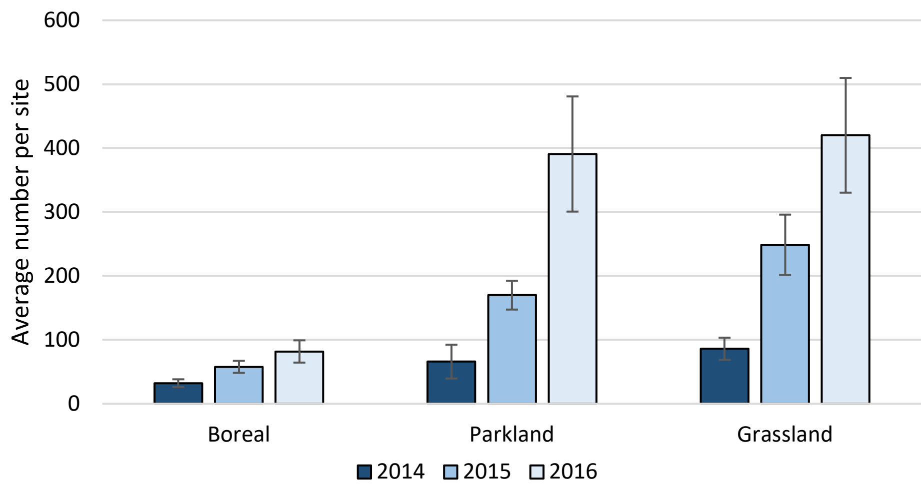


Figure 29. Change in average abundance (+S.E.) of thrips over the 3 year survey (2014-2016) in each agro-ecoregion of Alberta.

A small number of thrips with banded wings were collected every year and identified to the genus *Aeolothrips*. A single *Aeolothrips* species, *A. fasciatus* (L.), was reported in alfalfa by Harper (1988) and known to be an important in alfalfa fields as a predator. The bean thrip, *Caliothrips fasciatus*, a pest in seedling alfalfa stands, can be confused with *Aeolothrips* due to a similar appearance, but has not been reported in Alberta (Harper 1988) and was not identified in any of the survey samples.

The springtails and mites found in each sample were not identified beyond order due to the difficulty in identification and the lack of keys. Most springtails are not considered pests, but *Sminthurus viridis*, commonly called the Lucerne flea, can be a pest in alfalfa stands when numbers are sufficiently high. While this species has not been reported in Alberta (Harper 1988), a few springtails collected were of size with *S. viridis* and will need to be identified by an expert.

Grasshoppers

Though some grasshopper species are more destructive than others, alfalfa is not a preferred host for many species (Mulkern, *et al.* 1962), which means they are often seen only in low numbers in alfalfa fields. As few adult grasshoppers were caught they were not distinguished from nymphs when tallied. Grasshopper nymphs are difficult to identify to species and were, therefore, not further taxonomically divided. Due to the tendency for low numbers and their larger size, all grasshoppers from each sample were counted and numbers will be present in terms of 100 sweeps.

Numbers of grasshoppers were low in 2014, but increased in 2015 with the highest numbers seen in the boreal agro-ecoregion (Fig. 30). One boreal site, where 0 grasshoppers were collected in 2014, reached a total of 2487 in 2015 and dropped down to 0 again in 2016. Though the numbers dropped between 2015 and 2016, grasshopper nymphs remained common at sites across the province.

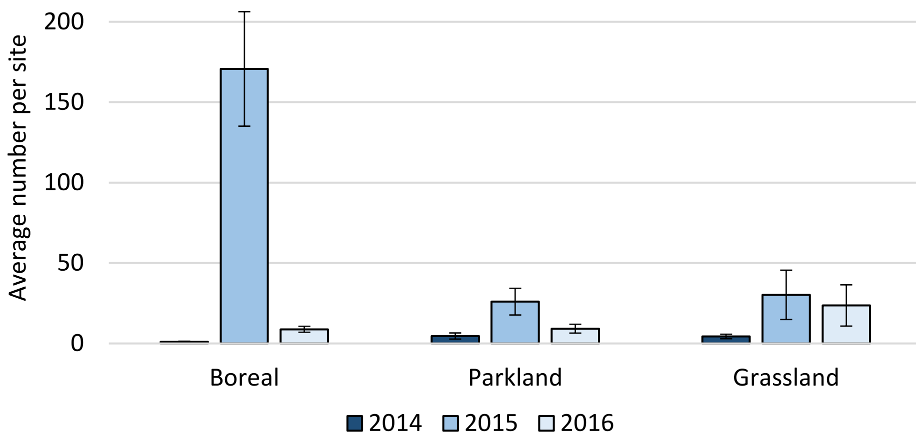


Figure 30. Average abundance (+S.E.) of grasshoppers, per entire 100 sweep sample, over the 3 year survey (2014-2016) in each agro-ecoregion of Alberta.

