IMPROVING CROP RISK ASSESSMENT TOOLS FOR BERTHA ARMYWORM

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Introduction

The bertha armyworm, *Mamestra configurata* Walker, is an economically significant pest of canola in western Canada. The range of this species extends across most of North America (King 1928, Jones and Heming 1979) and the first reported outbreaks were on flax, alfalfa, and sweet clover in the 1920s (King 1928). Prior to becoming an agricultural pest, its populations likely increased on an introduced weed, lambs quarters, *Chenopodium album* (Dosdall and Ulmer 2004). Currently its main hosts are the abundant monocultures of *Brassica napus* (Turnock 1985, Ulmer et al. 2001, Dosdall and Ulmer 2004). Its outbreaks in canola are sporadic but expensive; the 1971-1972 and 1993-1999 outbreaks cost producers tens of millions in damage and insecticide application (Reigert 1984, Turnock and Philip 1977, Mason et al. 1998).

The bertha armyworm (BAW) has one generation per year in the prairie provinces (Wylie and Bucher 1977). Adult moths emerge from pupae in the soil in mid-June to early August and greatly prefer to oviposit on crops in the full-flowering stage (Ulmer et al. 2002). The moths are most active (calling and mating) at the pre-dawn period (Struble et al. 1975, Swailes et al. 1975). Female moths begin to release pheromone and call mates 2 to 3 nights after emergence, and egg laying generally occurs the following night (Howlader and Gerber 1986). Under lab conditions, Howlader and Gerber (1986) found that almost 75% of a female's eggs are laid within 7 days of emergence. Most females lay between 600-1500 eggs (Bucher and Bracken 1976, Turnock 1985), and most eggs are laid in the upper portion of the crop canopy on the underside of the leaves (Ulmer et al. 2002) (Figure 1). In about 1 week the eggs hatch (Rempel 1951, Bailey 1976a) and tiny green neonates with black heads emerge (Figure 2). In about 3.5 weeks the larvae complete the first 4 instars (Figure 3) feeding on foliage (Dosdall and Ulmer 2004), and start into the more damaging stage of the fifth and sixth instars where they can move onto developing pods (Mason et al. 1998). During the sixth and last instar the larvae may remain green, or turn brown or velvety black, and consume approximately 80% of the food eaten by the larvae (Mason et al. 1998, Bailey 1976b). Development can progress more quickly with warmer weather (Bailey 1976a) and on more suitable host species such as canola (Dosdall and Ulmer 2004). Late in the summer mature larvae drop off the plants and crawl into the soil to pupate (Figure 4). Pupae are reddish-brown and overwinter 5-16 cm below the surface (Mason et al. 1998.

The major components of the bertha armyworm pheromone were determined in the early 1970's (Struble et al. 1975, Chrisholm et al. 1975) and a pheromone mixture was developed for use in traps (Underhill et al. 1977). These early pheromone traps were 3.5x more efficient at catching bertha armyworm moths than the light traps that were in use (Bucher and Bracken 1979) and greatly reduced the by-catch of non-target species. In 1976-1977 a pheromone trap network was tested at 36 sites across the prairie provinces and soon replaced light traps as the basis for detecting

Figure 1. Bertha armyworm eggs

Figure 2. Bertha armyworm neonates

Figure 3. Bertha armyworm larva

Figure 4. Bertha armyworm pupa

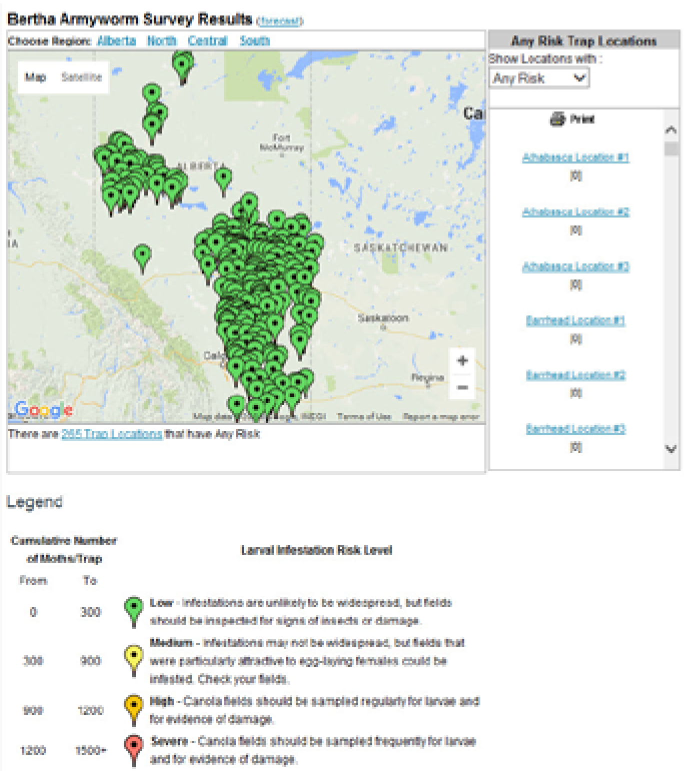

Figure 5. Alberta Insect Pest Monitoring Network Real Time Google Map

and forecasting bertha armyworm populations (Steck et al.1979). This trap network evolved into an early warning system in the early 1980s in Saskatchewan. It grew and improved into a coordinated monitoring system across the canola growing areas of Alberta, Saskatchewan, and Manitoba in 1995. In recent years more than 400 trapping locations have successfully monitored bertha armyworm in these provinces.

In Alberta, the traps of the Insect Pest Monitoring Network are checked weekly during the flight period and a map of moth catches is updated online (Figure 5). This map provides producers with real-time moth densities, allowing them to make informed management decisions if they have a canola field near a trap site with a moderate to high moth catch. Research in the 1980s showed that a high number of moths per trap often indicated that one or several fields nearby would subsequently have a larval density above the economic threshold (Turnock 1987). However, because of the great amount of variation between fields farmers need to scout each individual field for larvae density (Turnock 1987). The time between the peak trap catch and larval development to the damaging stage allows other factors to greatly influence the larval population. These include predation (Tamaki and Weeks 1972), parasitism and disease (Turnock 1988, Wylie and Bucher 1977, Wylie 1977a, Wylie 1977b), and inclement weather (Bailey 1976a).

A forecast map for the following year is produced based on current year trap catches, which alerts agrologists and producers to potential problem areas. Although other factors can influence pupal survival such as snow cover and thus soil temperature (Lamb et al. 1985, Bailey 1976a), farming practices and population levels of parasitoids (Turnock and Bilodeau 1984, Wylie and Bucher 1977). The high variability of bertha armyworm populations between years necessitates that the trap monitoring network be run yearly.

Major improvements have been incorporated into the bertha armyworm monitoring system since the original research was done. Today we use a different trap design (green unitrap) and an improved pheromone which is 2x more attractive (Struble et al. 1984). The canola industry has also changed dramatically in the last 20 years. Hybrid canola dominates the landscape, and is a popular choice as producers find that canola consistently has higher projected returns. In light of these changes, the relationship between the trap catches and larval populations found in Turnock's original research (1987) needs to be revalidated. Risk categories may need to be more clearly defined and the monitoring system could be fine-tuned to improve the forecasting efficiency.

The objectives of this research are to (1) determine the optimum density of traps to maximize accuracy and minimize overlap, (2) determine the association of larvae numbers and trap counts to improve the forecasting model through larval sampling associated with the trapping intensity study. This research will also (3) test the impact of trap height and location relative to the field on bertha armyworm moth catch. And finally, because bumblebee by-catch is a major concern in the Peace Region of Alberta, this research aims to (4) develop and test a system that would reduce bumblebee catch in bertha armyworm traps without affecting the moth catch for forecasting.

Materials and Methods

Optimal trapping density for outbreak prediction and validation of the forecasting model

The area for the trap density study was chosen based on increasing pheromone trap moth catches in 2011, which indicated a major bertha armyworm outbreak in 2012, the first year of our three-year study. Thirty-five townships (1 township = 23,040 acres) of cropland, covering parts of Lamont, Two Hills, and Minburn counties east of Edmonton, were selected as the study area for the three years (Figure 6). A canola field, belonging to a cooperating farmer, as close as possible to the centre of each township was selected as a trap site for each of the study years. Many of the farmer cooperators were able to participate throughout the study. Those that didn't have an available field were helpful in identifying neighbours that did. The location of all canola fields grown in these townships in the previous year was identified by driving through the entire area prior to seeding each year (Figure 7). All canola stubble located was mapped and the amount of canola in 1, 2, and 3 mile radiuses of the trap field were determined using the data collected by the driving the townships.

