FINAL PROJECT REPORT

Canola Agronomic Research Program (CARP)

Project Title: Surveillance networks for beneficial insects: can natural habitats serve as insect reservoirs, and do they contribute to canola yield?

Research Team Information

Lead Researcher:		
Name	***Institution***	***Project Role***
Paul Galpern (2016-2020)	University of Calgary	Principal investigator
Research Team Members (add rows as required)		
Name	***Institution***	***Project Role***
Dr. Jessamyn Manson (2016-2017)	University of Alberta	Collaborator
Monica Kohler (2016-2017)	Alberta Biodiversity Monitoring Institute	Collaborator
Dr. Jess Vickruck (2017-2019)	University of Calgary	Post-doctoral researcher
Dr. Sam Robinson (2019-2020)	University of Calgary	Post-doctoral researcher
Many additional field and laboratory technicians	University of Calgary	

Project Start Date: **May 1, 2016** **Project Completion Date: August 30, 2020**

Reporting Period: **April 1, 2020** **to August 30, 2020**

CARP Project Number: **2016-21**

1. Date of Completion: August 30, 2020

2. Status of Activity: (please check one)

_____ Ahead of Schedule _____ On Schedule _____ Behind Schedule _X___ Completed

Comment:

A second phase of the project was funded by CARP in 2019. Products of this first phase will continue to be analyzed in the second phase.

3. Completed actions, deliverables and results; any major issues or variance between planned and actual activities.
Please see attached.

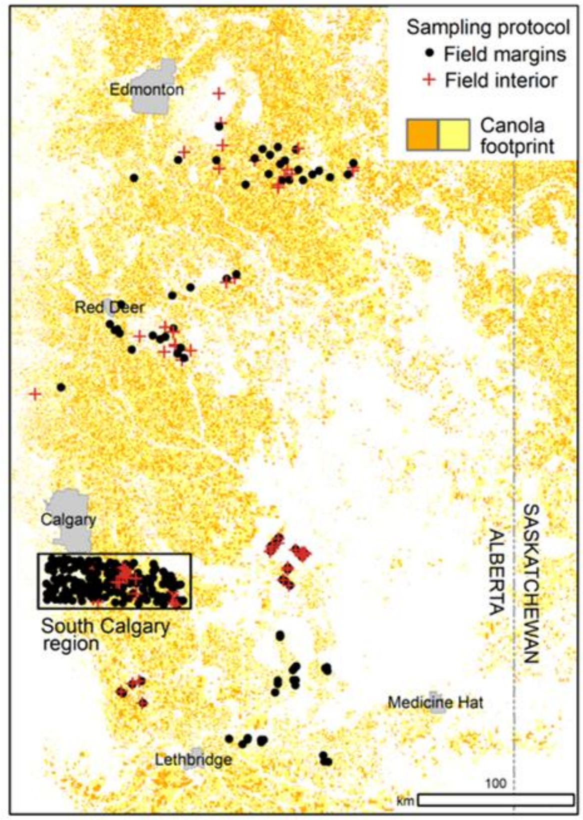
4. Significant Accomplishments
Research accomplishments are presented in the attached document. Additional accomplishments: ▪ **7 co-funding grants with a total cash value of $299,820** received from four different agencies, all of which contributed to first phase network objectives ▪ **2 publications from network research in print** in high-impact international peer-reviewed journals (*Agriculture, Ecosystems and Environment; Biological Conservation*) ▪ **8 articles covering network research by agricultural media organizations** including *Western Producer, The Furrow, Top Crop Manager, Grainews, Canola Digest*, and others. ▪ **10 oral presentations** of network research to grower and public audiences ▪ **5 oral presentations** of network research to scientific audiences ▪ **1 manuscript from network research submitted** to an international peer-reviewed journal ▪ **1 manuscript from network research in preparation** for submission to an international peer-reviewed journal

5. Research and Action Plans
Please see attached.

6. Final Project Budget and Financial Reporting
To be forwarded separately by University of Calgary Research Accounting.

A. Research abstract

Natural habitats and uncultivated areas ("non-crop areas") within or near fields may harbour reservoirs of beneficial arthropods that provide services such as pest control and pollination to canola crops. The principal objective of the Beneficial Insects Surveillance Network was to investigate these reservoirs by characterizing the abundance and diversity of beneficial species, and by conducting an initial assessment into the contribution to canola yield of beneficial species that are found in these reservoirs.



