FINAL PROJECT PROGRESS REPORT – 2018

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2.	Title of Research Project: Coordinated surveillance, forecasting and risk warning systems for field crop insect pests of the Prairie Ecosystem			
3.	Start Date: April 1, 2014		Completion Date: March 31, 2019	

4. Summary - 2018

There were no reported variances in 2018, the final year of this project. The annual insect surveys during the growing season provided a record of current insect populations, and reflected the future to varying degrees. Long-term surveys of insect populations provided a general overview of pest and natural enemy population trends over time. Provincial and industry collaborators, together with project team members, monitored 3047 sites for grasshoppers, 733 for wheat midge, 597 for cabbage seedpod weevil, 635 for bertha armyworm, 471 sites for pea leaf weevil, and 102 for wheat stem sawfly (Figure 1). In addition, sentinel sites were monitored for flea beetles, swede midge, *Contarinia brassicola* (a newly discovered species of midge attacking canola flowers), and cereal leaf beetle. The distribution of these sites is presented on the map below. The number of sites sampled in the 2018 growing season was greater than the number of sites sampled in 2017. The potential for migratory pest species, such as diamondback moth and leafhoppers and cereal rusts, was assessed using wind trajectory data (in collaboration with Environment and Climate Change Canada). Back trajectory data from 60 sites in Canada and forward trajectory data from 20 sites in USA and Mexico were assessed on a daily basis during each growing season (12,000 maps at three wind altitudes).

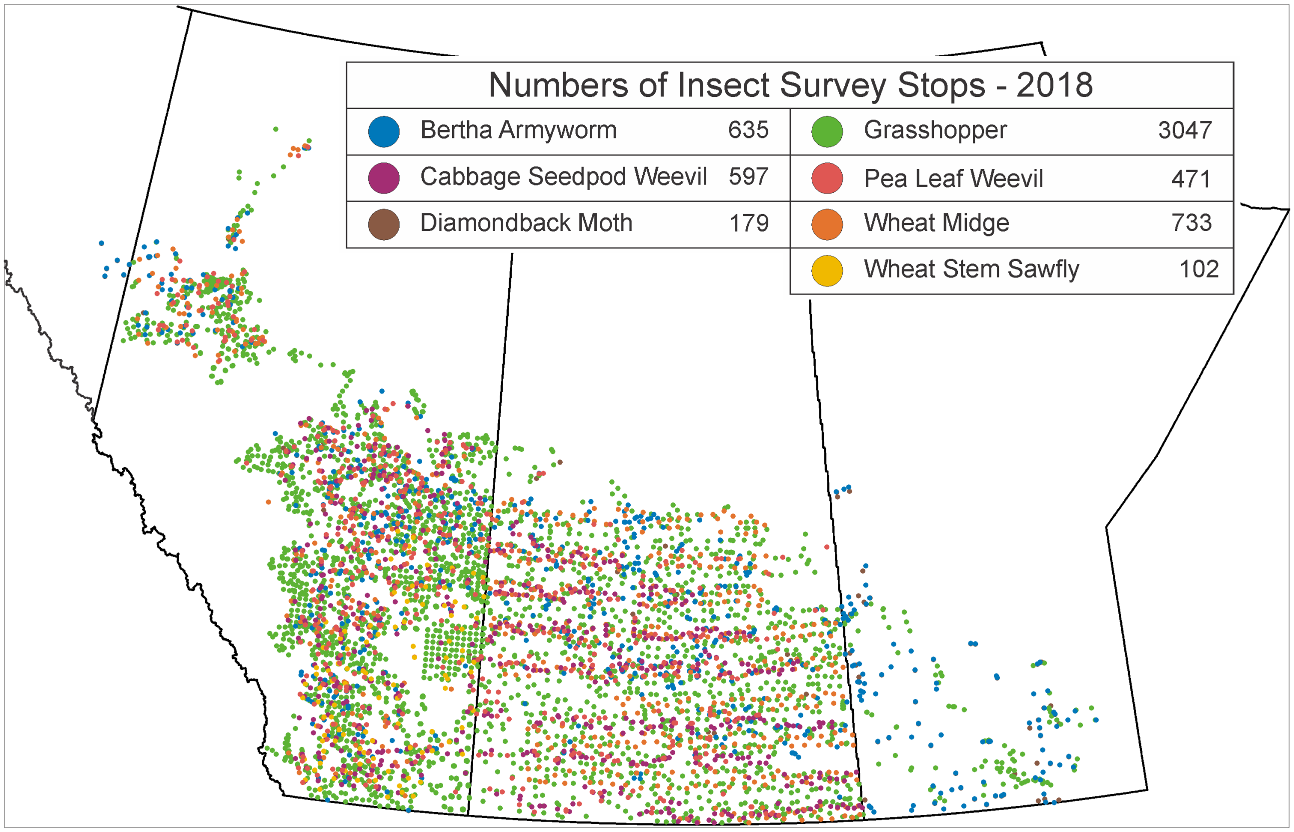

Figure 1. The total number of sites sampled for insect pests on the prairies in 2018.

Over the course of this project, insect pests of field crops in western Canada fell into three categories: (i) native insects such as grasshoppers (all crops), wheat stem sawfly (cereals), lygus (broadleaf crops); (ii) invasive alien species such as wheat midge (wheat and triticales), cereal leaf beetle (all cereals), cabbage seedpod weevil (canola) and pea leaf weevil (pulse crops); and (iii) migratory insect pests such as diamondback moth (canola) and leaf hoppers (transmission of Aster Yellows to all crops). A pictorial insect scouting chart spanning the growing season was developed for key insect pests of canola and flax production. Timely risk warnings, provided in map format and accompanied with interpretive text, were produced for the industry. Project participants spoke at various industry and scientific meetings, conferences, and outreach events to share information generated by this project. Project resources were leveraged to provide early warning of potential new invasive species for Canada and quantify risks associated with these invasions.

In all years of the project, emphasis was placed on documenting natural enemy populations. Beneficial insects collected in fields were divided into three functional groups: (i) Parasites/parasitoids (e.g. parasitic Hymenoptera); (ii) Pollinator/Nectar Feeders (e.g. bees, lacewings, hoverflies); and (iii) Predators (e.g. ladybird beetles, damsel bugs, pirate bugs). Parasitoids were the predominant natural enemy detected in all years of the project, although the population density and impact of predators may have been underestimated due to sampling bias, as most of the sampling practices used for crop pests (i.e. sweep net sampling, pheromone traps) do not accurately sample predatory species such as ground beetles.

5. Methods

The objectives of this project are to coordinate insect surveillance programs prairie-wide by: (i) Developing and implementing field surveillance technologies and laboratory assays for insect pests and their natural enemies (Monitoring Protocols described below); (ii) Developing forecast and risk assessment technologies (Risk Warning Methods described below); and (iii) Developing technology transfer and communication tools that contribute to the development of risk-reduction strategies (Technology Transfer described below).

(i) Monitoring Protocols

The specific details of the monitoring protocols are posted on the Prairie Pest Monitoring Network Blog (http://prairiepestmonitoring.blogspot.ca/p/ppmn-insect-monitoring-protocols.html). Updated versions of the protocol will be posted on the PPMN Blog and on the Western Committee on Pest Management website (http://www.westernforum.org/IPMNProtocols.html) in spring 2019. A short summary of the methods employed is presented here.

(a) Grasshoppers. The number of adult grasshoppers per m^2 was recorded in fall shortly after harvest to determine species composition, density and distribution. Later, before freeze-up, grasshopper eggs were collected at sentinel sites by sifting soil, to determine their density, their development and level of parasitism and predators.

(b) Bertha armyworm. Traps with pheromone lures were installed in canola fields (mid-June) to determine the time, distribution and density of adult moth flight. The extent of natural enemies (parasites and pathogens) of BAW was also monitored.

(c) Wheat midge. Wheat fields were sampled in fall using soil cores. The soil was washed and sieved to retrieve larval cocoons and free larvae. The larvae were dissected to determine the distribution, density and rates of parasitism of midge.

(d) Diamondback moth. Sentinel sites were established in canola fields by installing pheromone traps to determine the time, distribution and density of moth migrations from USA. This activity complements the wind trajectory component.

(e) Cabbage seedpod weevil. Weevil populations were surveyed using sweep nets (25 sweeps per field) to determine their distribution and density. The samples were brought back to the laboratory to be sorted and identified. All pest species of canola, and their natural enemies, found in the samples are also identified and recorded to assess multiple pest complexes.

(f) Flea beetles. Beetles were monitored using sticky traps, emergence cages and sweeping with nets in spring and fall. Cards and sweep samples were sorted and the beetles identified to species (with a focus on striped versus crucifer beetles). Flea beetle sampling was not conducted in all years of the project on the same scope as sampling for other insect pests.

(g) Pea Leaf Weevil. Weevil densities were estimated by plant damage assessments performed from 2^{nd} to 6^{th} node stages during the late May and early June, at five locations within each field.

(h) Wheat stem sawfly. Adults emerge in June and can usually be found in wheat fields until mid-July. Populations are assessed by a survey of wheat field margins late in the season and estimating the percentage of cut stems per m^2.

(ii) Risk Warning Methods:

(a) All data relating to insect populations were compiled on a weekly basis during the growing season. Spatial analysis systems were then utilized to accurately summarize the distribution and density of the pest populations.

(b) Near real-time weather data, obtained from Environment and Climate Change Canada on a weekly basis, were used to implement degree-day models (i.e. accumulated heat units) on a daily basis for pest species. Again, spatial analysis systems were then utilized to transform weather data into a format compatible with programs used to model insect population dynamics.

(c) Based on near real-time weather data, mathematical models for pest population establishment and growth were validated and implemented. Risk warnings were released at intervals appropriate to the pest - crop situation.

(d) Field sampling was conducted at sentinel sites to validate forecasts. Pest and crop data were collected at approximately weekly intervals during June and July to enhance the accuracy of risk warnings.

(e) Model output on wind movement was purchased from Environment Canada and evaluated daily in relation to the potential for diamondback moth, leafhoppers and aphids originating from the southern USA and Mexico and migrating to crop production regions of Canada.

(f) Bio-climate models were developed for potential invasive species to assess the risk of successful establishment in the prairies and assess the potential for successful establishment of biological control agents.