Lepidoptera

As with the grasshoppers, due to their large size the lepidopteran group was tallied for the entire sample rather than one-quarter. Adult Lepidoptera were rarely caught in a condition to allow ready identification, beyond moth or butterfly. Small white moths and European skippers accounted for the majority of the adult Lepidoptera caught throughout the survey years. More caterpillars were collected than adults, but, with the exception of the European skipper, they too were not identified to species. The number of immature and adult lepidopteran insects was lowest in 2014 across the province (Fig. 31). In the parkland and grasslands agro-ecoregions the numbers peaked in 2015, but continued to increase over the three years in the boreal agro-ecoregion (Fig. 31).

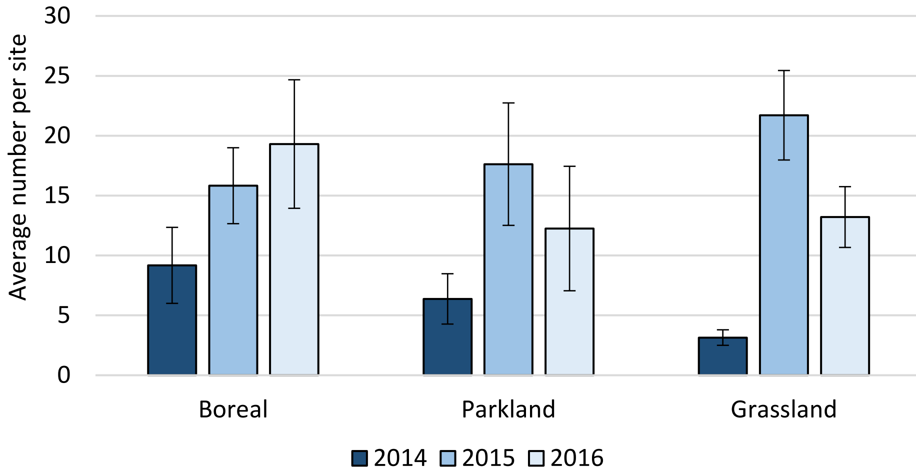


Figure 31. Average abundance (+S.E.) of Lepidoptera, per entire 100 sweep sample, over the 3 year survey (2014-2016) in each agro-ecoregion of Alberta.

Predators and beneficials

Big-eyed bugs (*Geocoris* sp.) were found in all agro-ecoregions, but will not be discussed further due to their scarcity. Larger predators (i.e. ladybird beetles, lacewings, syrphid flies, spiders and opiliones) were counted for the entire 100 sweep sample from each site. To account for this discrepancy and compare these predators to smaller predators that were counted per one-quarter sample (i.e. minute pirate bugs, damsel bugs, *Aeolothrips* sp. and big-eyed bugs), the larger predator numbers were divided by four to produce an estimate.

Over the three year survey, there was an average increase in predators that are able to hunt and/or disperse by flight, including: ladybird beetles, lacewings, syrphid flies, minute pirate bugs and the banded thrips (Fig. 32). The abundance of flying predators decreases from the southern grasslands agro-ecoregion to the northern boreal region, a trend that was observed in all three years (Fig. 32). However, the proportion of each predator remains relatively constant across agro-ecoregions (Fig. 32). Minute pirate bugs were the most prominent predator every year, in every agro-ecoregion (Fig. 32), which is standard for alfalfa insect communities (Harper 1988).