Beneficial arthropods (wild bees, spiders, ground beetles, and harvestmen) were sampled at 317 sites across central and southern Alberta between 2016 and 2018 (see map), with traps deployed between 500 and 8000 hours at any given site. Trapping locations included field margins and the interior of canola fields positioned at multiple distances from field and wetland margins. A total of 157,407 arthropods of 418 species were identified from these samples and are curated in the University of Calgary Invertebrate Collection. This sampling has generated what is likely to be the most geographically-extensive database on the distribution, abundance, and diversity of beneficial arthropods found in Canadian prairie croplands.

Analyses of network data show that non-crop areas such as wetland margins, field margins and pivot corners are reservoirs that serve as a source as well as a destination for beneficial arthropods at different times of the season (Robinson et al, submitted for publication). Wetland margins, in particular, may be hotspots for beneficial arthropods, and these organisms spill over into canola fields. A study published by the network (Vickruck et al, 2019), for example, showed that nearly twice as many wild bees were collected at wetland margins than at traps located at a distance of 75 m into canola fields, and demonstrating that the spill-over declines as the distance from the non-crop area increases.

Finally, the network collected evidence that beneficial arthropods found in non-crop areas do provide services to canola growers such as pest control and pollination. A correlational study of 60 million seeded acres of yield data in Alberta (2012 to 2017), conducted by the network, showed that counties in Alberta where fields have more non-crop areas also have slightly higher canola yields (Galpern et al, 2020). This provides preliminary and indirect evidence that non-crop areas can influence canola yield. A pilot study of five fields, that used cages to exclude arthropods from canola plants, also showed that the spill-over of arthropods from non-crop areas may increase canola seed weight. This result is being confirmed with additional field experiments in the second phase of the network.

This second phase began in 2019 and combines field experiments, the beneficial arthropod database, and precision agricultural data to further investigate the relationship between non-crop areas, arthropods and canola yield. The research reported here is part of the Canola Agronomic Research Program (CARP Grant 2016.21) with project funding provided by the Alberta Canola Producers Commission (Alberta Canola) and the Manitoba Canola Growers Association (Manitoba Canola Growers).

B. Development of a beneficial arthropods database

This project produced what is likely to be the most geographically-extensive database on the distribution and abundance of beneficial arthropods found in Canadian prairie croplands**.** This database is being further analyzed as part of the second phase of the Beneficial Insects Surveillance Network funded by the Canola Agronomic Research Program (CARP).

Key features of this database are summarized in Table 1. Figure 1 indicates the distribution of sampling. Figure 2 summarizes the abundance and the diversity of beneficial pollinators, including honey bees and wild bees. Figure 3 summarize the abundance of beneficial predators that may be natural enemies of crop pests. The database will be made available for download by canola growers when all network second phase analyses have been completed.

This research is part of the Canola Agronomic Research Program (CARP Grant 2016.21) with project funding provided by the Alberta Canola Producers Commission (Alberta Canola),the Manitoba Canola Growers Association (Manitoba Canola Growers) and SaskCanola

Table 1. Database summary. Arthropods sampled, curated and databased since 2016 where collection and/or taxonomic work was supported, in whole or in part, by Canola Agronomic Research Program funds. Sampling data is summarized by collection near fields (Margins), at multiple distances from pivot corners (Pivots) and at multiple distances from wetlands that were surrounded either by crop fields or grasslands. These data are provided, here, primarily as an indication of sampling, curation and taxonomic identification effort.

		Abundance by site type				*Species richness[1] by site type*				*Unique locations by site type*			
Order	**Family**	**Total**	**Margins**	**Pivots**	**Wetlands**	**Total**	**Margins**	**Pivots**	**Wetlands**	**Total**	**Margins**	**Pivots**	**Wetlands**
Spiders	Lycosidae	10841	8067	636	2138	28	27	18	20	113	86	10	17
	Thomisidae	501	352	49	100	14	13	7	6	91	67	9	15
Harvestmen	Phalangiidae	8909	2010	566	6333	1	1	1	1	57	36	8	13
Bees	Andrenidae	8105	4985	179	2941	48	39	15	26	258	200	10	48
	Apidae	101053	67140	7594	26319	116	102	37	70	317	246	10	61
	Colletidae	561	480	13	68	24	18	5	17	137	108	5	24
	Halictidae	22904	13518	1857	7529	90	77	30	55	316	245	10	61
	Megachilidae	4533	3234	567	732	97	83	22	61	303	234	10	59
Beetles	Carabidae	10657	2683	5152	2822	57	33	35	45	163	116	10	37
	Totals	157407	99786	11461	46160	418	360	135	256	317	246	10	61

[1]Rarer species of bees (fewer than 10 individuals) are typically identified to the genus or subgenus level and are counted here as morphospecies.