Figure 6. Map of townships included in trap density study (Study area townships indicated in Red).

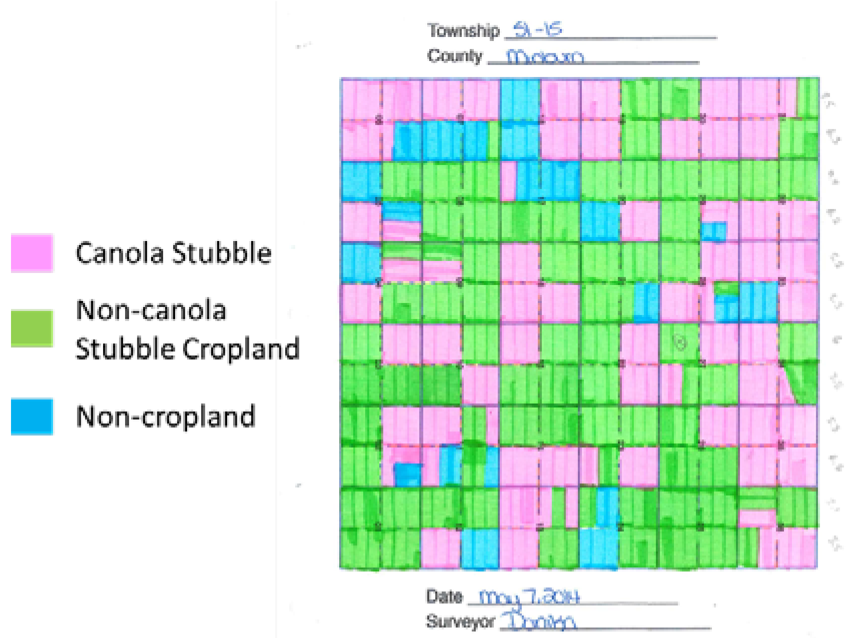

Figure 7. Example of the canola stubble map

Two unitraps were established in each field 2 metres from the field edge and 50 m apart. A pheromone-infused (Struble et al., 1984) rubber septum was placed inside the cage above the funnel, and a vapona strip was secured inside the trap bucket. The lures and vapona strips were purchased from Contech. The traps were wired securely to a metal post 150 cm above the soil surface. Bertha armyworm moths were removed from the traps and counted weekly from mid-June throughout July by the farmer or our staff. Colour photos and sometimes a plastic petri-dish with reference specimens of a bertha armyworm moth and other common by-catch noctuids were provided to help with identification. Removed moths were placed in a paper bag, identified with date and location, and frozen for later verification in the lab. Moth catches were added to the bertha armyworm map on "Ropin' the Web" Alberta Agriculture website as part of the bertha armyworm Insect Pest Monitoring Network already in place. Traps were taken down in August, cleaned and stored for the next summer. The numbers of moths in the two traps per location were averaged for use in statistical analysis.

Statistical analysis was attempted to identify the minimal and optimal number of trap locations for providing accurate forecasts and properly predicting outbreaks but no suitable approach was developed.

Moth catches were evaluated in relationship to canola acreage in the previous year from the surrounding area using a simple regression approach. This was calculated using both the amount of canola in 1, 2 and 3 mile radii around the trap field and canola within the township.

The relationship between adult moth catches in the pheromone traps and the resulting larval infestations was also re-evaluated to validate

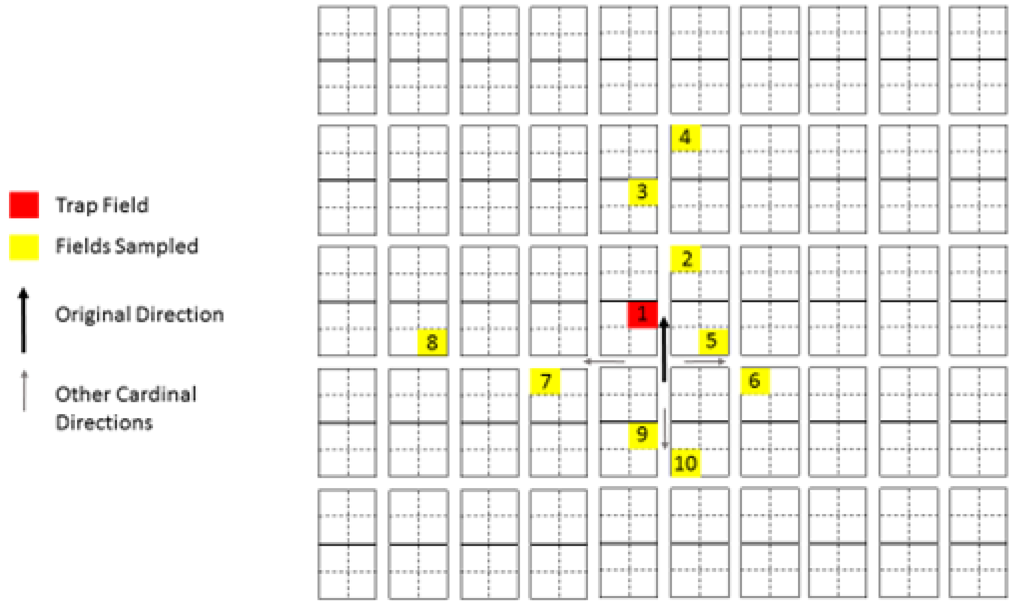

Figure 8. Larval sampling

the forecasting model that is based on trap counts. Larval sampling in selected trap fields and 9 fields surrounding them was carried out. The sampling plan (Figure 8) was to sample the trap field, then 3 more fields in the direction of travel the trap was originally approached from. Then from the closest intersection to the trap field, 2 more fields were sampled in each of the other cardinal directions. This larval sampling was carried out in 8, 13, and 12 trap fields and the 9 fields surrounding the trap field in 2012, 2013, and 2014 respectively.

The larval density was surveyed in August based on the "Manitoba" method described in Turnock and Bilodeau (1985). A quarter square metre of canola was shaken and the ground searched for larvae, in six sites 10 to 25 m from the field edge; two each at one end, the middle, and the other end of the field. The Alberta Agriculture bertha armyworm monitoring system allowed for the location of current outbreaks each year in various parts of the province to be identified.

In 2012, 79 fields in Lamont, Two Hills, and Minburn counties were surveyed.

In 2013, 132 fields in Lamont, Two Hills, Minburn, Smoky Lake, Wheatland, Stettler, and Paintearth counties were sampled. Agriculture Fieldmen of Paintearth, Stettler, and Smoky Lake and the Battle River Research Group assisted in field larval counts in 2013.

In 2014, 118 fields with low, medium, and high trap counts were sampled in the counties of Camrose, Leduc, Westlock, Stettler, Lacombe, Wheatland, Kneehill, and Forty Mile counties. The Canola Council and the Assistant Agriculture Fieldman of Kneehill county, assisted with field larval counts in 2014.

Larval counts were also carried out in Saskatchewan on 18 (2012) and 30 (2013) fields by staff from Agriculture and Agri-Food Canada, Saskatoon.

Effects of trap height and location on trapping efficiency

Trap heights of 150 cm (high) and 75 cm (low) were compared to determine if trapping efficiency was impacted. At 4 locations in Wheatland county 10 high and 10 low traps were evaluated in 2013 and 2014. Trap height was not evaluated in 2012 because of an inability to obtain enough traps from the supplier. All traps and pheromones were prepared and monitored according to the procedure in part A.

Relative efficiency of traps located on the north, south, east, and west sides of fields in Wheatland county and the study area 2012, 2013 and 2014. All traps and pheromones were prepared and monitored accord to the procedure in part A.

Trap modifications to reduce bumblebee catch

A trap which closed during the day, to exclude bumblebees, and opened at night to catch moths was developed by engineering students at the University of Alberta (U of A) as part of a fourth year project. A prototype was produced by 3-D printer, and then redesigned to reduce production costs. Engineers from the Agriculture Technology Center, Alberta Agriculture and Forestry, designed a second trap prototype. The U of A trap consisted of a rotating shield that bolted onto the top of the trap. The shield rotated closed during the day to exclude bees. The Ag Tech Center trap had a flap mechanism that sat inside the funnel of the trap. The flap closed during the day to exclude bees. Six traps of both new prototypes were constructed for the 2013 field season. The two designs allowed us to compare different approaches to solving the problem of bee by-catch (Figure 9).

Figure 9. Modified U of A Trap (L) Ag Tech Centre (R)

In 2013, both designs were tested in the Peace Region, where bumblebee by-catch was extremely high, as well as the main study area in central Alberta. Unfortunately, the opening and closing traps did not function in the field. The Agriculture Technology Centre (Lethbridge) re-designed the University of Alberta student project trap. Both trap designs were rebuilt for the 2014 field season. In 2014, the two trap designs were deployed in the counties of Newell, Wheatland, and Grande Prairie. Results shown are for the 2014 year only.