(iii) Technology Transfer

Knowledge and information on pest status, occurrence, forecasting tools, risk assessment analyses, and other outputs arising from the project were made available through a number of vehicles including websites, database summaries, models, software APPS, technology transfer reports, Twitter (@vanbugsky), and weekly email (via subscription). Scientific publications such as scientific papers, proceedings, research reports, invited talks, and posters were presented to research partners, the scientific community, and the public. Using the data collected, timely risk warnings, provided as risk map formats (prairie-wide, provincial and regional) and accompanied with interpretive text, were produced in a format useful to the industry (electronically, field days, producer meetings).

The project complemented the technology transfer networks already in place through the respective provincial networks. Team members and grower associations involved in this project have a long track record of timely and successful technology transfer, and share a commitment to technology transfer and extension; they have vibrant extension programs and have direct access to large numbers of growers and agriculture extension professionals.

In addition to the above approaches, the project pursued several additional technology transfer utilities. These included collaborating with AAFC Environment Resource Specialists that maintain *AgriMap* website to explore the potential for insect survey maps. Also, a ***BLOG*** site: (http://prairiepestmonitoring.blogspot.ca/) was continued in 2018 to post insect population updates (maps and phenology using visual tools), Insect of the Week, and other timely information of interest to the agriculture industry.

6. Progress during the Reporting Period - 2018

All objectives of the project to date were MET and are COMPLETED.

(i) Diamondback moth (DBM). In 2018, nearly 180 sentinel sites for diamondback moth were established across the prairies by installing pheromone traps in canola fields to determine the time, distribution and density of adult migrations from the USA & Mexico. Wind trajectory model output, purchased from Environment Canada, was analysed on a daily basis beginning in April to assist in predicting moth migrations from southern USA and Mexico. Results from both the sentinel sites and analysis of wind trajectories indicated that DBM began arriving across the prairies in late April and into May of 2018. DBM populations were low to medium throughout most of the prairies in 2018, but there were some pesticide applications required in Manitoba and Saskatchewan. Using data from the wind trajectory models and sticky traps at pheromone sites, regional risk information was shared with stakeholders via technology transfer activities. The presence of DBM in traps overseen by the PPMN and its collaborators are used to guide local, in-field scouting for DBM following the standard protocol which requires a measure of the number of larvae in 0.1 m^2 or approximately one square foot. In 2018, in-field scouting was recommended in areas surrounding positive sentinel sites, as illustrated in Figure 2.

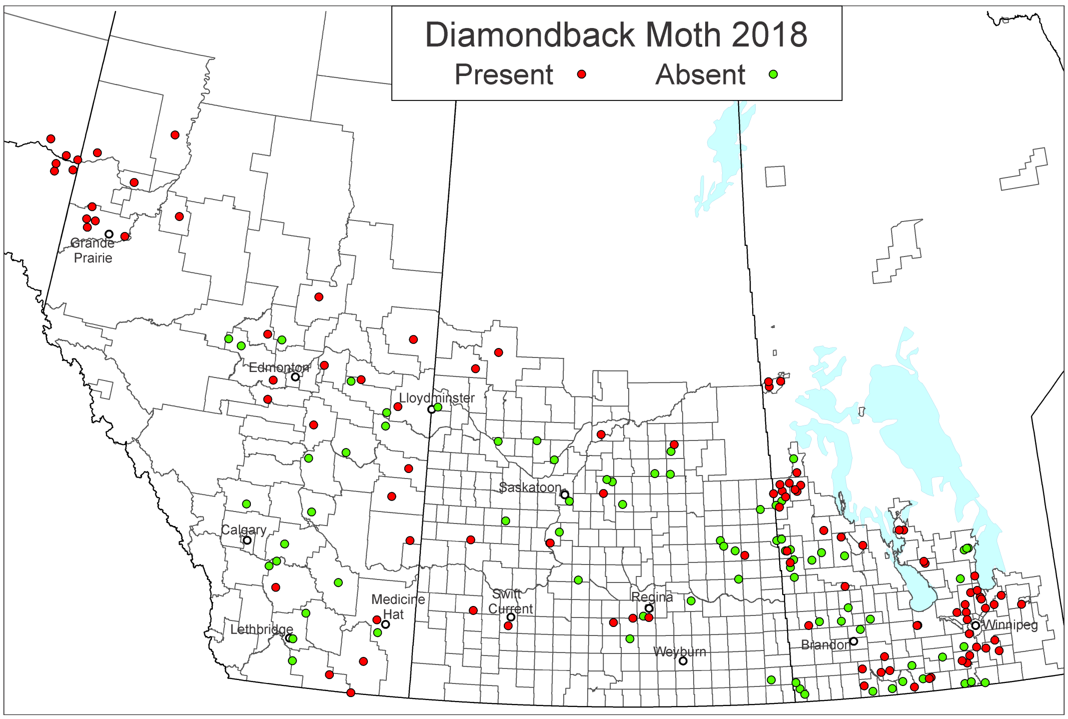

Figure 2. A map of the prairie region depicting the presence/absence of diamondback moth, *Plutella xylostella* in pheromone traps deployed in 2018.

(ii) Bertha armyworm (BAW). Collaborators monitored over 600 canola fields in Alberta, Saskatchewan, and Manitoba in 2018. This monitoring program utilizes pheromone traps that were installed canola fields in mid-June, at the approximate time of adult flight. The phenology model for BAW development, developed in conjunction with the PPMN, was used to predict the timing of larval pupation and adult emergence, and thus guide the timing of pheromone trap installation. In 2018, pupation was expected to be completed earlier than in previous years, due to several days of warm weather in mid-late May. This information was communicated to collaborators and trap hosts via the PPMN Blog and the Twitter account operated by M. Vankosky (@vanbugsky). Pheromone traps were monitored until the end of July, encompassing the 6-7 week flight period of adult BAW. Generally, trap catches were low across the prairies again in 2018, with a few areas with higher density flight activity that might be indicative of the onset of an outbreak cycle (Figure 3). Population densities in 2018 were similarly low in 2015 and 2017, with pockets of much higher BAW density observed in 2014 and 2016 (Figure 4).

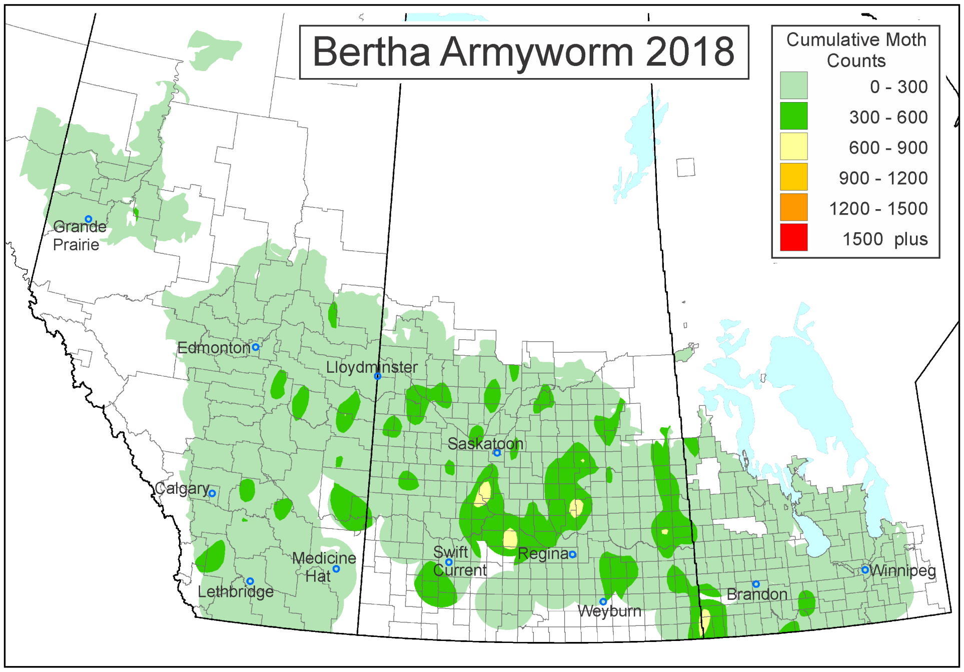

Figure 3. Cumulative *Mamestra configurata* (bertha armyworm) counts from pheromone traps deployed across the prairies in 2017.

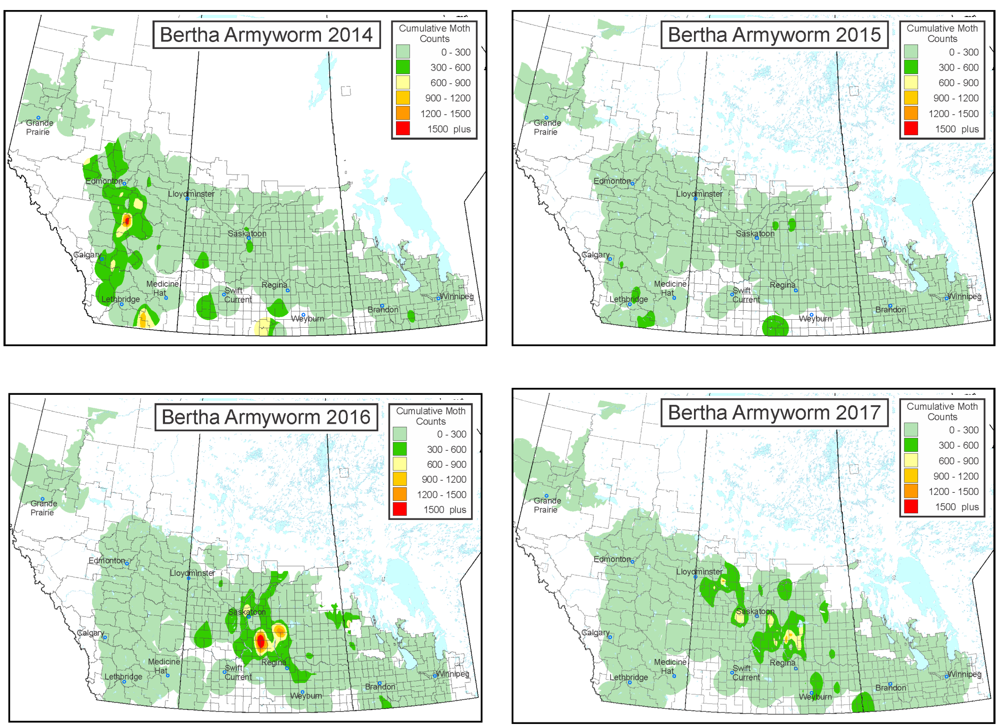

Figure 4. Composite maps showing previous cumulative pheromone trap counts of bertha armyworm from 2014 to 2018.