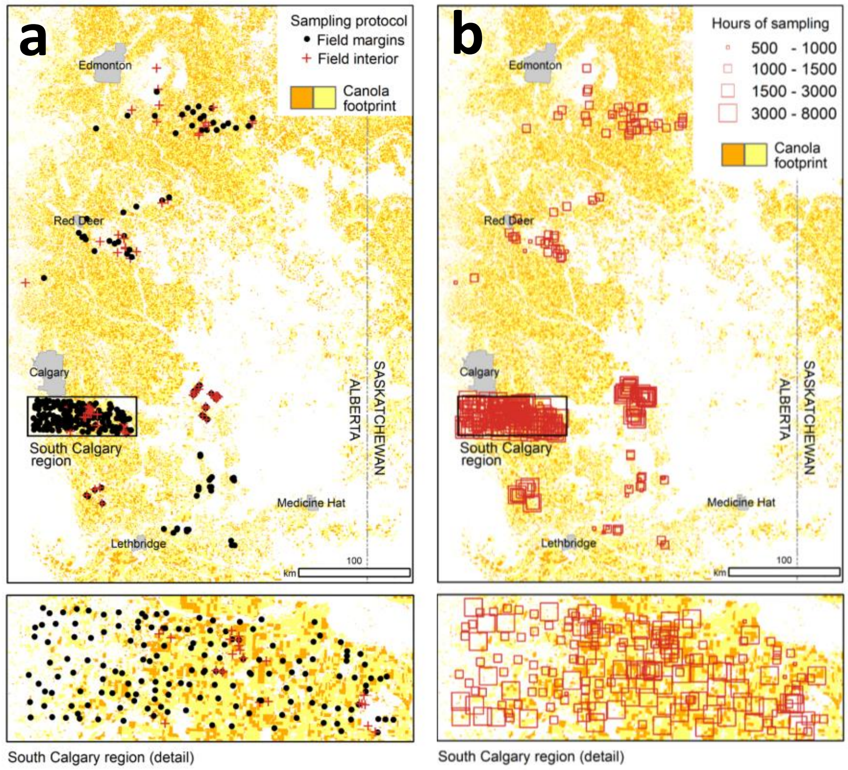


Figure 1. Sampling locations that represent the Beneficial Insect Surveillance Network. (a) Sampling occurred between 2016 and 2018 at 317 locations, with sites located at field margins or within the crop itself. (b) Passive trapping equipment was used, and resulted in 500 to 8000 trap-hours of sampling effort at any given site. Trapping occurred most often in a single year, but sometimes in two or three consecutive years.