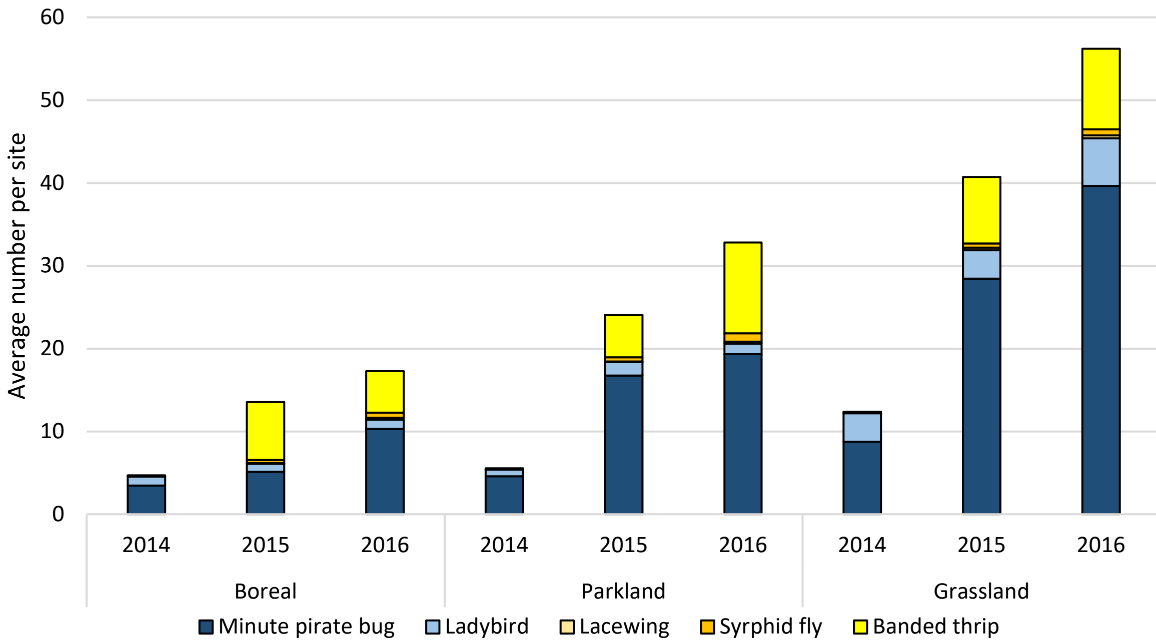


Figure 32. Average abundance of flying predators (ladybird beetles, lacewings, syrphid flies, minute pirate bugs and *Aeolothrips* sp.) over the 3 year survey (2014-2016) in each agro-ecoregion of Alberta.

Few lacewings and syrphid flies were collected over the course of the survey (Fig. 33) and the immature stage, which is the primary predacious stage of both lacewings and syrphid flies, was caught relatively rarely. As the numbers of these two predators are based heavily on the adult stage, they may not accurately reflect the actual number of the predacious larvae in the field. The larvae of both lacewings and syrphid flies are voracious predators, which means these predators may contribute more to pest control than their numbers in this survey indicate.

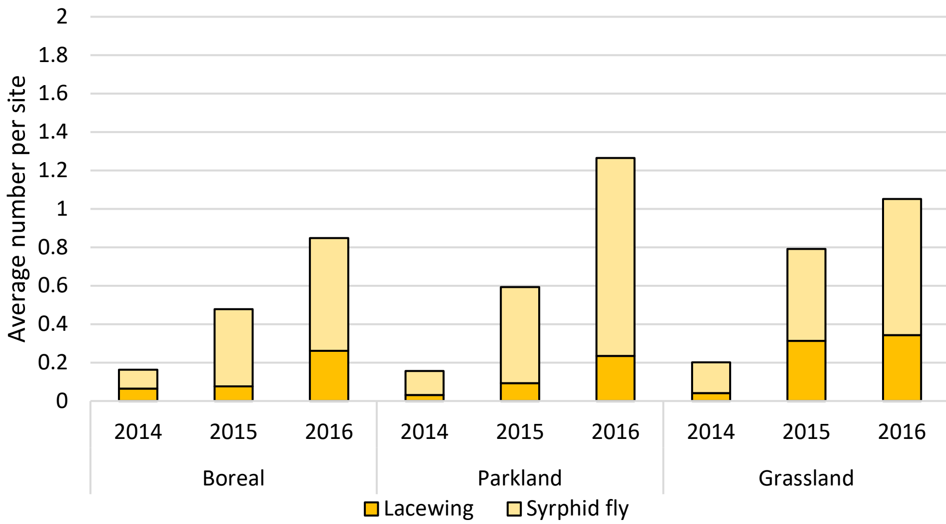


Figure 33. Average abundance of lacewings and syrphid flies over the 3 year survey (2014-2016) in each agro-ecoregion of Alberta.