(iii) Pea leaf weevil*.* The pea leaf weevil (*Sitona lineatus*) survey in 2018 included 471 fields, accounting for the continued geographical distribution of this pest of field pea and faba bean, largely in Saskatchewan. The survey assessed damage to the seedlings caused by adult feeding in early spring, which is related to adult weevil density (Figure 5). In 2018, pea leaf weevil densities were low across both Alberta and Saskatchewan, especially compared to the previous four years (Figure 6). The survey has now been expanded to include the Peace River Region, as specimens collected in pheromone traps in that area by Dr. Maya Evenden were confirmed to be pea leaf weevil in 2017. No sampling for pea leaf weevil has been conducted in Manitoba at this time, but it should be noted that weevils may be present in Manitoba, as damage has been recorded in fields close to the SK-MB border in both 2017 and 2018.

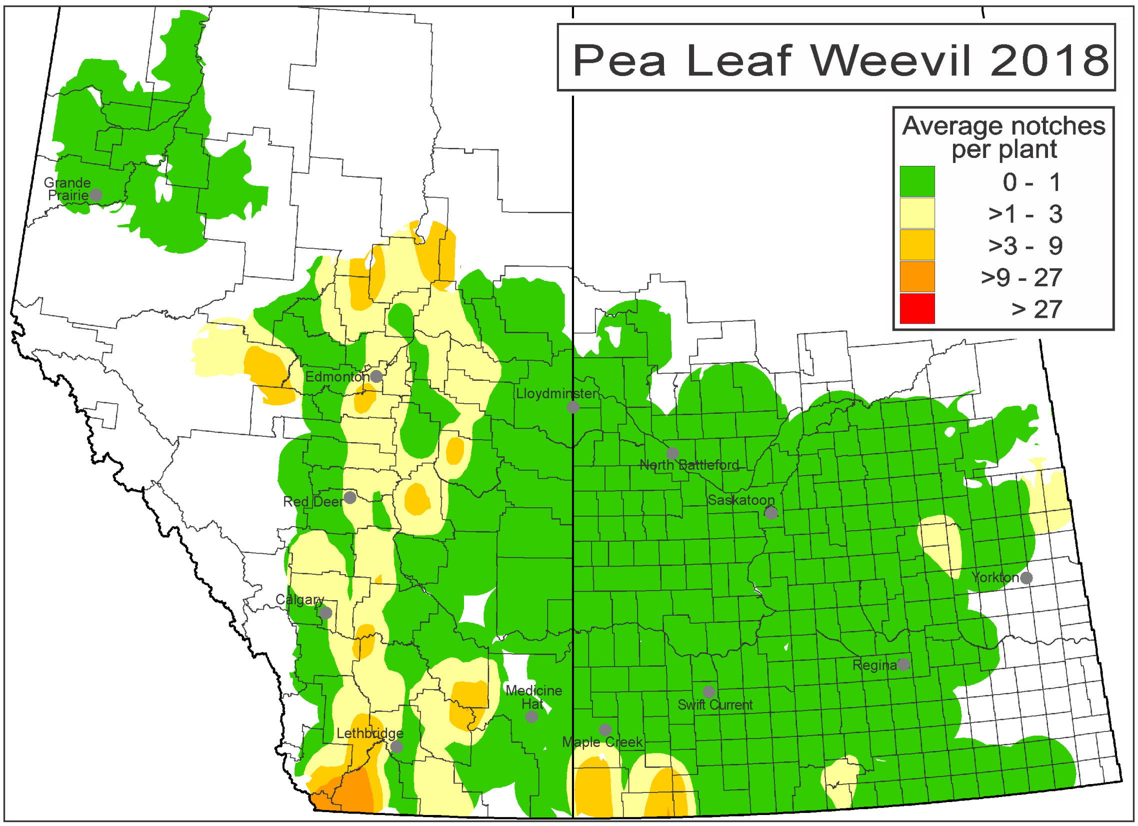

Figure 5. Adult pea leaf weevil (*Sitona lineatus*) densities in 2018 as estimated by counting the number of feeding notches per plant in 471 fields across the prairies.

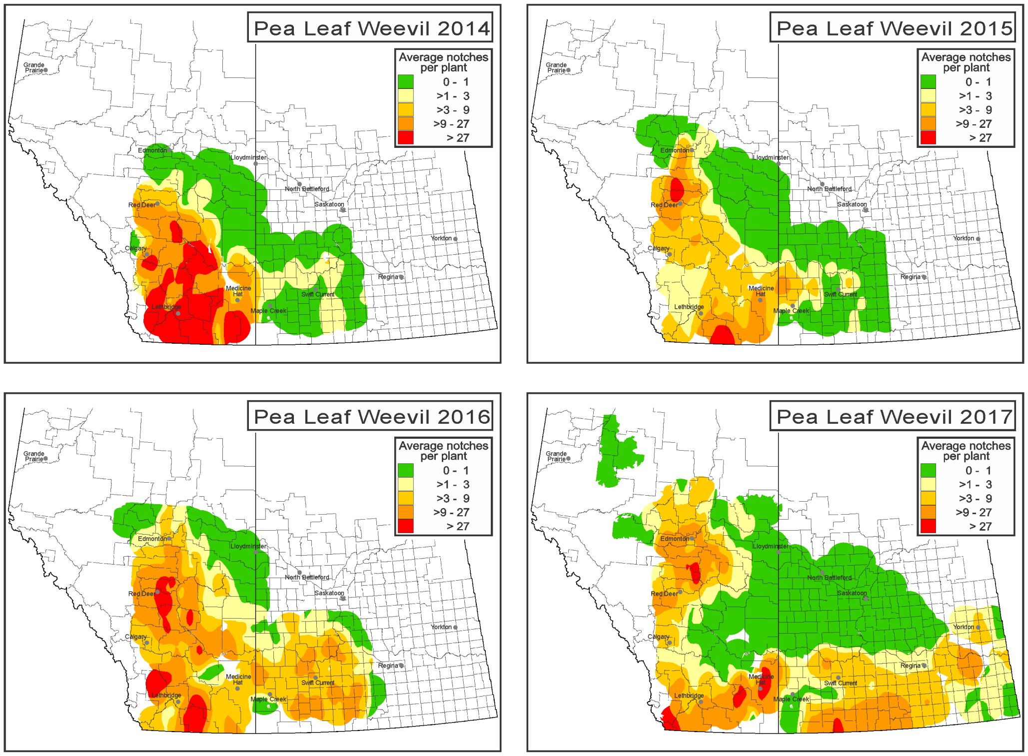

Figure 6. Adult pea leaf weevil (*Sitona lineatus*) densities estimated from surveys performed in 2014-2017.

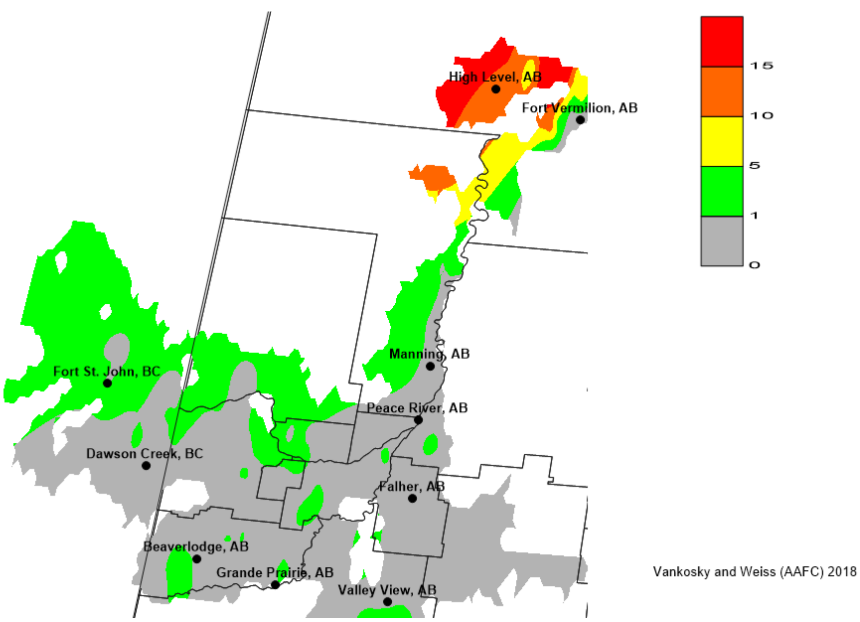

Figure 7. The number of Lygus spp. per ten sweeps recorded from canola fields surveyed in mid-July in the Alberta and British Columbia Peace River Region.

(iv) Lygus spp. An annual survey in canola has been conducted in the Peace River region since 2003. Lygus (Miridae: *Lygus* spp.) populations were relatively low in 2018 compared to the previous two years (Figure 7; previous page).

(v) Cabbage Seedpod Weevil (CSW). As in 2017, cabbage seedpod weevil (*Ceutorhynchus obstrictus*) population densities were lower in 2018 (Figure 8) compared to the previous three years (2014-2016; Figure 9). This is likely due, at least in part, to the hot and dry conditions experienced during the growing season, especially in the southern parts of Alberta and Saskatchewan. Of 330 fields sampled in Saskatchewan, only one field had >4 weevils per sweep and only 18 fields with >1 weevil per sweep. Weevil densities were reduced in Saskatchewan in 2018, but the total possible range of CSW has increased, with weevils detected more frequently just south of Saskatoon compared to previous years. The range of CSW again appeared to contract somewhat in Alberta in 2018, similar to what was observed in 2017. No weevils were recorded in the Peace River region of either Alberta or British Columbia in 2018. The presence of CSW was confirmed in Manitoba in 2017 but no weevils were detected in Manitoba canola fields sampled near the SK/MB border in 2018.