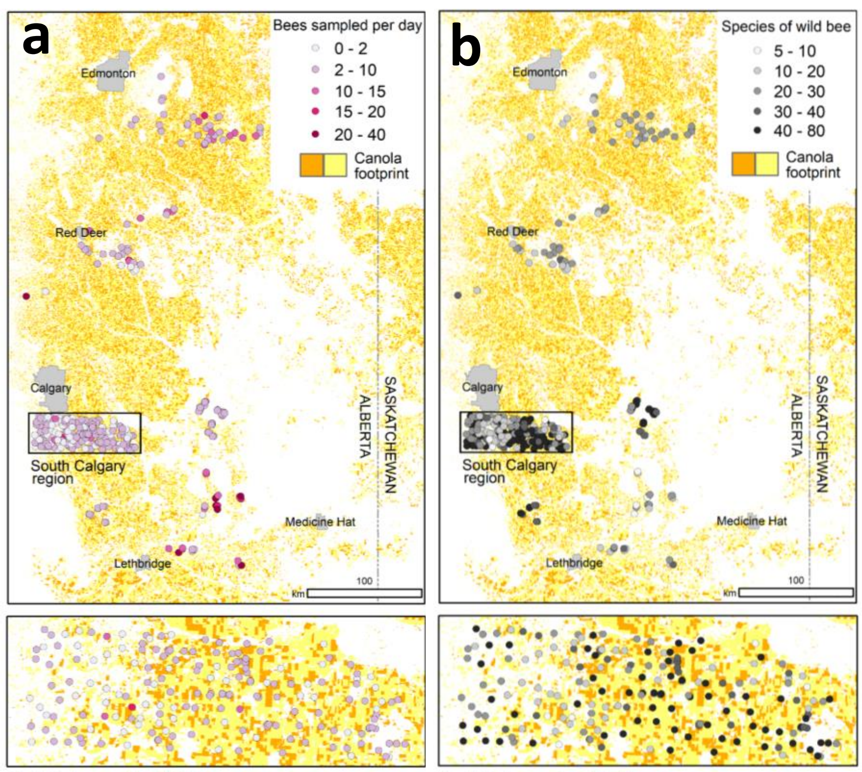
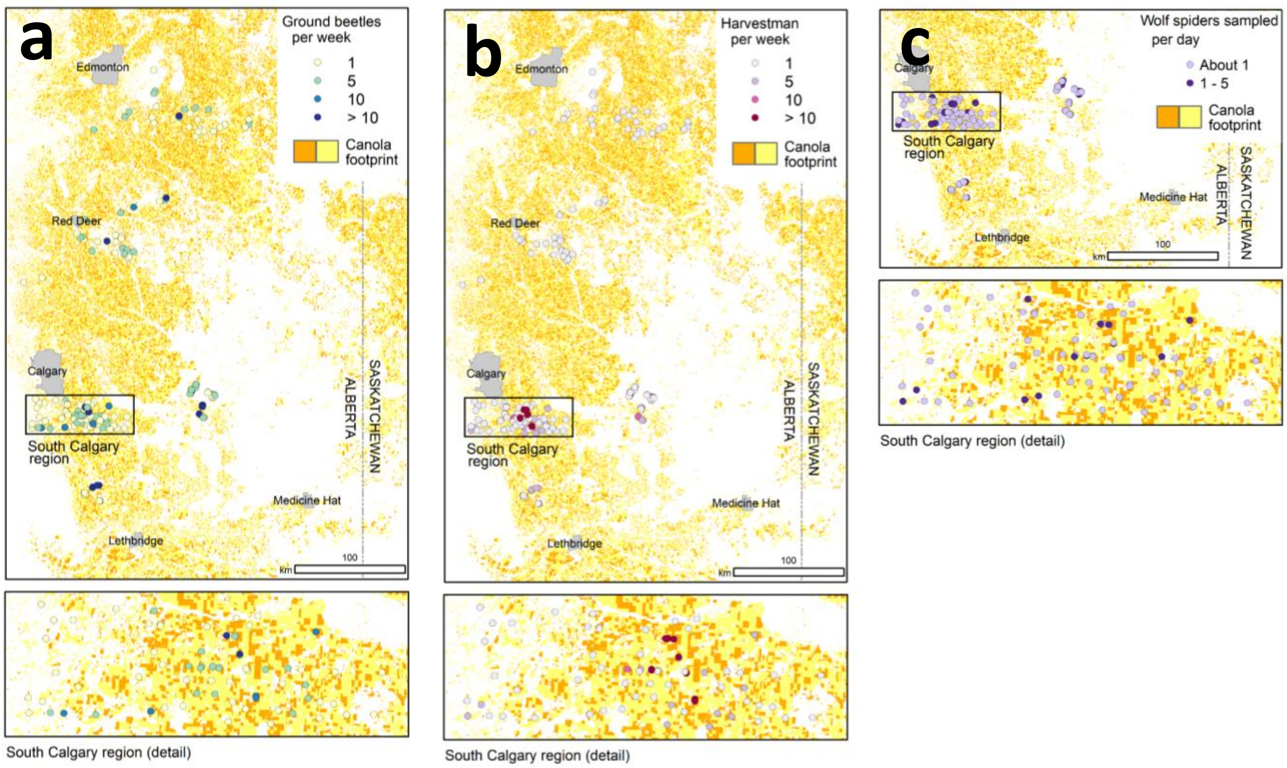


Figure 2. Beneficial pollinators sampled by the Beneficial Insects Surveillance Network, demonstrating wild bees are found in canola field interiors and margins and use this habitat for nesting and collecting pollen. (a) Pollinators, such as wild bees, were collected with varying abundance across all sites sampled. (b) Some sites recorded up to 80 different species of bee.

Figure 3. Natural enemies of crop pests sampled by the Beneficial Insects Surveillance Network, demonstrating (a) ground beetles, (b) harvestmen, and (c) and wolf spiders use field margins and field interior habitats where they are in a position to provide pest control services to canola crops.