Some species of Nabidae, commonly known as damsel bugs, found in alfalfa fields are able to fly; however, most are ambush predators and spend a significant amount of time motionless. Due to their tendency to walk rather than fly, damsel bugs were considered with the other walking predators, i.e. spiders and harvestmen. The lowest abundance of spiders and opiliones was see in 2014 in all regions, while their numbers peaked in 2015 (Fig. 34). Damsel bug numbers peaked in the grasslands in 2015 as well, but remained relatively constant in the other agro-ecoregions over the three year survey (Fig. 34). Spiders are the predominant walking predator in the grasslands agro-ecoregion, but neither the spiders nor the damsel bugs dominated in the other two agro-ecoregions (Fig. 34).

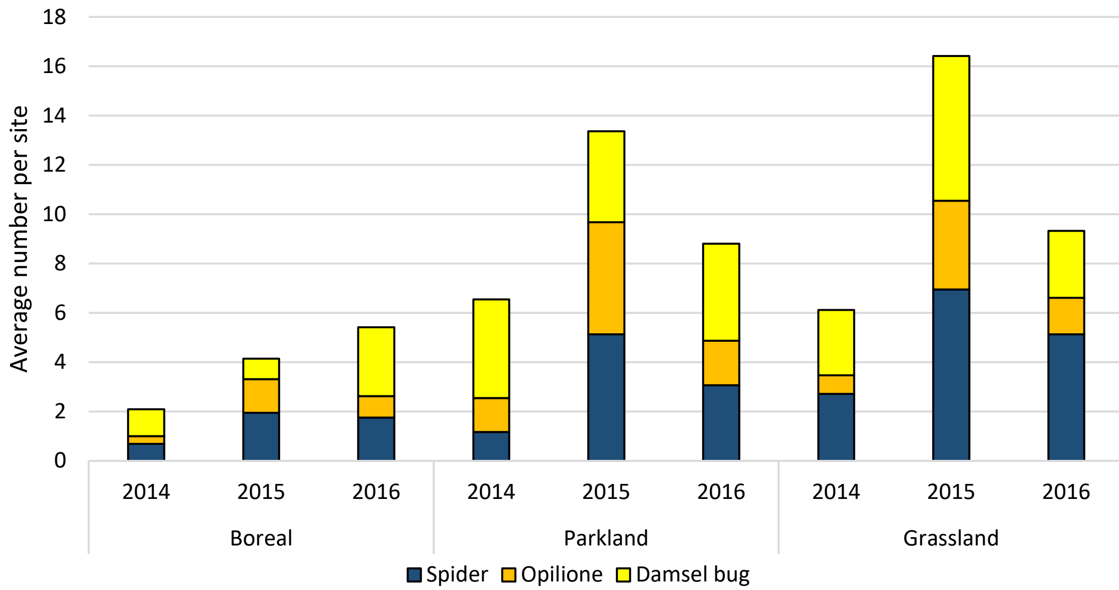


Figure 34. Average abundance of walking predators (spiders, harvestmen and damsel bugs) over the 3 year survey (2014-2016) in each agro-ecoregion of Alberta.

Ladybird beetles

The larvae of ladybird beetles, like the adults, are effective predators and, therefore, ladybird beetles are favored as biocontrol agents for pests. The popularity of ladybird beetles as predators has led to the introduction of non-native species to North America. Invasive species, mainly the seven-spotted ladybird beetle (*Coccinella septempunctat* L.), have been implicated in the decline and displacement of native species (Snyder *et. al.* 2004). Out of a total of twelve species of ladybird beetle caught across Alberta in the alfalfa survey, only one invasive species was collected, the seven-spotted (Table 5).

Ladybird beetles were most numerous in the grasslands agro-ecoregion (Fig. 35). No significant variation in abundance was found among years of the survey suggesting that populations of ladybird beetles in alfalfa fields remain relatively consistent; however, species diversity does vary. The highest species diversity was found in 2014 with nine species of ladybird beetle identified (Table 5). Over the entire survey, three species were consistently the most prominent: the seven-spotted ladybird beetle, the three-banded ladybird beetle (*Coccinella trifasciata* L.) and the parenthesis ladybird beetle (*Hippodamia parenthesis* Say).

Table 5. List of the 12 ladybird beetle species collected over the 3 year survey (2014-2016) in Alberta alfalfa fields and the ecoregions in which they were collected.