(vi) Wheat stem sawfly. Wheat stem sawfly populations have been consistently low in most of Alberta since 2011. Factors contributing to low populations may include the use of solid stem wheat varieties and parasitism. A survey of cut stem counts in Alberta wheat fields in 2018 indicated that the area at risk of economic sawfly populations has increased in some parts of Alberta (figure 10), but is still relatively low and similar to that observed in the previous four years Figure 11).

(vii) Grasshoppers. The grasshopper risk in 2019 is forecasted to be very low again in Saskatchewan in 2019 (Figure 12). The predicted risk in Manitoba and southern Alberta in greater than that forecast for 2018 (Figure 12, 13). Exceptionally wet conditions in late summer and fall of 2016 likely reduced egg-laying in fall. As a result, population densities in southern areas in 2017 were low and grasshoppers were not considered significant pests in 2017 in most areas. In 2018, conditions were again extremely suitable for grasshopper development, however, no outbreaks were recorded and little to no spraying took place in 2018. This could again be related to the wet fall of 2016, resulting in significantly decreased populations and a lag in population recovery.

(viii) Wheat midge (WM). As the 2018 growing season progressed, weekly simulation models were mapped to predict where WM emergence was predicted to begin. An example of the July 10th projection for 2017 is presented in Figure 14. This information, when updated weekly, assisted both the industry and growers to synchronize in-field monitoring for midge emergence but to also assess the likelihood of synchrony between peak WM flight and anthesis of wheat plants. The larval cocoon survey conducted in fall 2018 indicated that the risk of economic infestations of wheat midge in 2018 will be low in most of Alberta and Saskatchewan in 2019. Distribution of wheat midge, as illustrated in the 2019 Forecast Map (Figure 15), is based on non-parasitized cocoons present in soil samples collected in fall 2018. The risk of wheat midge damage to crops forecast in 2018 and 2019 has been much lower than in 2015-2017 and is likely related to the low level of spring precipitation that has fallen on the prairies in recent years.

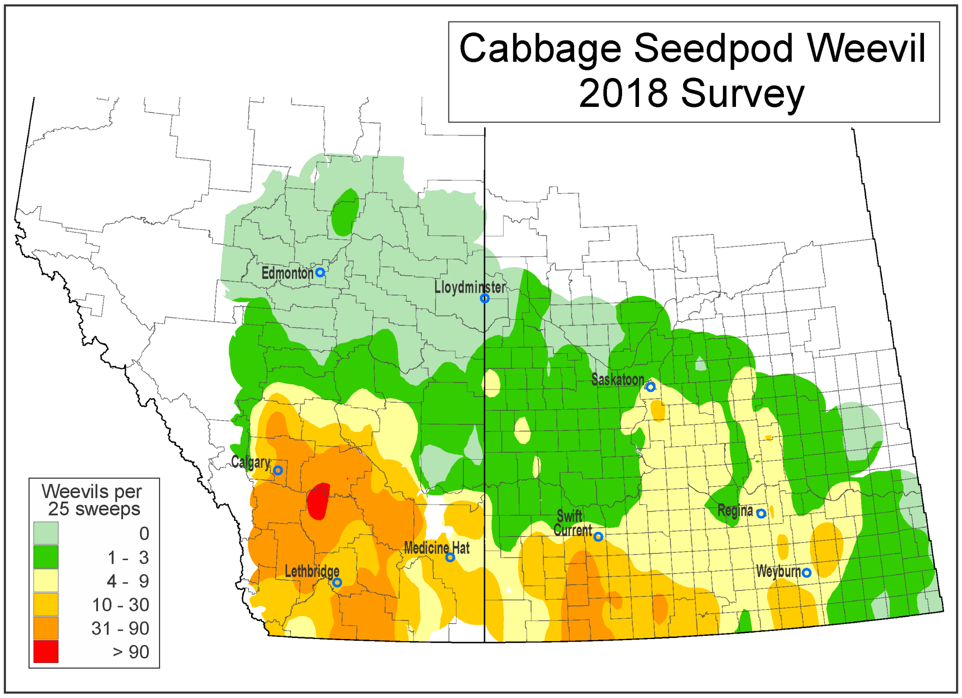

Figure 8. Densities of cabbage seedpod weevil (*Ceutorhynchus obstrictus*) estimated by sweep-net surveying performed in 2018.

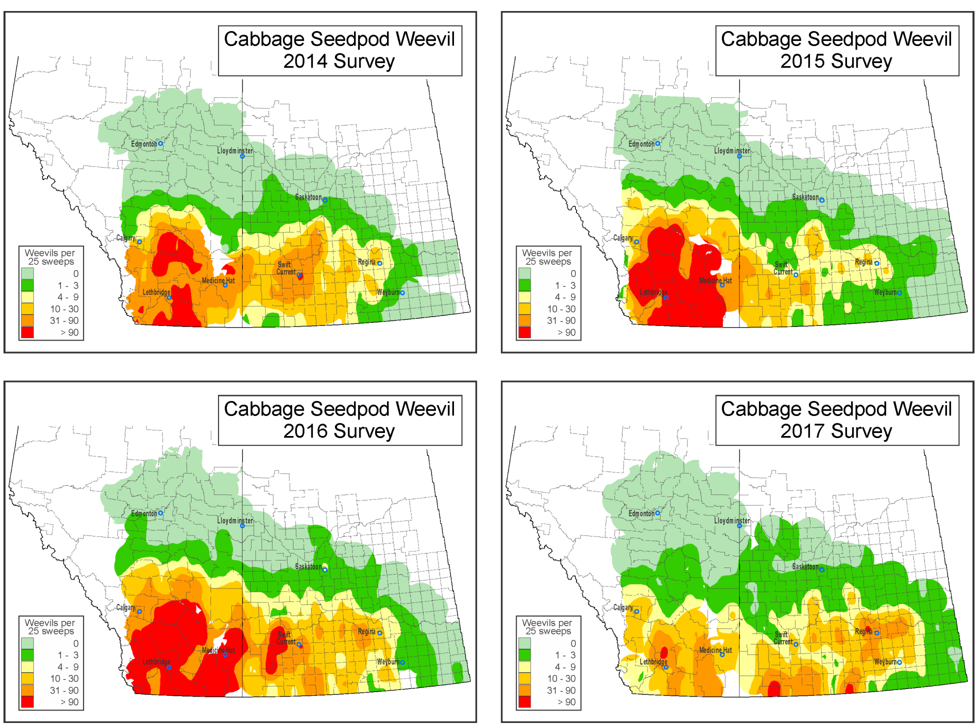

Figure 9. Cabbage seedpod weevil (*Ceutorhynchus obstrictus*) densities estimated by sweep-net surveying performed in 2014-2017.

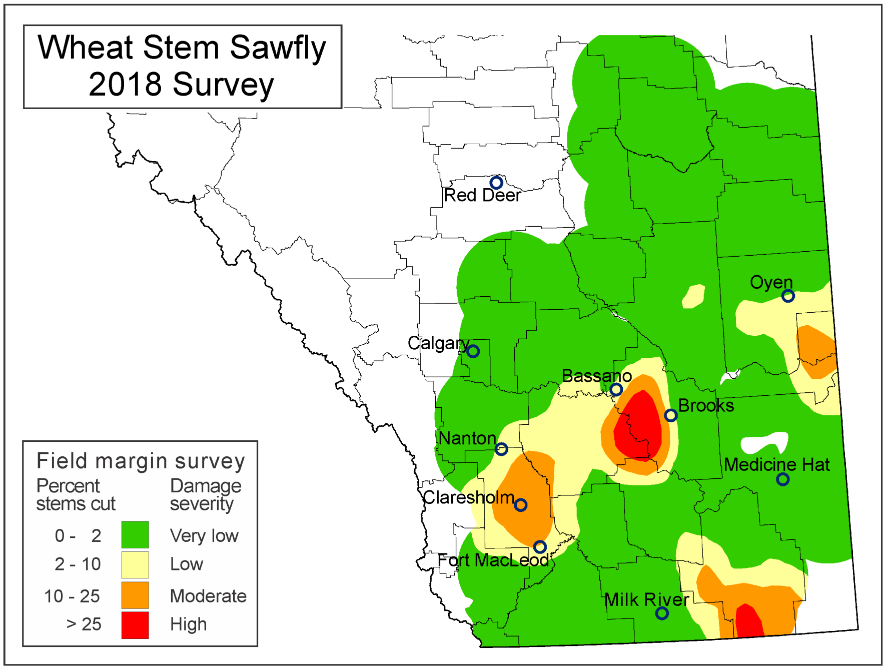

Figure 10. Densities of wheat stem sawfly (*Cephus cinctus*) estimated by determining the percent of cut stems in commercial wheat fields for the survey performed in 2018.

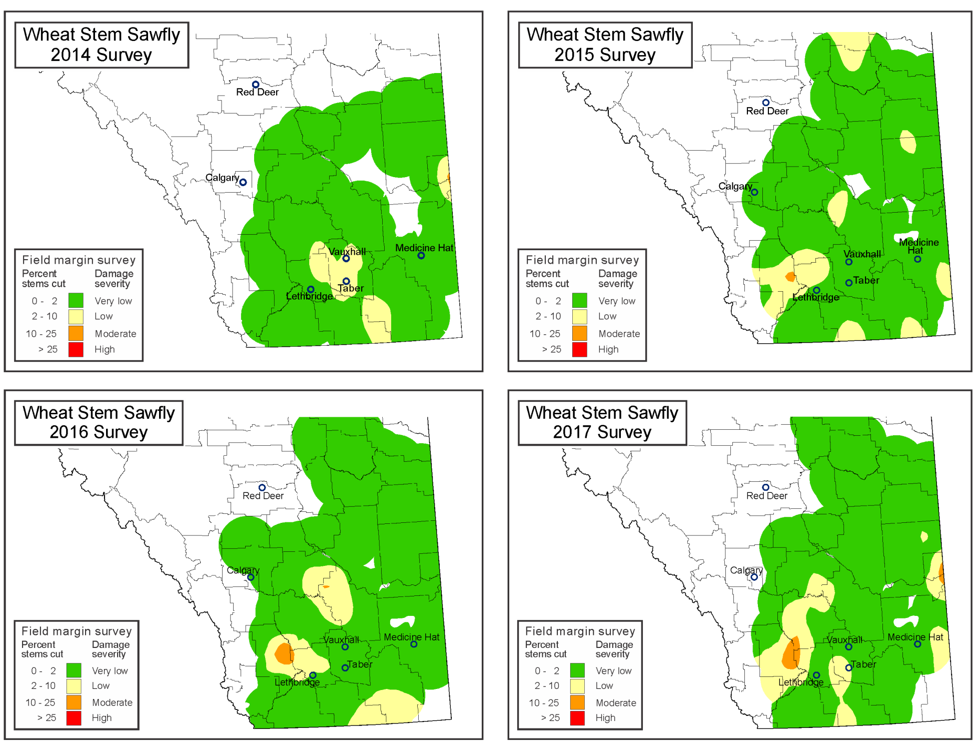

Figure 11. Wheat stem sawfly (*Cephus cinctus*) population densities estimated based on the percentage of cut stems in commercial wheat fields assessed in 2014-2017.