Automatic counting traps were tested as a side to this project. There is some promise although the traps counted everything from small flies to the target moths. Results are not shown because it is proprietary early generation research technology being developed by Michael Reinke, ISCA Technologies, Riverside, California, USA <www.iscatech.com>.

Results

Optimal trapping density for outbreak prediction and validation of the forecasting model

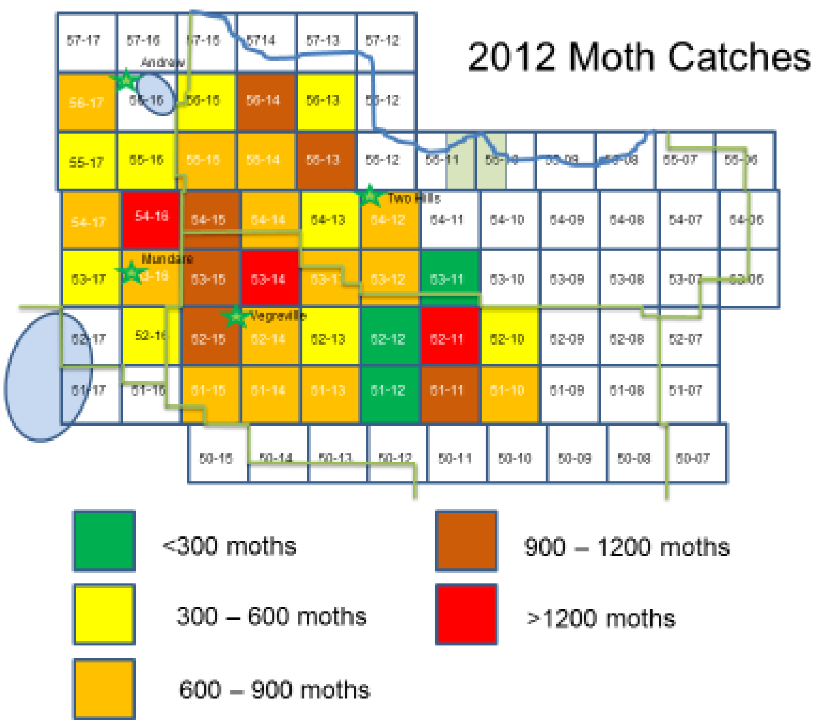

Figure 10. 2012 Moth catches from traps.

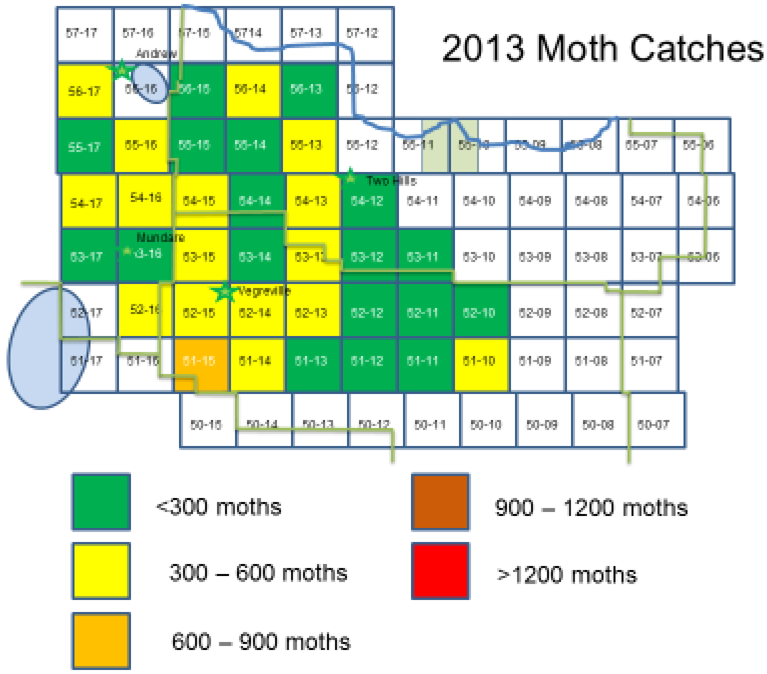

Figure 11. 2013 Moth catches from traps.

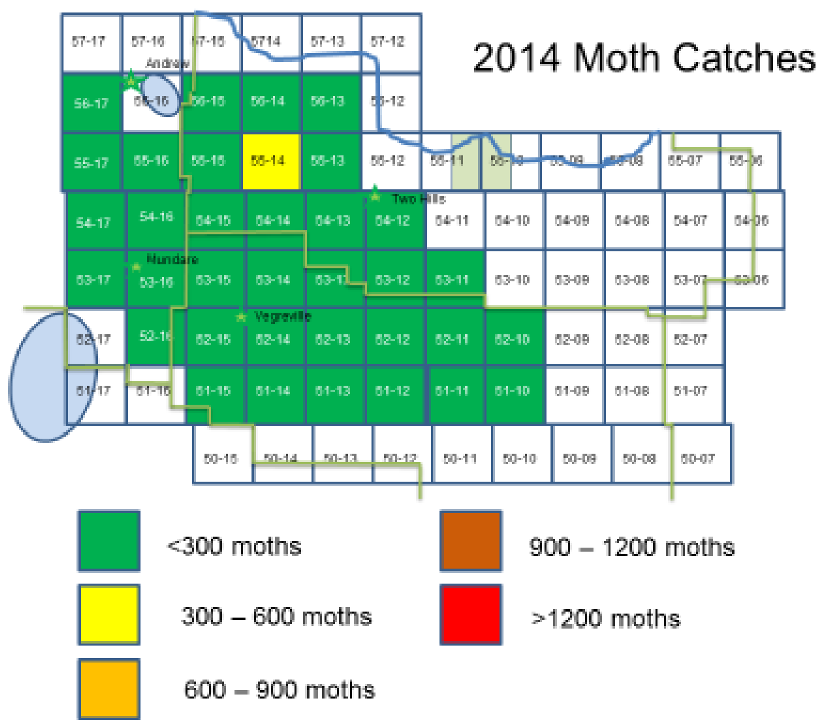

Figure 12. 2014 Moth catches from traps.

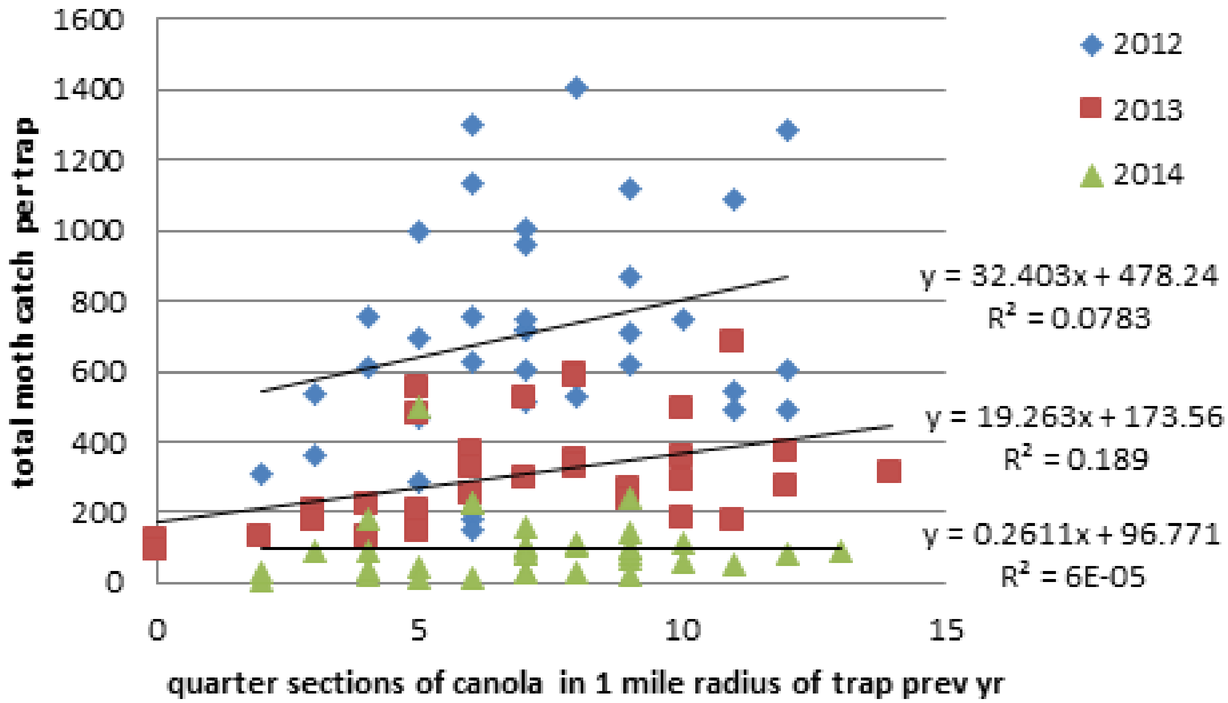

Figure 13. Moth catch per trap compaired to quarter sections of canola in a 1 mile radius