C. <u>Key findings</u>

1. The network identified approximately 375 species of wild bees in or near Alberta canola fields. This is in addition to the managed honey bee, *Apis mellifera* and managed alfalfa leafcutter bee, *Megachile rotundata,* also recorded in canola fields.

    - Many of these bee species were rare, and are unlikely to play any economically-important role in canola pollination. Fifteen species were found at 50% or more of the 313 sites sampled, suggesting that there are a core group of bee species that are widely-distributed and abundant and therefore should be considered the most probable visitors to canola flowers during bloom. The study did not examine flower visitation by these species, however.

2. The network identified at least 42 species of the most common spiders in or near Alberta canola fields. There were dozens of rarer species in canola fields that were not identified taxonomically.

    - Two species of wolf spider were notably abundant and widely-distributed. *Pardosa distincta* was most common and found at 98% of the 125 sites sampled, while *Pardosa moesta* was second most common and found at 67% of sites.

3. The network identified at least 57 species of ground beetles (in the family Carabidae). There were a small number of rarer species in canola fields that were not identified taxonomically.

    - The ground beetle *Pterostichus melanarius*, was the most abundant and universal in distribution. It was sampled both in field interiors and margins.

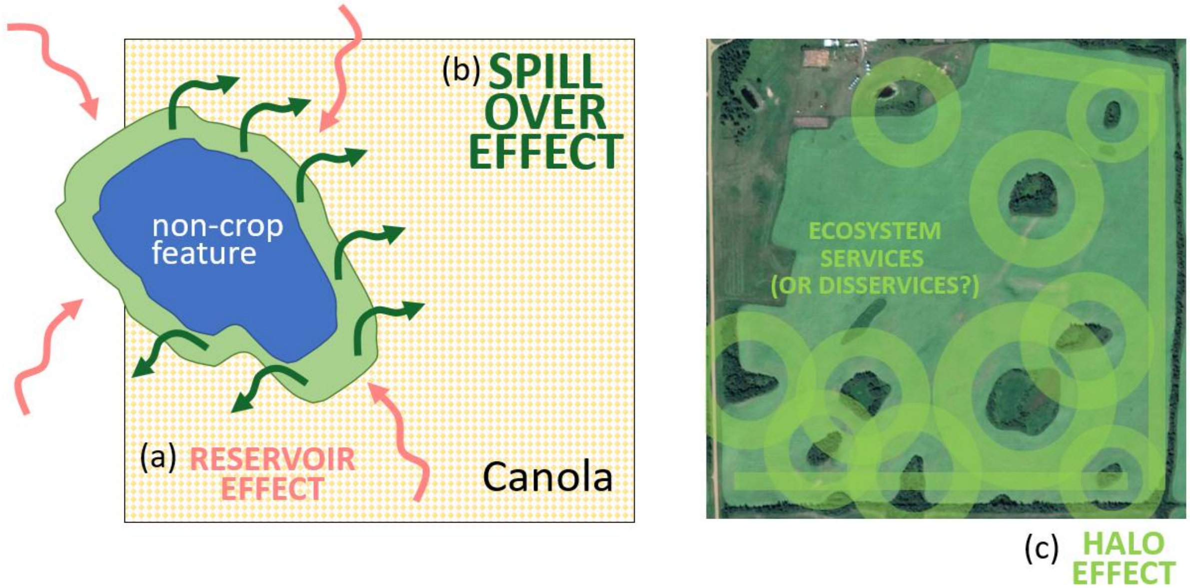


Figure 4. Three hypothesized effects that together would demonstrate a role for beneficial arthropods in supporting canola yields. Evidence for all three effects was recorded in the first phase of the network. (a) A *reservoir effect* (pink) implies that beneficial arthropods use non-crop features as habitat to support their life cycle, throughout the growing season or at specific times of the year. (b) A *spill-over effect* (dark green) implies that beneficial arthropods are more abundant within and near to a non-crop feature and that this abundance drops off with distance from the feature; this drop off implies that these features are also hotspots for these animals in the agricultural landscape. (c) A *halo effect* (light green) implies that any beneficial arthropods spilling over from a feature are providing ecosystem services (e.g. pollination or pest control) or ecosystem disservices (e.g., pests) to the crop, and this is revealed in a localized difference in crop yields. The "halo" of increased or decreased yield, however, may also be caused by non-living processes such as soil moisture or shading.