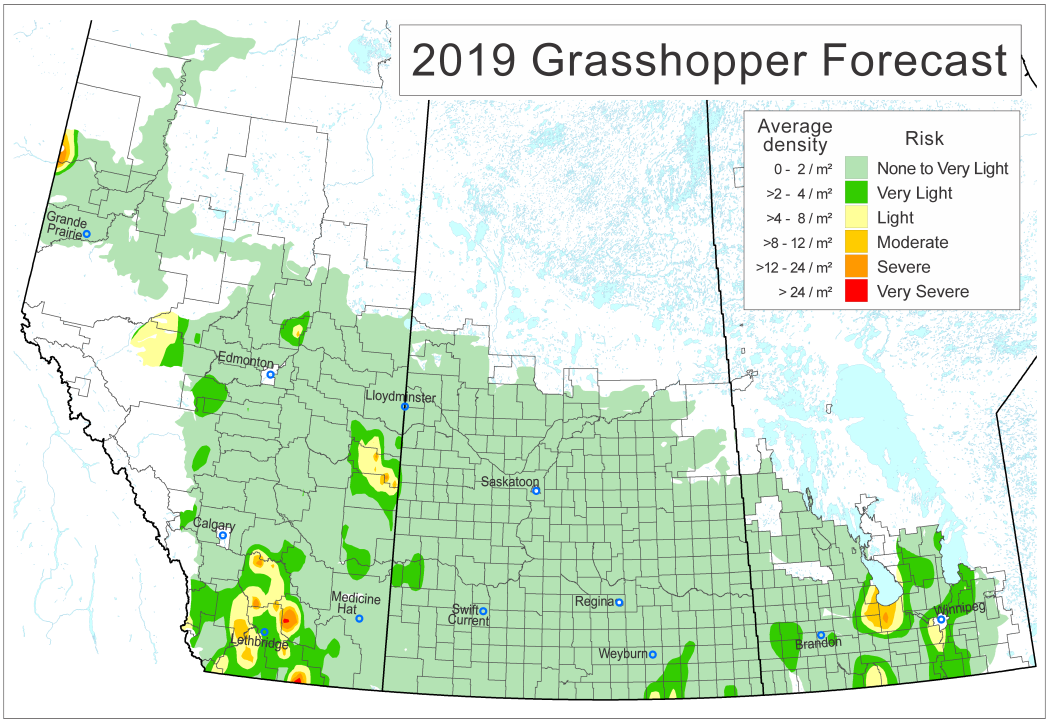

Figure 12. Grasshopper forecast for the prairies for the 2019 growing season.

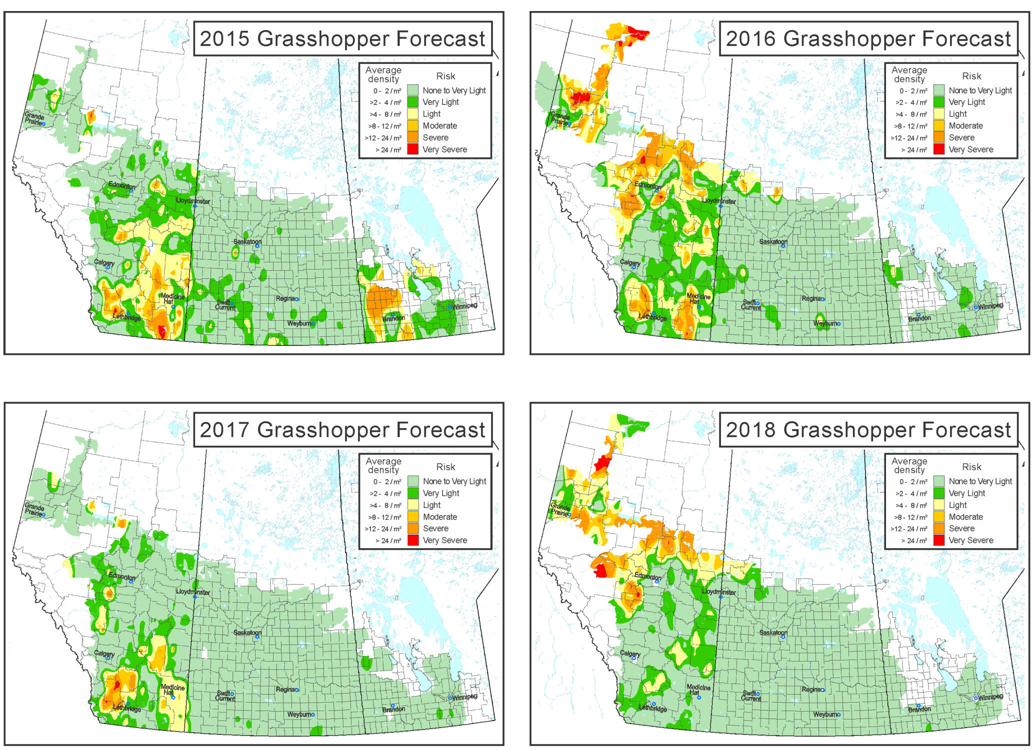

Figure 13. Composite of maps showing previous grasshopper forecasts for 2015-2018.

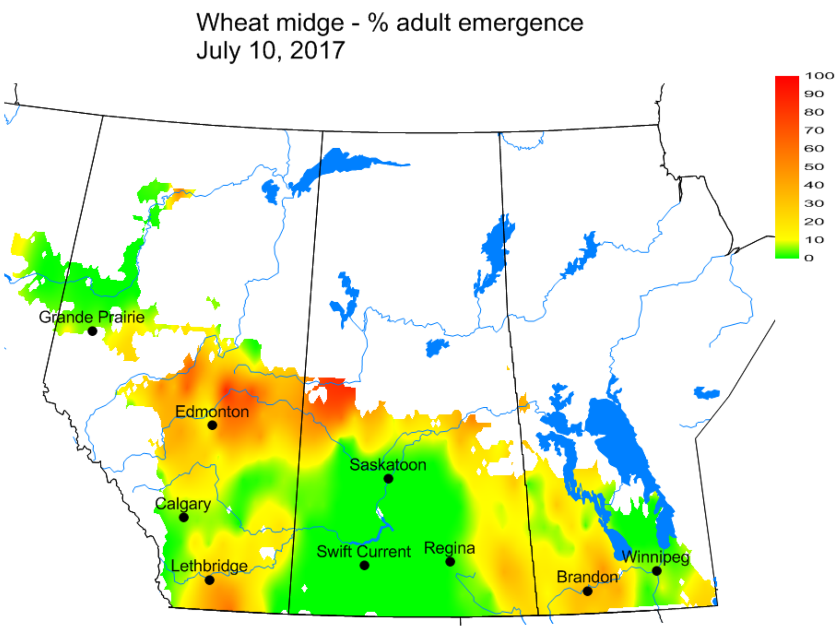

Figure 14. Example of predicted accumulation of heat units (as of July 10, 2017) necessary for *Sitodiplosis mosellana* to emerge from pupae developing in the soil.

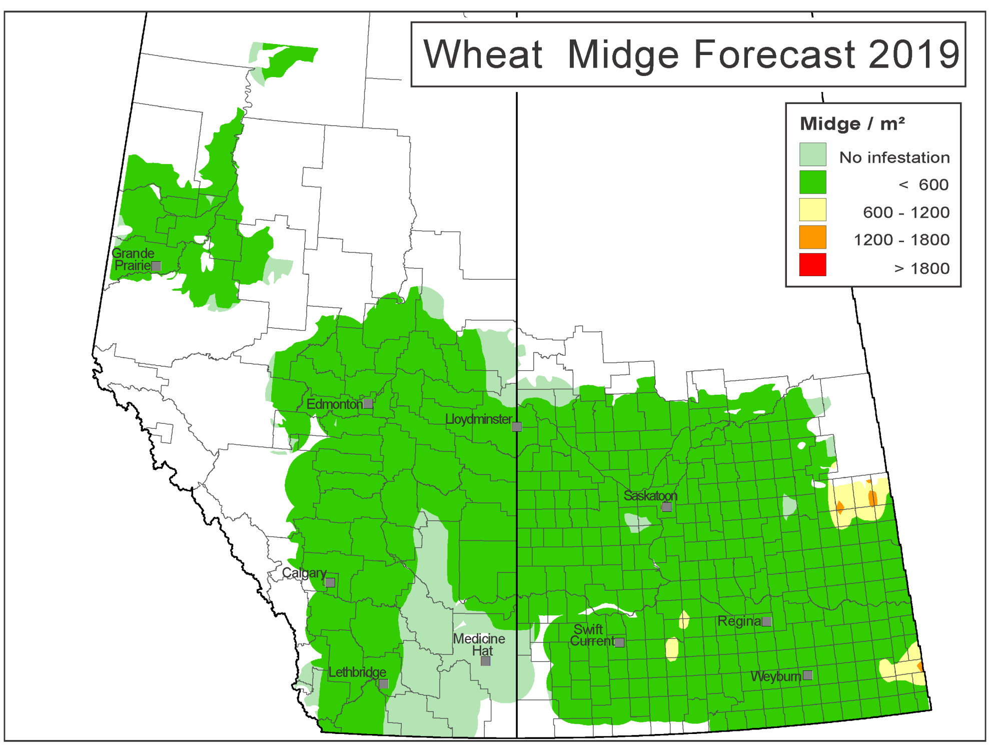

Figure 14. Wheat midge (*Sitodiplosis mosellana*) forecast for the 2019 growing season based on fall soil sampling of overwintering cocoons present in commercial fields of wheat.