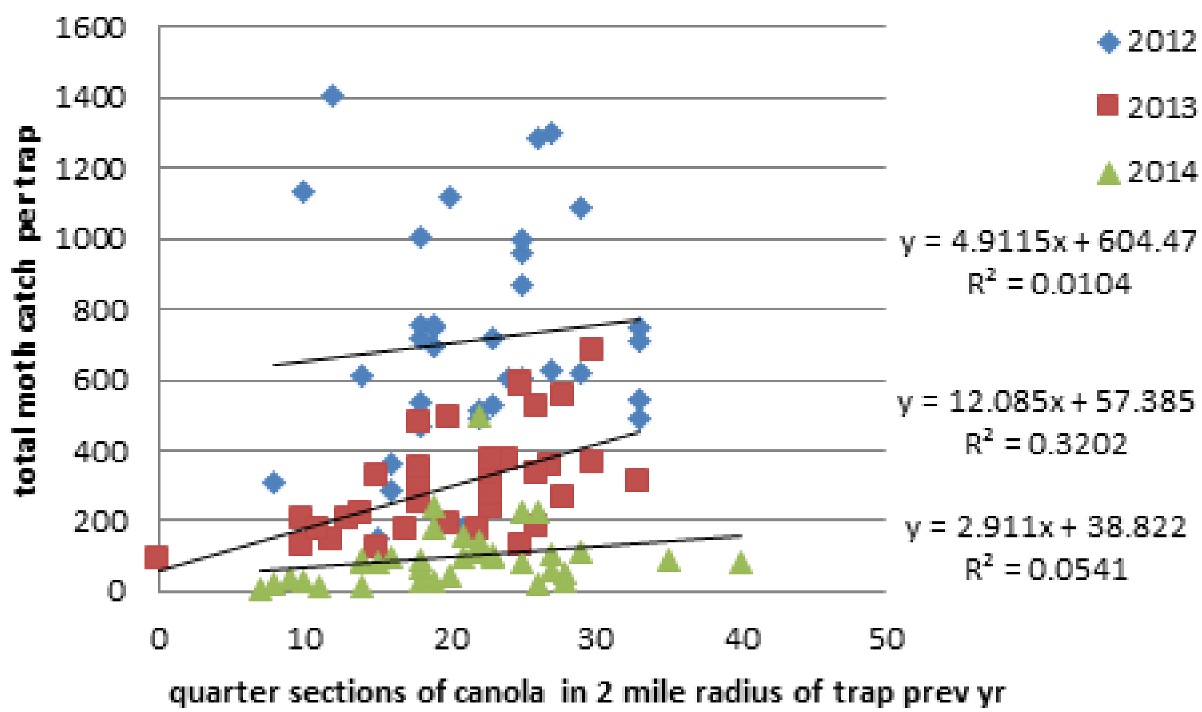

Figure 14. Moth catch per trap compaired to quarter sections of canola in a 2 mile radius

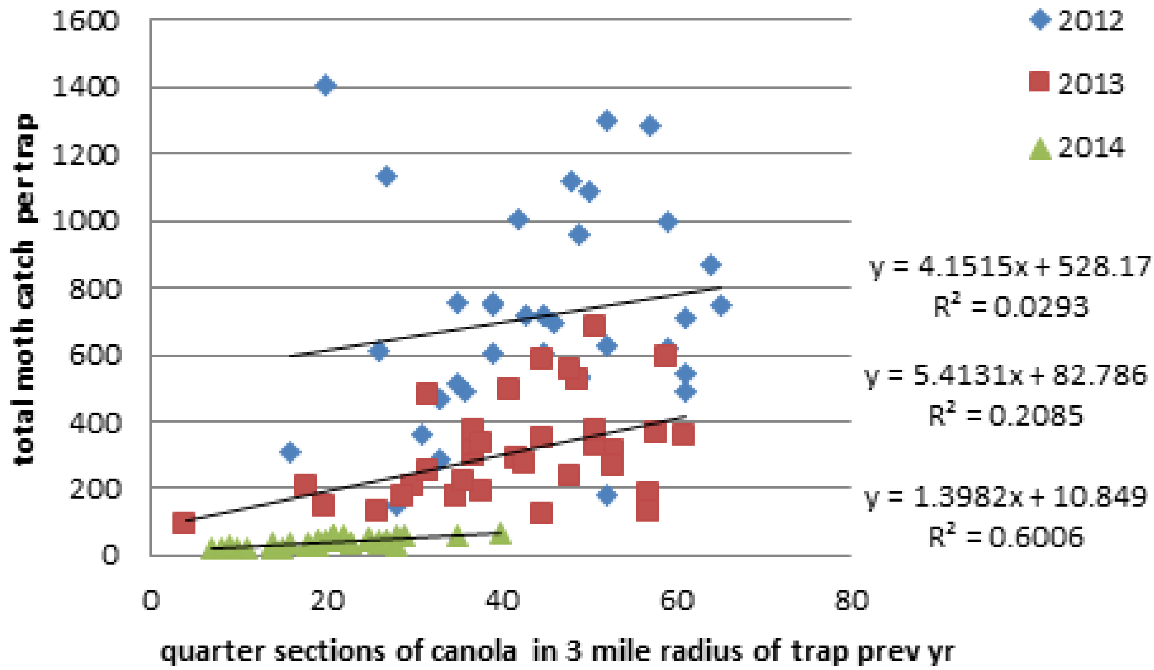

Figure 15. Moth catch per trap compaired to quarter sections of canola in a 3 mile radius

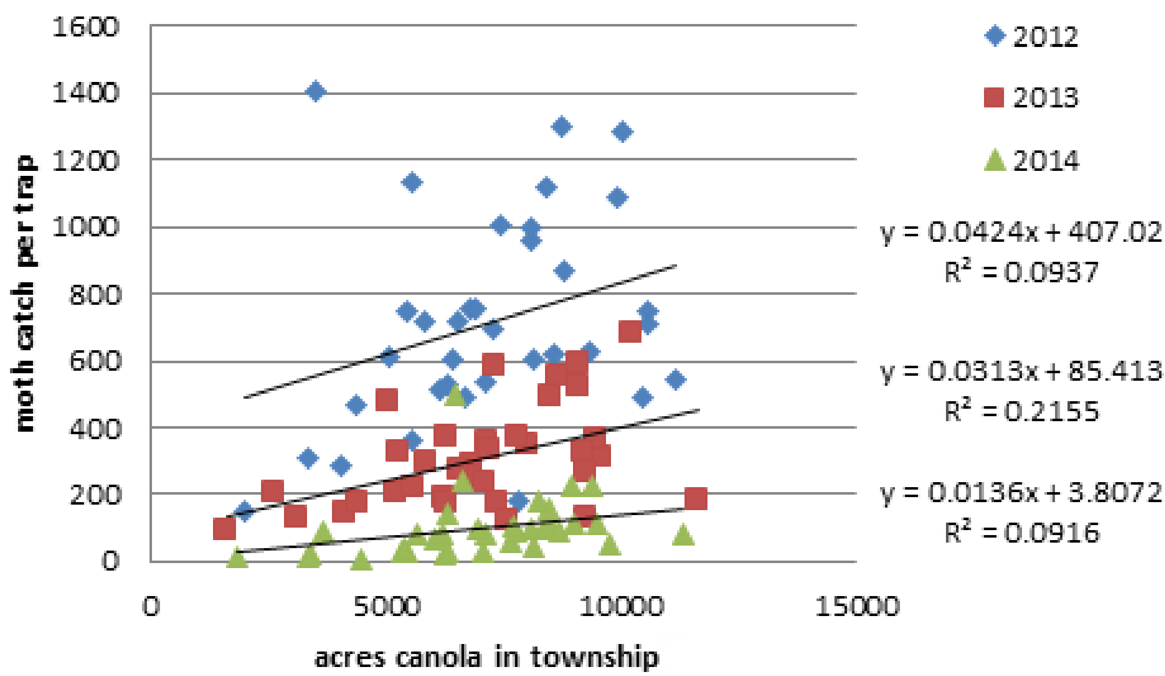

Figure 16. Acres of canola in a township

Relation between the number of *Mamestra configurata* moths captured with pheromone traps in 37 fields and the larval density in these trap fields as well as these fields plus surrounding fields (N = 334). The number of fields exceeding a larval density of 10, 20, and 30 per square metre is shown as a proportion of the number of fields.