4. Non-crop areas within or near to fields are likely to serve as a source as well as a destination for beneficial arthropods at different times of the season (Robinson et al, submitted; see Section C). This date-dependent *reservoir* effect (Figure 4, a) was observed in multiple taxa. For example:

    - The ground beetle *Pterostichus melanarius* appears to migrate to canola during the early summer (May-June), then migrates to nearby grasslands and wetlands around harvest time (late August)

- The wolf spider *Pardosa moesta* also moves to canola during the early summer, but migrates to nearby road margins and grasslands at the end of the growing season

- Several species of bumble bee (e.g., *Bombus ternarius*) tend to be found more often in uncultivated wetland margins later in the summer than in field margins, perhaps representing a shift in the availability of flowers.

5. Non-crop areas may often serve as hotspots for beneficial arthropods that spill over into canola fields, where they have the potential to provide services to canola growers such as pest control and pollination. This *spill-over* effect (Figure 4, b) into crop was tested specifically for wild bee species near wetlands in canola fields (Vickruck et al., 2019; see Section C). The trapping rate of wild bees was nearly twice as high at a wetland margin than it was at traps located at a distance of 75 m into the field from the wetland.

   - This drop-off in trapping rate suggests that wetlands may be localized hotspots within a field, either because bees are attracted to flowers growing in uncultivated buffers near the wetland, or because bees nest there.

   - A spillover effect implies that the chance of a pollinator visiting a canola plant increases when it is closer to a non-crop area like a wetland or a field margin. Our study did not directly measure pollinator visitation nor did we link this visitation directly to the productivity of a canola plant.

6. A correlational study of 60 million seeded acres of yield data in Alberta obtained from Agricultural Financial Services Corporation (AFSC) showed that counties in Alberta where fields tend to contain more non-crop areas also have slightly higher canola yields (Galpern et al, 2020; see Section C). This statistical effect was observed while controlling for climate and soil differences observed across the province, and correcting for annual trends in yields between 2012 and 2017.

   - This should be considered preliminary and indirect evidence for a *halo effect* (Figure 4, c). The cause of this effect remains uncertain. Among the possible causes are: (i) pest control or pollination services provided beneficial arthropods that use non-crop features as reservoirs and spillover into fields, and (ii) soil moisture or shade that may vary in proximity to non-crop areas within fields.

   - The size of the increase in yield observed was small. The observation of any increase at all, however, implies that negative effects of non-crop areas in fields on yield, such as reservoirs for pests or weeds, are not the dominant effect across Alberta’s canola fields.

- A correlational study at this scale reveals very broad trends, and is a first step to accurately measuring the size and agronomic importance of a non-crop area effect on yield. More localized studies are needed to understand the specific effects of non-crop areas on yield in a particular grower's field, as these are likely to depend on many factors. The second phase of the network, funded by CARP, begins such a study.

7. The *halo effect* was also tested experimentally in a study of five canola fields. In this experiment, cages were used to keep beneficial arthropods out, and the difference in canola plant productivity was measured inside and outside the exclosure at three distances from a wetland.

    - This pilot study suggested that it was only at intermediate distances from a wetland (e.g., Figure 5; 75 m) that plants had heavier seeds outside the exclosures than inside.

    - A hypothesized mechanism for this effect is that the spill over of bees near wetlands visiting canola flowers is increasing seed size, but an edge or soil moisture effect that reduces canola productivity is counteracting the positive effects of pollination at distances closer to the wetland. The absence of natural enemy species may also have played a role in the lower yields observed under the exclosure.

    - The pilot study is being repeated over three years in an additional nine canola fields as part of the second phase of the network.

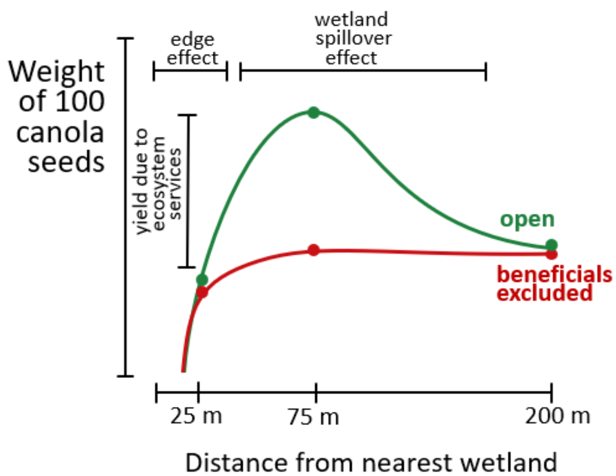


Figure 5. A stylized representation of the results from a pilot study of five fields, where pollinators and other beneficials were excluded using cages, and yield was compared inside (red) and outside (green) of the exclosure at three distances from a wetland. The small boost in yield observed in the pilot study at an intermediate distance (75 m) is being confirmed in the second phase of the network.