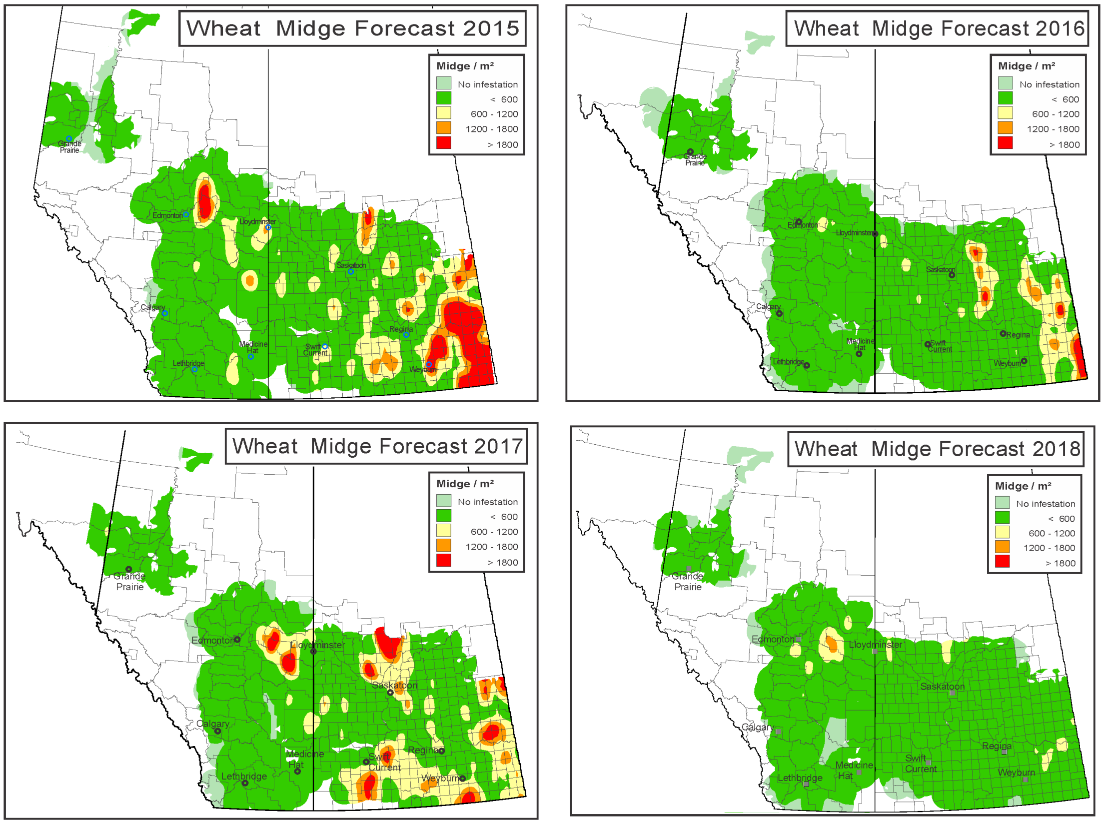

Figure 15. Composite maps showing previous *Sitodiplosis mosellana* forecasts for 2015-2018.

***(ix) Additional Pest Species*.**

(a) Swede midge. Drs. Boyd Mori and Meghan Vankosky reported that swede midge pheromone traps were deployed at 41 sites across the Prairie region in 2018 to monitor for populations of this brassica pest. Of the 41 trap sites, 16 were located in Alberta, 19 in Saskatchewan, and six in Manitoba. Two pheromone traps were deployed at each site. None of the traps were positive for swede midge in 2018, meaning that no swede midge have been detected on the prairies in the past three growing seasons (2016, 2017, and 2018).

(b) Flea beetle species shift (as reported in 2017 annual report). Soroka *et al*. (2017) published a paper on flea beetle (Coleoptera: Chrysomelidae) species and population dynamics in western Canada and North Dakota. Not surprisingly, peak numbers and relative species abundance varied with year, site, and ecoregion. Initially, they found that striped flea beetles were most common in northern ecoregions, whereas crucifer flea beetles were nearer to the 49th parallel. However, the authors identified a shift in dominance from crucifer flea beetles to striped flea beetles in recent years. Given the greater resistance of the latter to neonicotinoid seed treatments, which are the main method of insecticidal control, future monitoring is warranted to assess the implications of this change on levels of flea beetle damage in canola.

(x) Beneficial Insects. The survey of beneficial insects was conducted in canola fields in 2018 in conjunction with the cabbage seedpod weevil survey, which took place in late-June to early-July. In each field, 25 sweeps were taken. The beneficial insect specimens were divided into three functional groups: (i) Pollinators/Nectar Feeders (e.g. bees, lacewings, hoverflies), (ii) Predators (e.g. ladybird beetles, damsel bugs, pirate bugs) and (iii) Parasites (e.g. Hymenoptera). The breakdown of these three groups in 2017 and the previous three years is presented in Figure 16. Figure 17 depicts the breakdown of beneficial fauna observed in 2018.

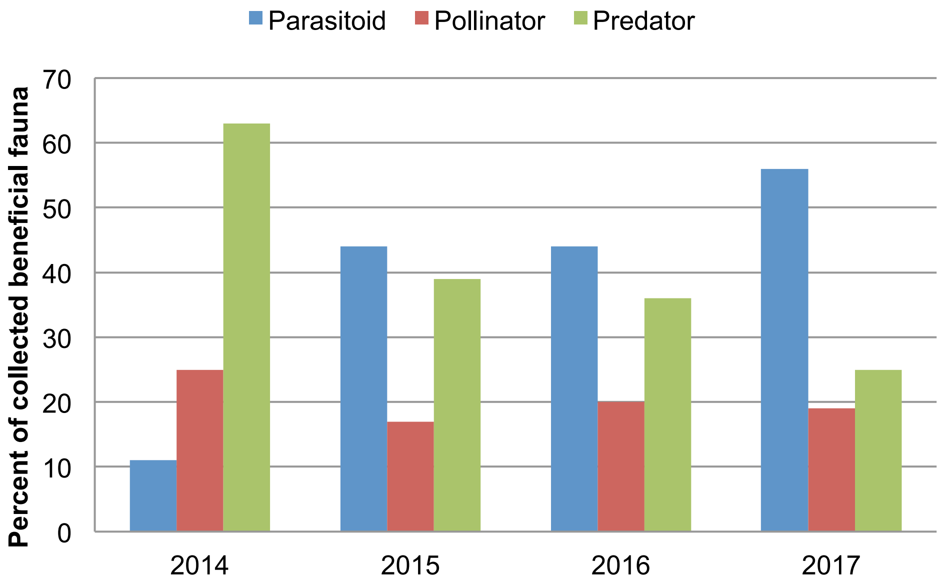

Figure 16. The percentage of the total number of beneficial insects (categorized into functional groups) observed in sweeps of blooming canola in 2014-2017.

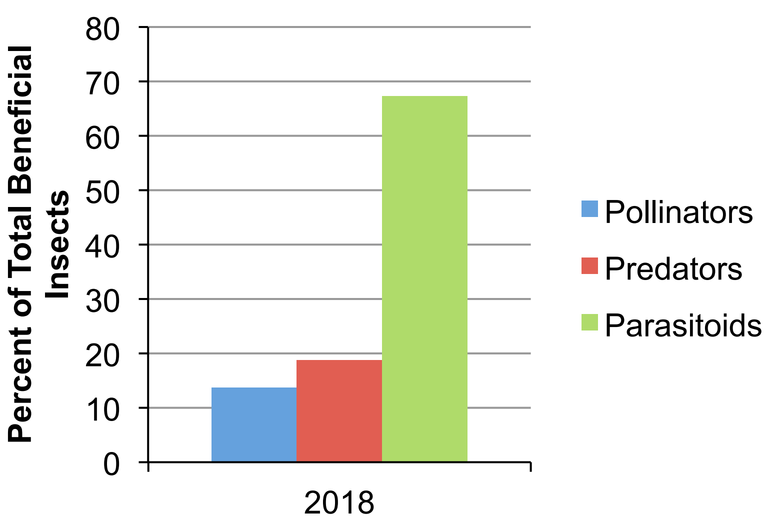

Figure 17. The percentage of the total number of beneficial insects that were categorized as one of three functional groups, observed in sweeps of blooming canola in 2018.

(xi) Wind trajectories. The potential for migratory pest species, such as diamondback moth, leafhoppers and cereal rusts were assessed using wind trajectory data (in collaboration with Environment and Climate Change Canada). Back trajectory data from 60 sites in Canada and forward trajectory data from 20 sites in USA and Mexico were assessed on a daily basis during each growing season (12,000 maps at three wind altitudes) (Figure 18).

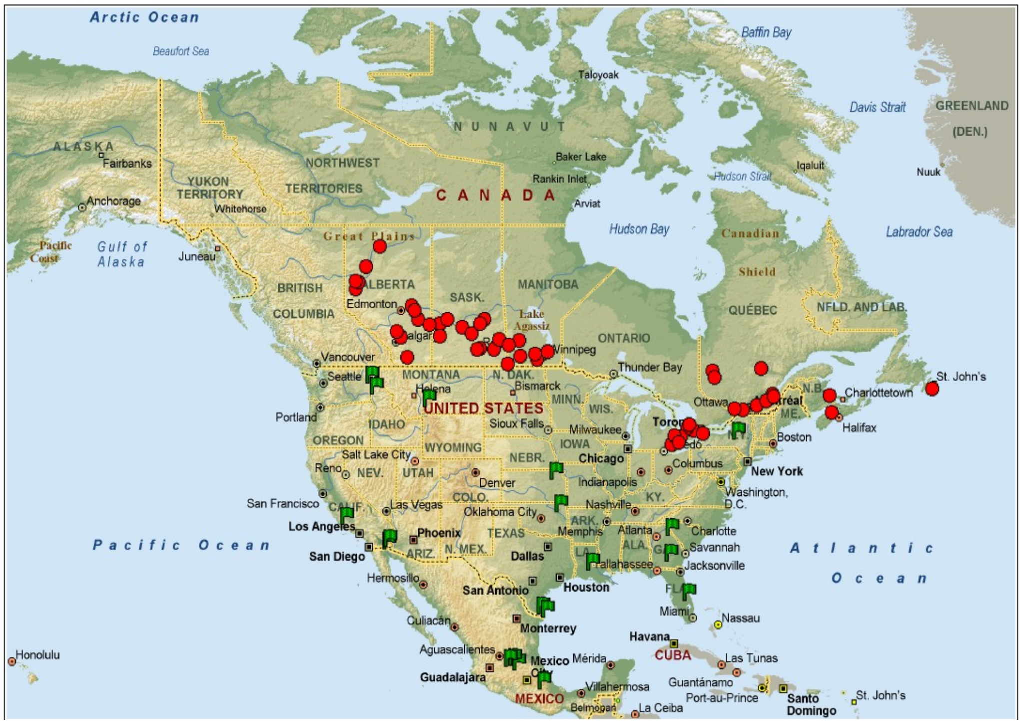

Figure 18. Locations of wind back trajectory sites (red dots) in Canada and wind forward trajectory sites in the USA and Mexico (green flags)