Table 1. Larval denisities all 3 years of study

Moths/ trap	Trap Fields						All Fields					
	Larvae/m²			*P**			Larvae/m²			*P**		
	N	x̄	max	>10	>20	>30	N	x̄	max	>10	>20	>30
0-299	8	2.00	8.7	0	0	0	54	3.35	18.0	0.07	0	0
300-899	19	4.9	25.3	0.11	0.05	0	165	4.71	34.0	0.12	0.06	0.01
900-1199	5	1.17	2.7	0	0	0	59	11.21	116.0	0.37	0.15	0.09
>1200	5	10.22	22.0	0.20	0.20	0	56	7.0	26.0	0.25	0.07	0

**P*=proportion of fields with larval densities above 10, 20 and 30 larvae per square metre.

Table 2. Larval densities 2012

Moths/ trap	Trap Fields						All Fields					
	Larvae/m²			*P**			Larvae/m²			*P**		
	N	x̄	max	>10	>20	>30	N	x̄	max	>10	>20	>30
0-299	0						0					
300-899	2	1.67	2.0	0	0	0	17	5.25	28.0	0.12	0.06	0
900-1199	3	1.33	2.7	0	0	0	31	11.2	41.3	0.45	0.19	0.13
>1200	3	10.22	22.0	0.33	0.33	0	31	7.42	23.3	0.26	0.07	0

Table 2. Larval densities 2013

Moths/ trap	Trap Fields						All Fields					
	Larvae/m²			*P**			Larvae/m²			*P**		
	N	x̄	max	>10	>20	>30	N	x̄	max	>10	>20	>30
0-299	6	2.67	8.7	0	0	0	23	6.14	18.0	0.17	0	0
300-899	8	3.92	7.3	0	0	0	70	5.13	34.0	0.10	0.06	0.01
900-1199	2	0.67	0.7	0	0	0	28	11.21	116.0	0.29	0.11	0.04
>1200	1	n/a										

Table 2. Larval densities 2014

Moths/ trap	Trap Fields						All Fields					
	Larvae/m²			*P**			Larvae/m²			*P**		
	N	x̄	max	>10	>20	>30	N	x̄	max	>10	>20	>30
0-299	3	0.33	0.7	0	0	0	31	1.2	7.3	0	0	0
300-899	9	6.95	25.3	0.22	0.11	0	78	4.19	33.0	0.12	0.05	0.01
900-1199	0	n/a					0	n/a				
>1200	1	n/a					12	2.91	8	0	0	0

Effects of trap height and location on trapping efficiency

Higher traps caught more bertha armyworm than lower traps on average in both 2013 and 2014, however the difference was not significant because of the large amount of variation between high and low trap catches. Two-sample t-test, assuming unequal variances, found no significant difference between high and low traps (p=0.3307 and p=0.7053 in 2013 and 2014 respectively).

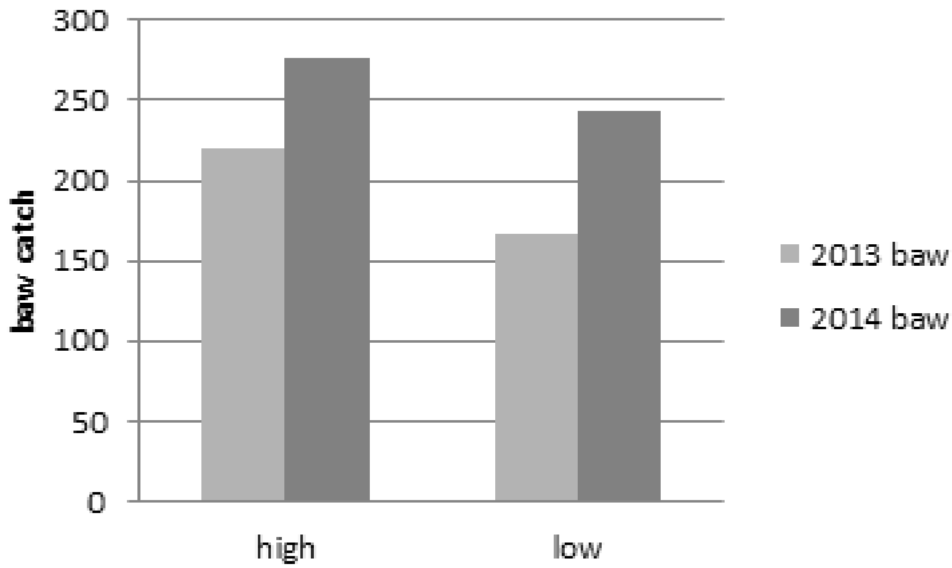

Figure 17. Larval counts at various trap catches.

The trap location study revealed no consistency as to which side of the field caught the most moths.

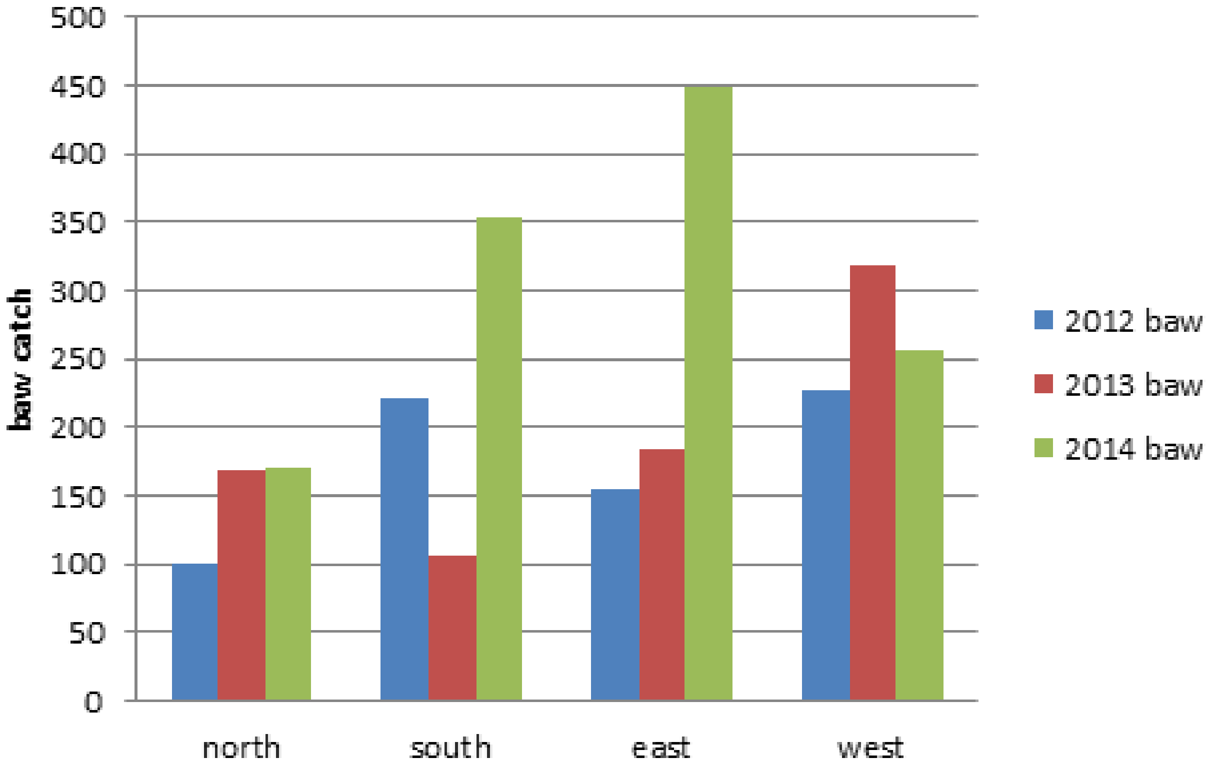

Figure 18. Average moth catch per trap at locations on the north, south, east, and west sides of the fields.

Trap modifications to reduce bumblebee catch

There was a significant decrease in the number of bumblebees caught in both Agriculture Technology Centre and the University of Alberta opening and closing traps. ($p= 0.047$). There was also a significant decrease in the number of bertha armyworm moths caught in each trap ($p= 0.009$). The reduced moth catch in the closing traps means we will not be adopting the current trap designs. It will be necessary to revisit this approach to reducing bumblebee by-catch.