		7-spotted	3-banded	Parenthesis	2-spotted	Expurgate	Sinuate	13-spotted	Wee-tiny	5-spotted	Convergent	Hieroglyphic	Hudsonica
2014	B	•	•	•				•		•			
	P	•	•	•		•		•	•				
	G	•	•	•	•	•	•	•					
2015	B	•	•	•	•								
	P	•	•	•							•		
	G	•	•	•		•					•		
2016	B	•	•	•									•
	P	•	•	•				•				•	
	G	•	•	•	•		•	•					

The seven spotted lady beetle, an alien species to Canada, was the most abundant species in the parkland and grasslands agro-ecoregions (Fig. 35). In the boreal agro-ecoregion, the number of seven-spotted ladybirds is low and native species, particularly the three-banded ladybird beetle, outnumbered the seven-spotted every year (Fig. 35). The three-banded ladybird beetle is naturally found alongside the seven-spotted in Eurasia so it is not surprising that the three-banded species is able to compete with the introduced seven-spotted in Alberta (Acorn 2007).

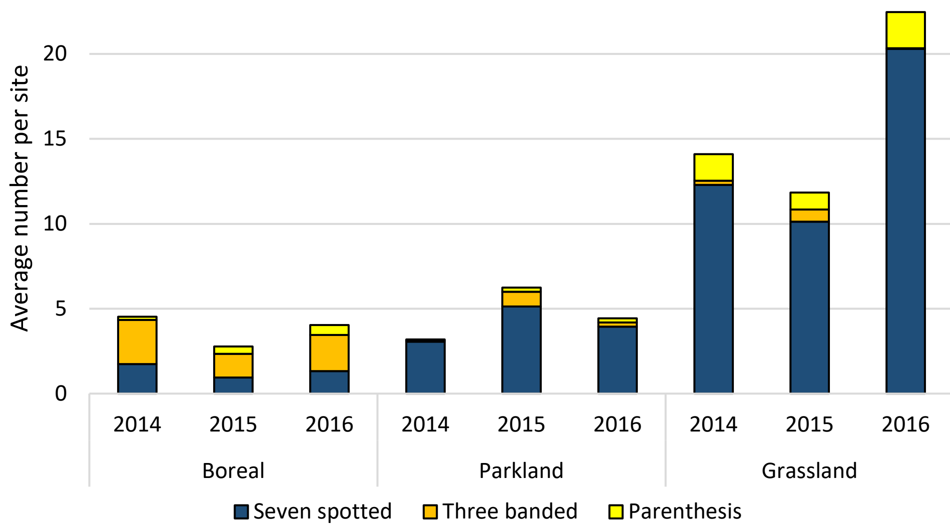


Figure 35. Average abundance of three ladybird beetle species (seven spotted, three-banded and parenthesis) over the 3 year survey (2014-2016) in each agro-ecoregion of Alberta.

A single two-spotted lady beetle (*Adalia bipunctata* L.) was collected every year, while the thirteen-spotted (*Hippodamia tredecimpunctata* L.) and the sinuate (*Hippodamia sinuate* Mulsant) ladybird beetles were found in two of the three years, 2014 and 2016. The numbers of both species in alfalfa were highest in 2016 with a total of 11 thirteen-spotted collected and 15 sinuate. The sinuate ladybeetle is physically similar to the convergent ladybird beetles (*Hippodamia convergens* Guerin) of which 16 were collected from alfalfa in 2015 only. It is interesting to note the temporal variation in species collection from alfalfa fields.

Spiders

Spiders are generalist predators found at the majority of sites across Alberta. Spiders collected from alfalfa fields in 2015 and 2016 were taxonomically divided to family, far enough to identify the method of prey capture used by these spiders. Spider species within a family generally use the same method of prey capture, which can include web building, ambush and active hunting.

Members of ten spider families were found in alfalfa fields in 2015 and 2016: five web building families, long-jawed (Tetragnathidae), orb-weavers (Araneise), mesh web weavers (Dictynidae), cob web weavers (Theridiidae) and sheet web weavers (Linyphiidae); two ambushing families , crab (Thomisidae) and running crab (Philodromidae) spiders; and three hunting families, wolf spiders (Lycosidae), jumping spiders (Salticidae) and sac spiders (Clubionidae). The number of spiders in web building families outnumbered those in the ambush and hunting families in both 2015 and 2016. The most dominant families were the long-jawed spiders, orb-weavers, crab spiders and running crab spiders. The long-jawed spiders, the most abundant spider family in alfalfa, constituted on average around 40% of the spider population in alfalfa fields across Alberta (Fig. 36). Few of the other families, such as wolf and sac spiders, were collected, likely due to their speed and ground dwelling, nomadic behavior.