(xii) Weekly Updates. A weekly summary of weather, crop, and insect pest information was compiled and circulated to industry and growers. A total of 19 Weekly Updates were produced and distributed in 2017 spanning late May to early August. Electronic copies were distributed by e-mail, posted to the Insect Pest Monitoring Network webpages hosted by the Western Forum on Pest Management's website, posted to the WGRF website, SaskCanola website, and the Alberta Canola Producers Commission website. The Weekly Updates were also linked to via newsletters, and e-mails circulated by the Alberta Pest Surveillance Network, Western Grains Research Foundation, and Canola Council of Canada. Past and present Weekly Updates on the PPMN Blog (http://prairiepestmonitoring.blogspot.ca/). The Blog is also used to distribute other information, including the popular *Insect of the Week* feature. Prior to development of the PPMN Blog, Weekly Updates and other PPMN material was available on the Western Forum for Pest Management site (Western Committee on Crop Pests) available at: http://www.westernforum.org/IPMNWeeklyUpdates.html.

7. Project Progress to Date (at Project Completion)
Annual surveys provided a snapshot in time and, depending on a large number of factors, reflected the future to varying degrees. Long-term surveys of insect populations provided a general overview of pest and natural enemy population trends over time. The data also contributed to the development of risk-reduction strategies required for assessment of future changes in agronomic practices, crops and climate. Climate is the dominant force determining the distribution and abundance of most insect species. Bioclimate models continue to be developed to predict the geographic range and abundance for regions where species of interest do not currently occur.

Protocols. The Prairie Pest Monitoring Network supports insect pest management through the compilation of established monitoring protocols that include biological information on the pest, diagnostic images, descriptive monitoring methods pertinent to the pest species, and applicable economic thresholds (if available). A total of 14 monitoring protocols are currently maintained on the Prairie Pest Monitoring Network Blog (http://prairiepestmonitoring.blogspot.ca/p/ppmn-insect-monitoring-protocols.html), including protocols for insect forecasting, distribution/abundance, and collaborative research protocols. Prior to 2015, the protocols were also maintained and updated on the Western Forum for Pest Management website (www.westernforum.org/IPMNProtocols.html). The protocols on both sites are currently under review by subject matter experts and will be updated in Spring 2019.

Prairie Pest Monitoring Network Annual Meeting. Thanks to co-funding from SaskFlax and this project's funding agencies, annual meetings of the PPMN were held in all project years, with the final annual meeting for this funding cycle taking place on 26 March 2019 at the AAFC Saskatoon Research and Development Centre. A total of 36 researchers, industry members, extension specialists, and technical staff participated in the annual working group meeting. Dr. Vankosky chaired the 2019 meeting. At the 2019 meeting (as in previous years) participants: (i) reviewed and discussed the results of field monitoring data from 2018 and forecast data for 2019 across the prairies; (ii) discussed future research priorities for insect crop pests on the prairies; (iii) discussed new research results, new monitoring methods, and new technologies; and (iv) facilitated collaboration between university, federal, provincial, and industry researchers from across the prairies. At the 2019 annual meeting, David Holden provided an update on CFIA led activities, largely for forest pests, and provided information and guidelines for reporting finds of new invasive insects. Researchers also presented on their work, completed and in-progress, including Dr. Hector Carcamo, Dr. Haley Catton, Dr. Boyd Mori, and Miss Amanda Jorgensen (title slides from presentations at the annual meeting are provided on the last page of this report, Figure 19). Finally, industry provided updates from their commissions and researchers around the room participated in a round-table to provide short updates on new research projects across the prairies, especially those funded by the Canadian Agricultural Partnership.

In Summary, all data relating to insect populations continues to be compiled and directly incorporated into the insect population trend database for analysis of factors influencing population increase and decrease over time. The next iteration of the Prairie Pest Monitoring Network has been funded by the Canadian Agricultural Partnership Integrated Crop Agronomy Cluster. The work described in this report will continue until March 2023.

8. Administrative Documentation and Project Output

(i) Project Personnel

Collaborators throughout the project lifetime:

Provincial
Dr. John GAVLOSKI, Manitoba Agriculture, Crop Industry Branch, Carman MB
Mr. Scott HARTLEY, Saskatchewan Ministry of Agriculture, Regina SK
Dr. James TANSEY, Saskatchewan Ministry of Agriculture, Regina SK
Mr. Scott MEERS, Alberta Agriculture and Forestry, Brooks AB
Mr. Keith ULOTH, BC Pest Monitoring Contractor, Dawson Creek, BC

Federal
Dr. Owen OLFERT, Agriculture and Agri-Food Canada, Saskatoon SK
Ms. Jennifer OTANI, Agriculture and Agri-Food Canada, Beaverlodge AB
Dr. Meghan VANKOSKY, Agriculture and Agri-Food Canada, Saskatoon SK
Dr. Julie SOROKA, Agriculture and Agri-Food Canada, Saskatoon SK
Dr. Hector CARCAMO, Agriculture and Agri-Food Canada, Lethbridge AB
Dr. Boyd MORI, Agriculture and Agri-Food Canada, Saskatoon, SK
Dr. Haley CATTON, Agriculture and Agri-Food Canada, Lethbridge AB

University
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(ii) Project Output (2018-2019 fiscal year with some overlap depending on publication dates)

Scientific Journal Articles

Cárcamo, H.A., M.A. Vankosky, A. Wijerathna, O.O. Olfert, S.B. Meers, M.L. Evenden. 2018. Progress towards integrated pest management of pea leaf weevil: a review. Annals of the Entomological Society of America 111: 144-153.

Haye, T., O. Olfert, R. Weiss, P.G. Mason, G. Gibson, T.D. Gariepy, D.R. Gillespie. 2018. Bioclimatic analyses of *Trichomalus perfectus* and *Mesopolobus morys* (Hymenoptera: Pteromalidae) distributions, two potential biological control agents of the cabbage seedpod weevil in North America. Biological Control 124: 30-39.

Olfert, O., R.M. Weiss, H. Catton, H. Carcamo, S. Meers. 2019. Bioclimatic assessment of abiotic factors affecting relative abundance and distribution of wheat stem sawfly (Hymenoptera: Cephidae) in western Canada. The Canadian Entomologist 151: 16-33.

Olfert, O. Weiss, R.M., Soroka, J.J. and Elliott, R.H. 2017. Bioclimatic approach to assessing factors influencing shifts in geographic distribution and relative abundance of two flea beetle species (Coleoptera: Chrysomelidae) in North America. The Canadian Entomologist 150: 66-79.

Soroka, J., Otani, J., Gavloski, J. Olfert, O. 2018. Flea beetle (Coleoptera: Chrysomelidae) species in canola fields of the Northern Great Plains. The Canadian Entomologist: 150: 100-115. https://doi.org/10.4039/tce.2017.60

Technical Bulletins and Weekly Updates

Vankosky, M., O. Olfert, S. Meers, J. Tansey, J. Gavloski, D. Giffen, J. Otani. 2019. Bertha armyworm in western Canada in 2018. 2018 Crop Variety Highlights and Insect Pest Forecasts. Saskatoon Research Centre Technical Bulletin No. 2019-01. Pp. 1-2.

M. Vankosky, O. Olfert, S. Hartley, J. Tansey, J. Gavloski, S. Meers, D. Giffen, J. Otani. 2019. The 2019 Prairie Grasshopper Forecast. 2018 Crop Variety Highlights and Insect Pest Forecasts. Saskatoon Research Centre Technical Bulletin No. 2019-01. Pp. 3-4.

M. Vankosky, O. Olfert, S. Meers, J. Tansey, D. Giffen, J. Otani. 2019. Wheat midge forecast in Saskatchewan and Alberta for 2019. 2018 Crop Variety Highlights and Insect Pest Forecasts. Saskatoon Research Centre Technical Bulletin No. 2019-01. Pp. 5-6.

M. Vankosky, O. Olfert, S. Meers, J. Tansey, D. Giffen, J. Otani. 2019. Cabbage seedpod weevil in Alberta and Saskatchewan in 2018. 2018 Crop Variety Highlights and Insect Pest Forecasts. Saskatoon Research Centre Technical Bulletin No. 2019-01. Pp. 7-8.

M. Vankosky, S. Meers, H. Carcamo, D. Giffen, O. Olfert. 2019. Wheat stem sawfly in Alberta in 2018. 2018 Crop Variety Highlights and Insect Pest Forecasts. Saskatoon Research Centre Technical Bulletin No. 2019-01. Pp. 9-10.

M. Vankosky, S. Meers, J. Tansey, D. Giffen, O. Olfert. 2019. Pea leaf weevil in Alberta and Saskatchewan in 2018. 2018 Crop Variety Highlights and Insect Pest Forecasts. Saskatoon Research Centre Technical Bulletin No. 2019-01. Pp. 11-12.

Otani, J., R. Weiss, D. Giffen, J. Gavloski, H. Carcamo, M.A. Vankosky, E. Svendsen, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, August 23, 2018 edition. 2018-16: 1-13. http://prairiepestmonitoring.blogspot.com. (*This link can also be used to access the 2018 Weekly Updates described below by selecting the "Weekly Updates" tab).*

Otani, J., R. Weiss, D. Giffen, M.A. Vankosky, E. Svendsen, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, August 16, 2018 edition. 2018-15: 1-16.