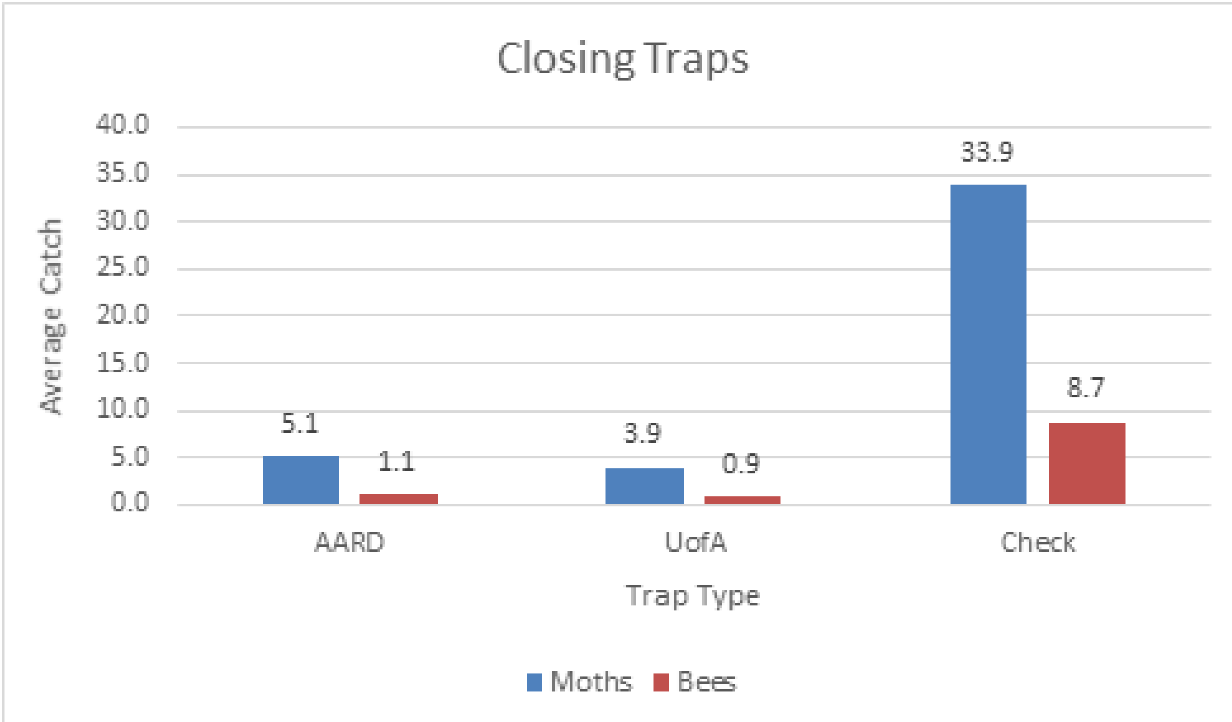

Figure 19. Comparison of the 2 opening and closing trap styles

Summary and Discussion

We were fortunate with the timing of this study. The study area was situated in the region of a bertha armyworm outbreak in 2012. Watching the year to year fluctuations in trap catches; paying close attention to 2011 moth catch increase allowed us to position the study area.

Steck et al. (1979) looked at moth catch in relation to proximity of current year canola within 1 km and found no significant relationship. In contrast, we looked at the amount of canola grown in the previous year and found a positive correlation with the moth catch. This suggests that localized outbreaks can develop in a locale if there is population build-up in previous years, especially if canola is continually grown in the same area as is now common in all canola growing regions. This also suggests that the closer the current year canola is to the previous year, the more likely a pheromone trap will catch a representative sample of the population. It also at least partially, explains the lack of differences in the study into which side of the field to place traps. The proximity of last year's canola is more important than any differences that may be created by prevailing wind direction. We also found the traps tended to catch more moths in areas of intense canola production the previous year. This could be used to recommend placing traps in areas where canola production is more intense.

Optimal trap density was one of the major objectives of this study. Unfortunately it was not possible to statistically determine how many traps would be ideal to forecast an impending outbreak. If we look at the 2012 map, virtually any trap would indicate a warning with 32 of 35 traps suggesting a potential problem. At the current density of 5 trap sites per county on average, the risk would be apparent. At lower levels of moth catches, many more traps would be needed to pick up any small or localized field problems. The practical limits of finding enough cooperators will limit the number of traps that can be successfully placed. Watching building populations in preceding years can be used to suggest where more intensive trapping is needed to catch potential outbreaks.

Turnock (1987) suggested that bertha armyworm moths travel in search of blooming canola fields during the first couple nights after emergence, prior to when reproductive activities begin. This idea of dispersal is supported by Swailes et al. (1975) who caught male moths in traps baited with virgin females up to 80 km away from the nearest infested field. When Bucher and Bracken (1979) compared early pheromone traps to light traps they found that pheromone traps 200 meters from the emergence/release point caught twice as many moths as light traps only 120 m away. The idea that the moths disperse early after emergence supports our results which, although finding a relationship between the amount of canola the previous year and moths caught, found no consistent increase or decrease in the strength of this relationship based on canola in 1 mile, 2 miles, or 3 miles radiuses.

Steck et al. (1979) suggested that adult counts of 1000-2000 males/trap/season would correspond to economically damaging larval numbers. Our results support this as traps with a cumulative total of 900 or more moths had the highest proportions of nearby fields with larval counts above the economic threshold (Table 2). However, we found even in high moth catch areas, the majority of fields were still below threshold larval density, and there was a large variation between fields. Steck et al. (1979) also warned that weather and parasite populations could impact the larval population and that larval density of each field would need to be verified prior to proceeding with control measures.

The population trend over the study period (in both the study area and the province) was from outbreak (2012) to virtually no spraying for bertha armyworm in 2015 in the entire province. Traps tended to be less predictive of damaging larval populations in succeeding years after an outbreak as biotic factors such as parasitism and diseases take a toll on larvae. Evidence of feeding on lower leaves but no larvae found in eastern area of study in 2012 and throughout the study area in 2013. This may be the result of epizootic events on small larvae but there is no way to confirm this. Also very high moth counts followed by very low counts the following year occurred in several locations during the study.

The trap near Alix (Lacombe County) had the highest moth catch 2013, but virtually no larvae were found in and around the area. The entire area experienced 2 heavy hail storms which may have affected the larvae as virtually no larvae were found. Just to the east of the Alix trap near Stettler (an outside the hail damaged area) the trap average was almost 600 and several fields near that trap had larval counts above threshold.

It is interesting to note the trap field may not be the highest in the area for larval feeding damage. This was often the case when scouting for larvae in and around the trap field. This is important to note traps are more indicative of the risk to an area and not to specific fields.

The number of moths is correlated with the number of canola fields close by. This holds true for canola within 1, 2 and 3 miles of the trap. The amount of canola from the previous year in the township surrounding the trap resulted in a predictable increase in moths caught compared to lower concentrations of canola. This suggests that traps should be placed in areas with high concentrations of canola the previous year. This also suggests the possibility that areas with large canola acreage one year followed by very little the next leads to a concentration of egg laying and a possible increased risk of damaging larval populations that year.

It wasn't possible to statistically determine the optimal number of traps in a given area but generally more would be better, especially in years with lower risk. It is possible to have very localized problem that wouldn't be caught by a low trap density. For example only one trap caught greater than 300 moths in 2014. Only a trap (and perhaps several would be needed) in that area would catch enough to sound a warning if that was a small localized population. On the other hand when problematic numbers of larvae were observed often several traps in an area were above the 300 mark. Experience has taught us that a trap catch of 300 results in occasional need for treatment somewhere in the surrounding area. That isn't always the case though as more often than not the 300 level does not result in damaging populations of larvae.

Larval counts were extremely variable from field to field and often within a field itself. This was true especially in variable topography fields.

Although we found no significant difference in the number of moths caught in traps at 150 cm compared to 75 cm, the higher traps did catch more moths on average so our recommendation on trap height will not change.

Location of the trap along the field margin produced no significant difference. This is in agreement with Steck et al. (1979) who compared north-south to east-west alignment of traps and found no significant difference. Steck et al. (1979) conducted their study in Saskatchewan, and suggested that there was no difference due to the lack of a consistent and prevailing wind.

The relative distance from the previous years canola is likely more important than which side of field the trap is situated on. Traps appeared to catch more bertha armyworm moths adjacent to the previous years canola than adjacent to other crops or pasture. This, however, was not accounted for in the data collection.

The opening and closing traps succeeded in excluding a large number of bumblebees. The design was not acceptable as there was a reduced number of moths caught. Therefore this would have a negative impact on the annual survey and forecast. Further design adjustments may need to be considered. In any case, this is a great advancement towards the reduction of bumblebee mortality as a result of the Alberta Pest Monitoring Network.