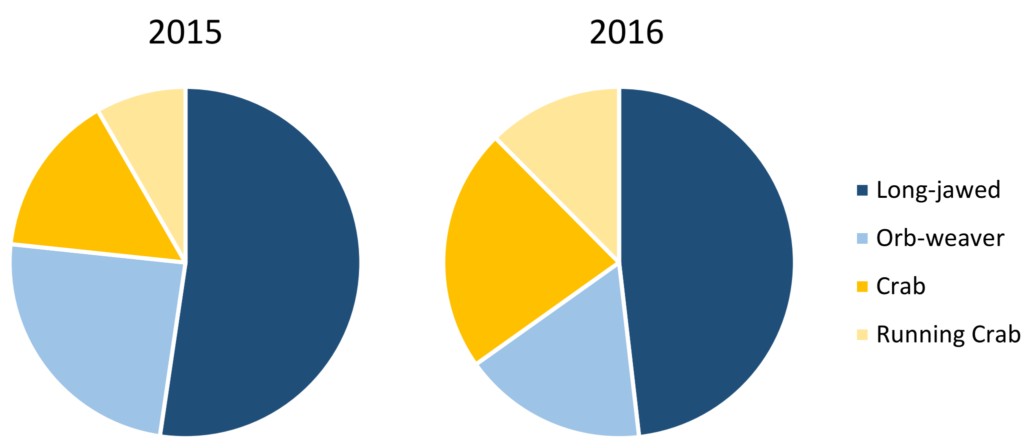


Figure 36. Main taxonomic family composition of total spider catch across all three agro-ecoregions in 2015 and 2016.

Wasps

The wasp category encompasses multiple families with many different habits. Wasps can be pollinators as well as predators and parasitoids. The wasps from each sample were all grouped together and not further taxonomically split. However, the majority of the wasps collected were small parasitoids from families such as Braconidae and Ichneumonidae, and many of these small parasitoids, such as species in the genus *Bathyplectes*, will use crop pests as hosts. Due to the lack of taxonomic identification past “wasp”, the numbers of wasps collected within the survey were not examined.

Bees

The number of bees caught throughout the alfalfa survey was low. In 2014, the average number of bees per 25 sweeps was below one in every agro-ecoregion. By 2016, the average number increased to one in the boreal and two in the parkland and grasslands agro-ecoregion. The low numbers are likely the result of the surveys occurring before or during early flowering in forage crops.

Only honey bees, the predominant group of bees collected, were identified to species, but a few leafcutter bees, belonging to the genus *Megachile*, were collected each year. Harper (1988) reported five native *Megachile* species present in alfalfa, as well as the introduced alfalfa leafcutter bee, *Megachile rotundata* Fabricius, which is used commercially for alfalfa pollination. Leafcutter bees can be subject to various diseases and parasites, including parasitism by flies in the Conopidae genus *Physocephala* (Stuke and Cardoso 2013). Multiple species within the *Physocephala* genus have been recorded parasitizing the commercial alfalfa leafcutter bee, *M. rotundata* (Stuke and Cardoso 2013), and these parasites have been important economic pests in some areas (Mihajlović *et al.* 1989, Seidelmann 2005). Though the manual for Alfalfa leafcutter bee management in Western Canada (Richards 1984) identifies conopid flies as a pest of foraging adult leafcutter bees, this family has received little attention in Canada and was not recorded in Harper’s list of insects in alfalfa (1988).

A female conopid fly, tentatively identified as *Physocephala furcillata* Williston (Fig. 37), was found in sweeps from Fairview County in the last year of the current survey. Unfortunately, the host species of *P. furcillata* is unknown and could be any of the bee species collected over the survey, including one of the native *Megachile* spp. or the commercial *M. rotundata*. As *Physocephala* spp. have been economic pests of *M. rotundata* in other areas of the world (Seidelmann 2005), it would be valuable to determine their impact on *M. rotundata* in Canada.

Figure 37. Suspect *Physocephala furcillata* Will. collected from an alfalfa field in Fairview County, AB in 2016.

Grey Tortrix moth

For both the 2014 and the 2016 survey for the Grey Tortrix moth neither larvae nor evidence of feeding by the Grey Tortrix moth were found. A follow up with the Alberta Lepidopterists Guild confirmed that this species has yet to be reported in Alberta (Greg Pohl personal communication). Continued monitoring for this pest should continue to avoid potential expansion into Alberta going undetected.