Vankosky, M.A., E. Svendsen, R. Weiss, D. Giffen, J. Otani, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, August 9, 2018 edition. 2018-14: 1-11.

Otani, J., R. Weiss, D. Giffen, M.A. Vankosky, E. Svendsen, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, August 2, 2018 edition. 2018-13: 1-28.

Otani, J., R. Weiss, D. Giffen, B. Mori, M.A. Vankosky, E. Svendsen, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, July 26, 2018 edition. 2018-12: 1-23.

Otani, J., R. Weiss, D. Giffen, B. Mori, M.A. Vankosky, E. Svendsen, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, July 19, 2018 edition. 2018-11: 1-25.

Otani, J., R. Weiss, D. Giffen, M.A. Vankosky, E. Svendsen, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, July 12, 2018 edition. 2018-10: 1-15.

Otani, J., R. Weiss, D. Giffen, E. Svendsen, M.A. Vankosky, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, July 9, 2018 edition. 2018-9: 1-21.

Otani, J., R. Weiss, D. Giffen, S. Meers, S. Barkely, K. Floate, H. Catton, E. Svendsen, M.A. Vankosky, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, June 28, 2018 edition. 2018-8: 1-27.

Otani, J., R. Weiss, D. Giffen, K. Floate, H. Catton, E. Svendsen, M.A. Vankosky, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, June 21, 2018 edition. 2018-7: 1-27.

Otani, J., R. Weiss, D. Giffen, S. Dufton, H. Carcamo, W. van Herk, R. Vernon, A. McGowan, M.A. Vankosky, E. Svendsen, O. Olfert. Prairie Pest Monitoring Network Weekly Update, June 14, 2018 edition. 2018-6: 1-22.

Otani, J., R. Weiss, W. van Herk, R. Vernon, H. Catton, A. McGowan, M.A. Vankosky, E. Svendsen, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, June 7, 2018 edition. 2018-5: 1-20.

Otani, J., R. Weiss, D. Giffen, M.A. Vankosky, E. Svendsen, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, May 31, 2018 edition. 2018-4: 1-26.

Otani, J., R. Weiss, D. Giffen, K. Floate, M.A. Vankosky, E. Svendsen, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, May 24, 2018 edition. 2018-3: 1-24.

Otani, J., R. Weiss, D. Giffen, M.A. Vankosky, E. Svendsen, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, May 17, 2018 edition. 2018-2: 1-16.

Otani, J., R. Weiss, D. Giffen, M.A. Vankosky, E. Svendsen, O. Olfert. 2018. Prairie Pest Monitoring Network Weekly Update, May 10, 2018 edition. 2018-1: 1-19.

Presentations

Vankosky, M.A., J. Otani, J. Gavloski, S. Meers, J. Tansey, O. Olfert. 2019. The Prairie Pest Monitoring Network: An overview of form, function, and successes. CFIA Canadian Plant Health Network Workshop. Ottawa, ON, Canada, January 31, 2019 [invited].

Vankosky, M.A., J. Otani, J. Gavloski, S. Meers, J. Tansey, O. Olfert. 2018. Tactics for detection and surveillance of invasive insect species on the Canadian prairies. Monitoring and Managing Agricultural Insects Crossing Borders, Section Symposium; Entomology 2018 (joint meeting of the entomological societies of Canada, America, and British Columbia); Vancouver BC, Canada, November 11-14 [Invited].

Olfert, O., M. Vankosky, J. Otani. 2018. Adding value to an agricultural monitoring program in western Canada. Biological Control Agents in New Environments, Member Symposium; Entomology 2018 (joint meeting of the entomological societies of Canada, America, and British Columbia); Vancouver BC, Canada, November 11-14 [Invited].

Otani, J., S. Dufton, D. Giffen, R. Weiss, E. Svendsen, M. Vankosky, J. Gavloski, S. Meers, J. Tansey, O. Olfert. 2018. Developing decision support tools for the agricultural industry – the Prairie Pest Monitoring Network Blog. Monitoring and Managing Agricultural Insects Crossing Borders, Section Symposium; Entomology 2018 (joint meeting of the entomological societies of Canada, America, and British Columbia); Vancouver BC, Canada, November 11-14 [Invited].

Vankosky, M.A., J. Otani, J. Gavloski, S. Hartley, S. Meers, O. Olfert. 2018. Prairie Pest Monitoring Network: Coordinated monitoring of field crop pests of the Canadian Prairies. International IPM Symposium; Baltimore, Maryland, USA, March 19-22 [Poster].

Vankosky, M.A. 2018. Insect pests of pulse and cereal crops: Prairie research update. Regional Meeting of Alberta Pulse, Wheat, and Barley Growers. Two presentations: Westlock Alberta, November 21, 2018; Willingdon Alberta, November 22, 2018.

Vankosky, M.A. 2018. Insect pests of field crops and their natural enemies (group display). CROPS-a-PALOOZA Portage la Prairie; Canada-Manitoba Crop Diversification Centre, Portage la Prairie, MB, Canada (July 25).

Vankosky, M.A., J. Otani, S. Dufton, K. Floate, V. Hervet, et al. 2018. Insect pests of canola and their natural enemies (group display). CanolaPALOOZA Lacombe; AAFC-Lacombe Research and Development Centre, Lacombe, AB, Canada (June 27).

(iii) Acknowledgements:

Thanks to the above grower organizations that provided the necessary funds to successfully implement this prairie–wide project. The collaboration of the many people involved with annual in-field monitoring and surveying was highly valuable to the success of this project from the time of its initiation to its date of completion. Provincial, federal, university, industry members, and growers all supported data collection for field crop pests and their continued support and collaboration is appreciated. We express special thanks to the many undergraduate and graduate students who contributed to data collection described in the various objectives and sub-objectives of this project. The continued efforts and expertise of the technical staff associated with this project, including Ross Weiss, David Giffen, Nancy Melnychuk, and Jonathon Williams are greatly appreciated.

We also thank Dr. Kelly Turkington, the voluntary webmaster of the Prairie Pest Monitoring Network page hosted on the Western Forum on Pest Management website for timely posting of materials (http://www.westernforum.org/IPMNMain.html). The website contains information regarding insect pest monitoring, Weekly Updates, and Annual Summary Maps and Forecast maps. In addition, work and creativity on the part of staff at AAFC-Beaverlodge led to the creation of a Blog for this project that has been integral in supporting communication regarding this project.

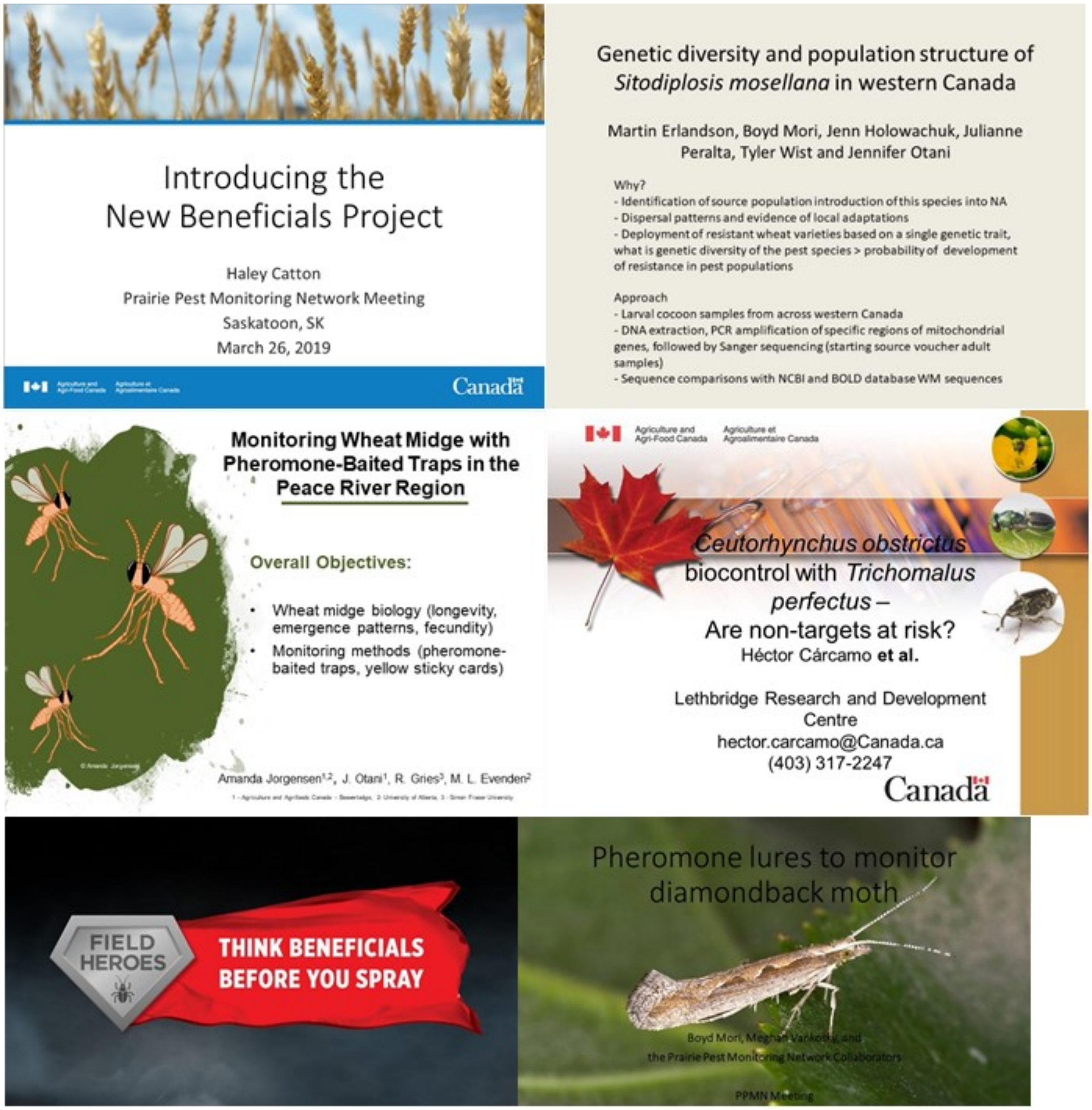

Figure 19. Title slides from invited presentations given by PPMN collaborators at the PPMN Annual Working Group Meeting on 26 March 2019.