Automatic counting traps were tested as a side to this project. There is some promise although the traps counted everything from small flies to the target moths. Results not shown because it is proprietary early generation research technology being developed by Michael Reinke, ISCA Technologies, Riverside California, USA <www.iscatech.com>. Work needs to be done on calibrating the catch but it will be possible to sort the day flying insects from the night flying moths. The biggest problem with this technology will be the cost but it would be possible to have a remote reporting system that connects to a website via cellular signal. The counting traps may prove to be very useful in measuring the exact timing and parameters surrounding male moth flights.

Other benefits of this research include presentations given at meetings during and after the project. Material collected was used in a bertha armyworm, and other related species, genetics project that was underway at the same time. Parasitoids collected through larvae surveys have been documented and that information is included in presentations. Placing the study in an outbreak area helped create confidence in the trapping system with farmers and agrologists.

In summary the current survey and forecasting system stood up well to the studies carried out in this project. The following adjustments to the bertha armyworm monitoring protocol and forecasting models are suggested:

1) More traps will always give us a better read on bertha armyworm populations but due to limitations the current rate of approximately 300 in the province appears to be doing a good job as long as they are relatively well distributed. This is giving us a trap density of approximately 5 per county which is about equivalent to the size of our study area.

2) Placing traps in areas of higher concentration of canola from the previous year are more likely to catch potential outbreaks.

3) The current warning thresholds based on moth catches appear to be serving us well.

4) There is no need to change the trap height we are currently using and there is no need to prescribe a specific side of the field when placing traps.

5) Development and testing of a trap design to reduce bumblebee catch is still needed.

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Apendix 1

Report on the study *Improving Crop Risk Assessment Tools for Bertha Armyworm* 2012-2013

Prepared by: Taylor Kaye
Student assistants 2012: Taylor Kaye, Jeffery Stafford, Michelle Cook
Student assistants 2013: Taylor Kaye, Andrew Rigby

1. Study Site Description 2012

RM 252 was selected as the study site based on the 2011 Bertha Armyworm forecast map. In addition the rectangular boundaries of this RM help to facilitate trap placement. Canola was abundant in the RM allowing for the 5 trap locations to be spread out within the RM (Figure 1). Table 1 lists the GPS coordinates of the 5 trapping sites and the number canola and canola stubble fields that fell within a 1.6 km radius of the trap site.

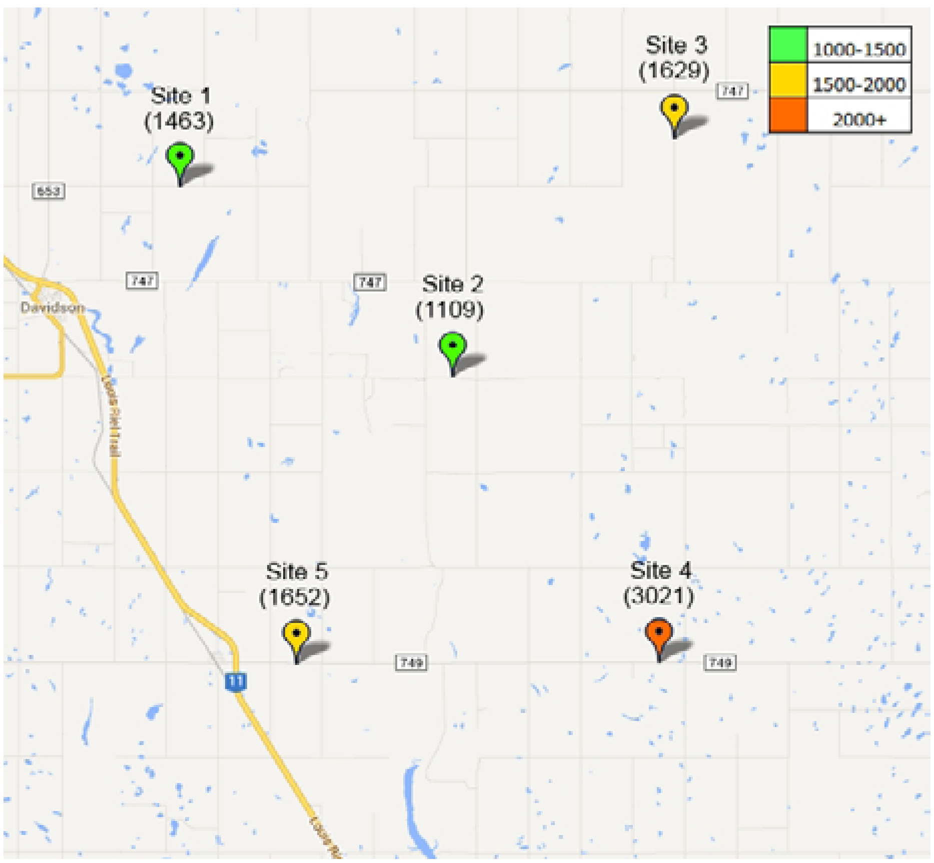


Figure 1. *2012 study sites located in RM 252 with the mean cumulative moth counts for 2012.*

Table 1: GPS coordinates of the five trapping sites and the number of canola and canola stubble fields within a 1.6 km radius

Trap Site	Latitude	Longitude	Number of canola fields in in a 1.6 km radius	Number of canola stubble fields in a 1.6 km radius
1	51.2994	-105.2994	5	2
2	51.2407	-105.2407	1	2
3	51.3192	-105.7098	3	0
4	51.1541	-105.7122	1	2
5	51.1540	-105.8740	1	1

2. Bertha Armyworm Pheromone Traps 2012

The traps were deployed on June 12, 2012. Two traps were deployed at each of the 5 sites in for a total of 10 traps (Figure1). Once a week the traps were emptied and samples were returned to the lab where the moths were counted (Table 2). The canola growth stage was recorded on the day the trap was emptied (Table 3). A sub-sample of moths collected from each trap was supplied weekly to Martin Erlandson's laboratory to be included in his BAW genomics study. The traps were removed on July 31. Adult moth counts were high in 2012 and had the most substantial increase in the week of July 3. The cumulative counts for each trap, except for traps at site 2, fell into the high risk threshold.

Table 2: Weekly adult moth counts collected in each trap at the 5 study sites in RM 252.

Site	Trap id	Jun-19	Jun-26	Jul-03	Jul-10	Jul-18	Jul-24	Jul-31	Total
1	A	3	40	386	748	389	1	0	1567
1	B	5	153	390	520	271	19	0	1358
2	A	7	124	464	372	123	3	0	1093
2	B	6	122	442	327	221	7	0	1125
3	A	2	123	543	479	252	21	2	1422
3	B	5	144	711	663	288	19	6	1836
4	A	35	598	1112	724	595	14	3	3081
4	B	35	504	1142	889	418	30	5	3023
5	A	12	125	696	558	364	4	0	1759
5	B	13	222	555	408	340	6	1	1545

Table 3: Canola growth stages at each or the 5 trap sites within RM 252.

Site	Jun-19	Jun-26	Jul-03	Jul-10	Jul-18	Jul-24	Jul-31
1	Rosette	Bolting	Bolting	50% Bloom	Full Bloom	Late Bloom	Pods
2	Rosette	Bolting	Bolting	80% Bloom	Full Bloom	Late Bloom	Pods
3	Rosette	Bolting	Bolting	20% Bloom	Full Bloom	Late Bloom	Pods
4	Rosette	Bolting	Bolting	50% Bloom	Full Bloom	Late Bloom	Pods
5	Rosette	Bolting some early bud formation	50% Bud some early flowering	Not recorded	Full Bloom	Late Bloom	Pods

2. Larval Counts 2012

Larval counts occurred at the beginning of August. Locations were selected for each risk category (low, uncertain, moderate, high) based on SKPPMN moth counts (Table 4). The study site at Davidson was used as the high risk area. At each risk area 6 fields were selected at random for larval counts. 3 of these fields were located near the SKPPMN trap location (near) and 3 were farther away from the trap (far). At the study area (high risk) all the five study fields plus 1 addition field were sampled. At this location the trap at site 4 was considered to be the PPMN trap. To keep similar naming convention in Table 4 study sites 4 & 5 are considered to be N1 & N2 with the additional field (N 51.1383 W-101.8686) being considered N3. Likewise study sites 1, 2 & 3 are considered to be F1, F2, and F3. Larval counts were done at 6 locations within each selected field. The canola plants were shaken and BAW larvae that fell within a ¼ m^2 quadrat were counted (Table 5). Maps showing the location of the fields for each risk category can be found in Appendix 1. Very few larvae were found during the larval count survey considering the high number of adult moths present in the pheromone traps.