8. Different species of arthropod at our study sites have peaks in abundance at different times of the growing season. Growers are advised to think about pollination or pest control services in terms of a portfolio of different species providing services at different times of the growing season, rather than in terms of a single pollinator or natural enemy species that should be encouraged to visit the crop. For example:

    - Maintaining non-crop areas that provide habitat for a diverse community of insects and spiders which together have peaks in abundance at different times of the season is likely to maximize the chance that at least one pollinator species is abundant when canola is in bloom, or a natural enemy species is available to respond to a pest outbreak.

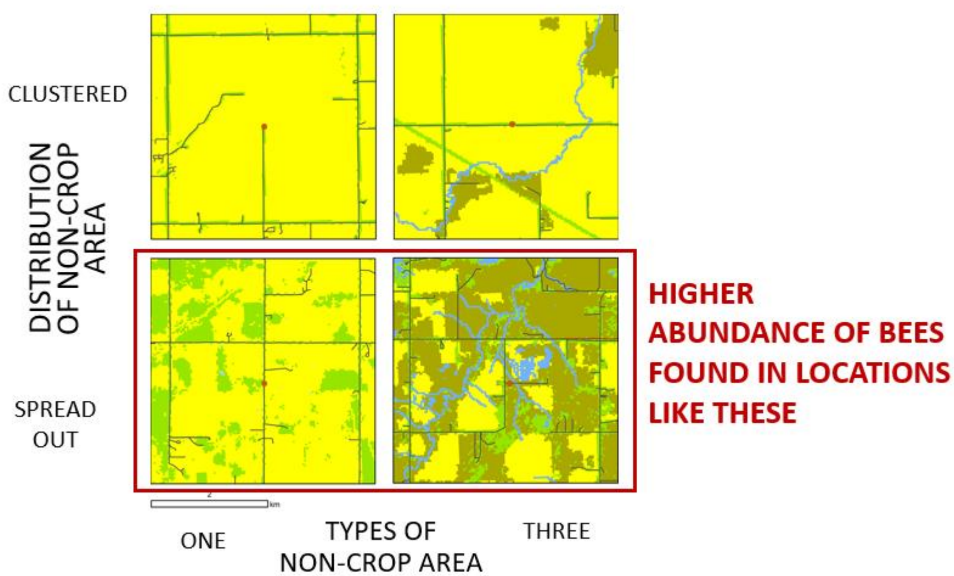


Figure 6. More complex landscapes, such as those in the lower two images, that have a spread-out distribution of non-crop area, are likely to host a higher abundance of bees. This effect may be due to landscape complementation, where different types of non-crop area complement one another by providing resources that together support the life cycle of the bee species studied. Yellow in these images are crop fields, while other colours indicate non-crop areas such as pasture, shrublands, wetlands, and intermittent stream courses. A manuscript detailing this work is in preparation.

9. Study locations that had smaller patches of non-crop area where these were distributed more evenly within and near fields had higher abundances of many bee species (Figure 6; Galpern et al., in preparation).

    - This could be caused by an effect known as landscape complementation. It may be helping beneficial arthropod increase their population sizes, by allowing them to move between crop and non-crop areas to complete their life-cycles.

- In other words, different types of non-crop features are complementary with one another and the crop itself, and when they are all available in close proximity, a higher population size is supported.

- Growers can take advantage of the landscape complementation effect by retaining many small non-crop areas within and near their fields. This effect is likely to be stronger rather than fewer larger areas that are not evenly distributed.

- Evidence suggests this effect exists for pollinator species. It may also exist for natural enemies such as spiders and beetles. Tests for these groups will be reported in the second phase of the network.

D. <u>Abstracts of scientific publications from the first phase of the network</u>

Full versions of these publications are available from paul.galpern@ucalgary.ca upon request. Two are currently published in international peer-reviewed journals. One of these (Robinson et al) has been submitted for publication. A fourth is in preparation (see Figure 6).