Paired *Lygus* study

Due to the variation in harvest time of alfalfa fields during the 2014 paired study, there were no "cut" groups that contained sufficient field pairs for analysis. Only results from the 2015 and 2016 component of the paired study will be presented. Throughout the study, both canola and alfalfa fields were dominated by *L. keltoni* and *L. lineolaris* while numbers of *L. borealis* and *L. elisus* were low (Table 6). The species *L. borealis* was more common in alfalfa fields than canola fields (Table 6); however, the low number of *L. borealis* in each sampling period prevented this difference from being significant. Due to the lack of significant variation in species composition between alfalfa and canola fields, all species were lumped together and the total catch was analyzed.

Table 6. The percent (%) species composition of the total *Lygus* catch from "cut" and "uncut" canola and alfalfa fields over the length of the paired study (2015 and 2016).

		L. lineolaris	*L. borealis*	*L. elisus*	*L. keltoni*
2015	"Cut" Canola	49.25	1.57	0.26	48.92
	"Cut" Alfalfa	36.94	7.72	0.30	55.04
	"Uncut" Canola	51.80	3.60	0.72	43.88
	"Uncut" Alfalfa	42.47	22.60	0.68	34.25
2016	"Cut" Canola	28.93	3.14	0.00	67.92
	"Cut" Alfalfa	27.87	5.74	1.09	65.30
	"Uncut" Canola	16.67	4.17	4.17	75.00
	"Uncut" Alfalfa	10.74	5.25	3.10	80.91

Harvesting of "cut" alfalfa did not coincide with increases in *Lygus* spp. numbers in "cut" canola fields in 2015 (Fig. 38) nor in 2016 (Fig. 39). In fact, *Lygus* spp. populations in "cut" canola fields decreased following alfalfa harvest 2015 (Fig. 38) and 2016 (Fig. 39). In both study years, *Lygus* spp. population trends in "cut" canola fields (Fig. 38 and Fig. 39) were consistent with trends observed in the "uncut" canola fields (Fig. 40 and 41), regardless of alfalfa harvest time. Therefore, it appears that the changes in *Lygus* spp. population numbers in the paired canola fields are largely independent of alfalfa harvest in neighboring fields.

Peaks in *Lygus* spp. populations in canola are seen in early July in both years (Fig. 38-41) and again in late July and early August in 2016 (Fig. 39 and 41); however, a decreasing trend is seen in *Lygus* populations in alfalfa across both years (Fig. 38-41). The peaks and decreases in *Lygus* spp. are similar to those observed in Saskatchewan canola and alfalfa fields (Braun *et al.* 2001). Similar population trends in canola fields from two different provinces suggests the relationship between the pest and crop type is responsible for increasing pest pressure rather than harvest time in alfalfa. The belief that lygus bugs move from alfalfa to canola following harvest is, therefore, likely due to alfalfa harvest preceding natural population booms of *Lygus* spp. in canola fields rather than dispersal from the harvested field.

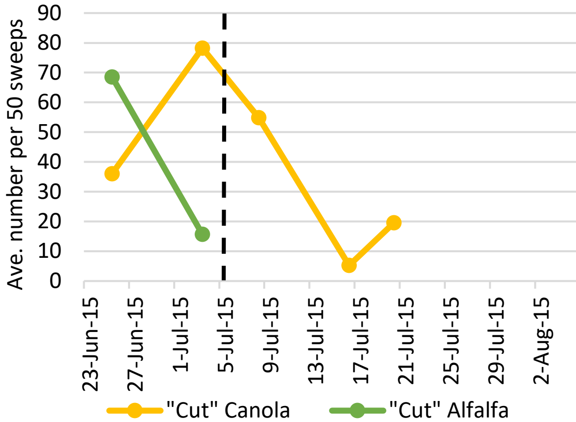


Figure 38. *Lygus* population trends in "cut" canola and alfalfa fields in 2015. Dashed line indicates harvest in "cut" alfalfa fields.

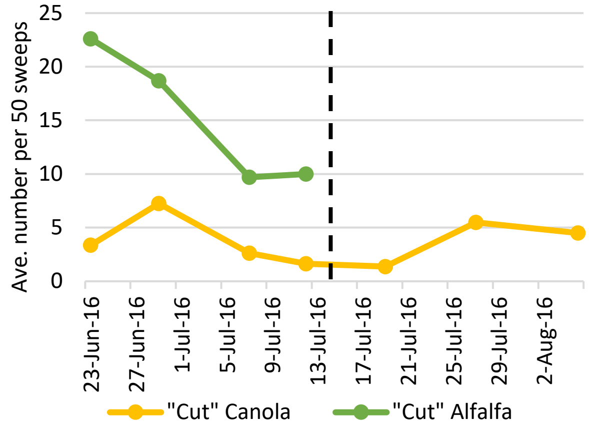


Figure 39. *Lygus* population trends in "cut" canola and alfalfa fields in 2016. Dashed line indicates harvest in "cut" alfalfa fields.

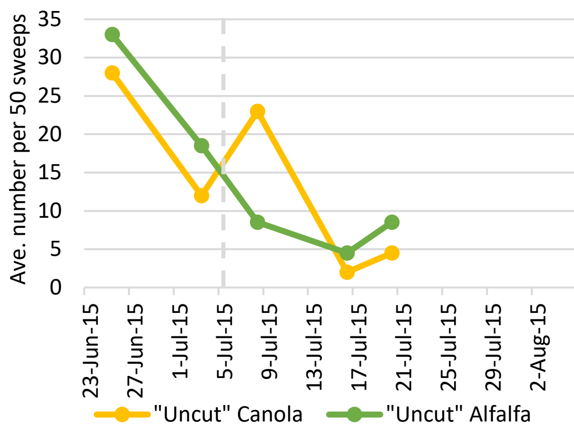


Figure 40. *Lygus* population trends in "uncut" canola and alfalfa fields in 2015. Dashed line indicates harvest in "cut" alfalfa fields.

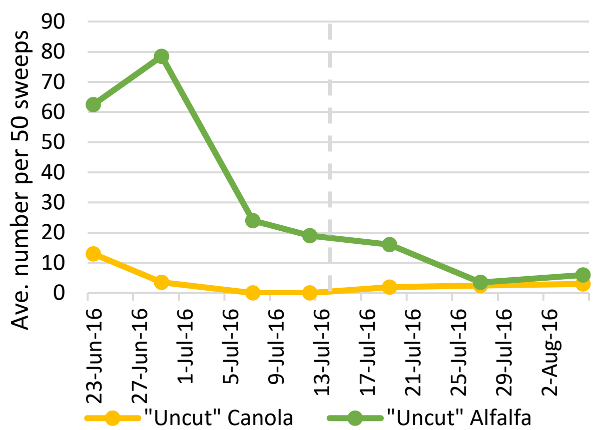


Figure 41. *Lygus* populations trends in "uncut" canola and alfalfa fields in 2016. Dashed line indicates harvest in "cut" alfalfa fields.

Conclusions

The three year survey (2014-2016) of alfalfa fields across the province of Alberta provided an abundance of information, on both pest and beneficial insects, that can be used to define the range of known and new pest species, provide a foundation for future surveillance work and help with developing integrated pest management strategies. In order to effectively predict and control for alfalfa pest outbreaks, it is necessary to know which pest insect are present in the area and the how the population numbers change. The Alberta alfalfa survey has shown that the range of the alfalfa weevil, a major pest of alfalfa, is expanding northward into areas that have not previously dealt with this pest. It is key for growers in these regions to be aware of the new threat by alfalfa weevil, as well as by new pests.

The presence of the alfalfa blotch leafminer in Alberta was not realized until recently, in 2005, and it was thought that its range would be limited; however, the alfalfa survey revealed the range of the alfalfa blotch leafminer to be across all agro-regions of the province. Through DNA barcoding, it was revealed that only this single species of leafminer, *A. frontella*, is responsible for the majority of damage done to leaves by mining larvae. Due to its extensive range, it will now be important to determine what parasitoids have moved with this pest and if their impact is enough to keep populations of alfalfa blotch leafminer below economic thresholds.

Several other insects that have potential to be pests were also tracked through the three years very few instances of populations that were of a concern were found. This information can be used to form a baseline should populations begin to change in future years.

The paired study of canola and alfalfa fields supports the findings of Cárcamo et. al. (2003) who found no relation to the cutting of alfalfa and movement of lygus into canola. Rather it appears the movement is more related to the flowering of canola.

Alfalfa fields support a very large and diverse population of insects, most of which are not pest species. In addition, in Alberta, very seldom do pest insects reach Economic Injury Levels. For the most part insect pests are kept in check by natural enemies. The biggest exception to this is alfalfa weevil which appears to be greatly increasing its range and in some cases severity as well. More attention should be paid to this pest species in the future.

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