ABSTRACT 1 – IN PRINT

Pothole wetlands provide reservoir habitat for native bees in prairie croplands (*Biological Conservation*, 2019; v232, pp. 43-50)

Jess L. Vickruck, Lincoln R. Best, Michael P. Gavin, James H. Devries, Paul Galpern

The act of converting prairie grassland to agricultural farmland has negative implications for pollinator communities. In the Prairie Pothole Region, wetland remnants are a common feature in intensively cultivated landscapes. These wetlands are typically small and often left embedded in the cropland matrix and may act as the only semi-natural feature in a radius of several hundred metres. To quantify the role that these in-field wetlands play in supporting native pollinators, we sampled bees at three distances from the wetland margin into the surrounding cropland (0 m, 25m and 75 m) across the season in three field types (canola, cereal and perennial grassland). We used Bayesian multilevel models to test the hypothesis that native bees are using infield wetlands as habitat for nesting and foraging. Native bee abundance and diversity decreased further away from the margin of wetlands in both canola and cereal fields, while it increased in wetlands located in perennial grassland. Community composition did not change further away from wetlands, which may be because the foraging range of most species was within the sampling distance of the study. These results suggest that wetlands play an important role in providing critical resources for native pollinators, and encouraging farmers not to drain or plow through these wetlands will have beneficial impacts for native pollinators in the area. Maintaining in-field wetlands may have additional pollination benefits for farmers growing crops such as canola, which is known to benefit from insect visitors.

ABSTRACT 2 – IN PRINT

Landscape complexity is associated with crop yields across a large temperate grassland region (*Agriculture, Ecosystems and Environment*, 2020; v290, 106724)

Paul Galpern, Jess Vickruck, James H. Devries, Michael P. Gavin

Establishing semi-natural areas within annual croplands can provide habitat for beneficial organisms and ecosystem services to crops through a spillover effect. However, this approach to increasing landscape complexity may have no effect on crops, or it may promote pests, weeds and other disservices that reduce productivity. An argument for changing landscape complexity may be more persuasive if it is associated with higher crop yields. Here, we examine regions that vary in their landscape complexity and, therefore, may also naturally differ in the potential for ecosystem services, disservices and crop yields. Specifically, we examine crop-growing districts in the Canadian province of Alberta to test whether the presence of more non-crop land covers has increased crop yields. Our dataset covered about one-quarter of the seeded area in Canada between 2012 and 2017 consisting of 10,069 records representing average field-level yields reported to a crop insurance provider. In total, we analyzed summary data for 250,000 km2 of seeded area for seven grain crops. Using a functional regression approach, we found evidence for a plausibly positive association between yield and the non-crop land covers found within and near fields in four of seven crops. Landscape complexity, therefore, represented a measurable yield benefit for farmers, although the variance in yield explained by the landscape was small. These findings suggest there may be a low risk of disservices to crops from non-crop land covers in this region. Our study adds support at a broad geographic extent for initiatives that restore perennial and other semi-natural vegetation in annual cropping systems and suggests that, in this temperate grassland region, their promotion (e.g., as carbon stores or as biodiversity refugia) may have no adverse effects for crop production.

ABSTRACT 3 – SUBMITTED

Non-crop sources of beneficial arthropods vary within-season across a prairie agroecosystem (Submitted for publication)

Samuel V. J. Robinson, Diane Edwards, Jess L. Vickruck, Lincoln R. Best, Paul Galpern

1. Ground-dwelling arthropods can be important generalist predators in agroecosystems, and can use non-crop features as overwintering habitats. However, it is unclear which types of landscape features constitute useful non-crop habitat, and at what spatial scale organisms gather resources. Additionally, the same landscape feature may act as a source or a destination for arthropods at different times of the year, but this is rarely considered.

2. We modeled the abundance of four common species of Canadian prairie arthropods caught in a set of 198 in-field and roadside pitfall traps (June to August of 2017). Functional regression was used in order to simultaneously consider both the habitat preferences and the timing of movement from the land cover classes.

3. *Pterostichus melanarius* (Coleoptera: Carabidae) and *Pardosa moesta* (Araneae: Lycosidae) were attracted to canola (*Brassica napus*) during the early summer, then dispersed to grasslands, wetlands, and grassy road margins at the end of the summer. In particular, *Pterostichus melanarius* aggregated in canola early in the growing season, suggesting that its role in suppressing crop pests may be underestimated. *Pardosa moesta* (Araneae: Lycosidae) and *Phalangium opilio* (Opiliones: Opilionidae) showed weak patterns of seasonal migration, and were more influenced by large-scale geographic patterns rather than landscape composition.

4. Synthesis and applications: Our results suggest that predatory arthropods migrate into canola crops during the early summer, and that grasslands and wetlands act as seasonal reservoir habitats. Farmers and land managers should consider preserving existing habitat in order to maintain pest-control services across the season