Table 4: GPS coordinates of the four PPMN traps in each RM surveyed and the risk category of each RM according to the cumulative moth counts

RM	Lat.	Long.	Cumulative Moth Count	Risk Category
402	52.617	-105.9953	295	Low
308	51.6561	-104.3798	494	Uncertain
224	50.8998	-106.8933	708	Moderate
252	51.1541	-105.7122	3021	High

Table 5: Mean number of bertha armyworm larvae per 1/4^{m2} for fields near (N1-3) and far (F1-3) from the SKPPMN trap for each risk category.

Field	RM 252 (High Risk) 7-Aug-12	RM 224 (Moderate Risk) 10-Aug-12	RM 308 (Uncertain Risk) 8-Aug-12	RM 402 (Low Risk) 9-Aug-12
N1	0	0	0	0.33
N2	0.5	0	0.17	0.5
N3	0.17	0.17	0.67	0.17
F1	0	0	0.17	0
F2	0	0.33	0.67	0
F3	0	0.17	1.17	2.5

3. Study Site Description 2013

Five new trapping sites were selected in RM 252. The sites in 2013 were situated in the same vicinity as the 2012 sites, however, canola acreage in the RM was down from 2012 with only 7 fields of canola being found, 5 of which were chosen for sampling (Figure 2). Canola and canola stubble fields that fell within a 1.6 km radius of the trap site were recorded (Table 6).

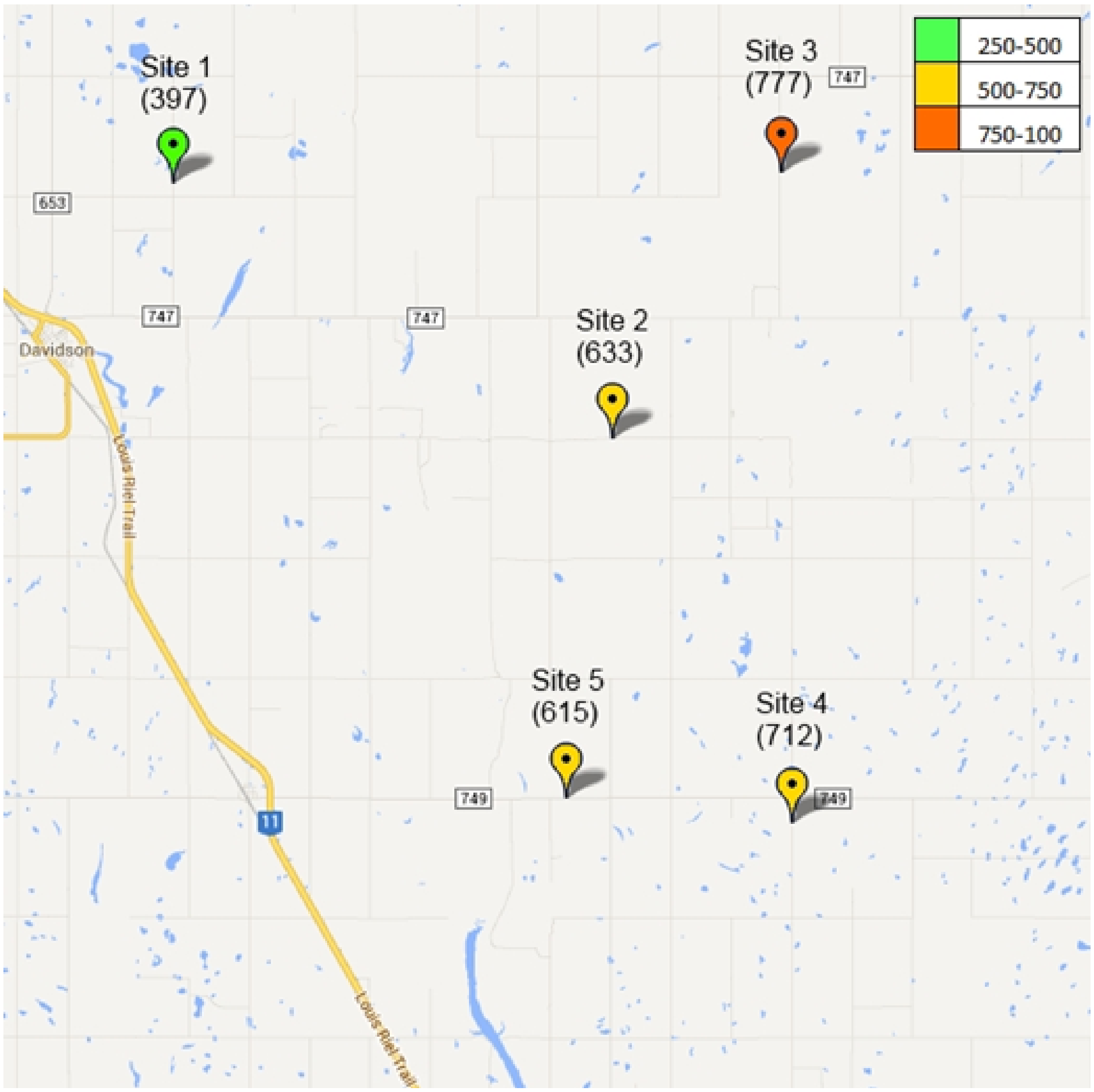


Figure 2. *2013 study sites located in RM 252 with the mean cumulative moth count for June and July 2013.*

Table 6: GPS coordinates of the five trapping sites and the number of canola and canola stubble fields within a 1.6 km radius

Trap Site	Latitude	Longitude	Number of canola fields in in a 1.6 km radius	Number of canola stubble fields in a 1.6 km radius
1	51.3033	-105.9443	0	5
2	51.2413	-105.7752	0	1
3	51.3059	-105.7099	0	3
4	51.1479	-105.7056	0	1
5	51.1541	-105.7931	0	1

4. Bertha Armyworm Pheromone Traps 2013

BAW traps were deployed on June 11, 2013. The protocol used was the same as 2012. Traps were emptied weekly and samples were returned to the lab where the moths were counted (Table 7). The traps were taken down on July 30, 2013. Trap 3A was missing a pheromone lure for the weeks of Jun 18 and Jun 26, and trap 2B was found knocked over and empty on the week of Jun 26, these interferences make any results collected from those traps on the affected dates not applicable. The canola growth stage was recorded on the day the trap was emptied (Table 8). As in 2012, a sub-sample of moths from each trap was supplied weekly to Martin Erlandson's laboratory for use in their genomic study. In 2013 each study site was monitored for egg mass between June 26 and July 30. The undersides of the leaves from 10 randomly selected plants were examined for egg masses. No eggs masses were detected. The adult moth count in 2013 was down from 2012. In a change from 2012, none of the traps reached the high risk threshold. All traps except for 3B and 2B landed in the uncertain risk category.

Table 7: Weekly adult moth counts collected in each trap at the 5 study sites in RM 252.

Site	Trap id	Jun-18	Jun-26	Jul-03	Jul-10	Jul-17	Jul-24	Jul-30	Total
1	A	10	67	147	51	80	15	5	375
1	B	3	83	194	90	40	4	5	419
2	A	3	50	105	93	68	11	12	342
2	B	4	n/a	513	218	151	27	10	923
3	A	n/a	n/a	195	188	101	17	12	513
3	B	4	59	612	249	109	4	4	1041
4	A	3	96	403	147	79	21	18	767
4	B	3	56	374	139	63	15	6	656
5	A	6	160	263	243	96	19	15	802
5	B	1	43	274	42	22	14	32	428

Table 8: Canola growth stages at each or the 5 trap sites within RM 252.

	Jun-18	Jun-26	Jul-03	Jul-10	Jul-17	Jul-24	Jul-30
Site 1	Rosette	Bolting	Full Bloom	Full Bloom	Bloom w/ 25% Pods	Bloom w/ 75% Pods	Pods
Site 2	Rosette	Bolting	Full Bloom	Full Bloom	Full Bloom	Bloom w/ 75% Pods	Pods
Site 3	Rosette	Bolting	Bloom/Budding	Full Bloom	Full Bloom	Bloom w/ 75% Pods	Pods
Site 4	Rosette	Rosette	Bolting	Full Bloom	Full Bloom	Bloom w/ 75% Pods	Bloom w/ 95% Pods
Site 5	Rosette	Bolting	Full Bloom	Full Bloom	Bloom w/ 25% Pods	Bloom w/ 75% Pods	Pods

5. Larval Counts 2013

In 2013 the study site at Davidson was used as an additional sampling location. Due to low larval numbers observed in 2012 it was decided to take weekly larval counts at each trap site (Table 9), but rain interference only allowed for larval counts to occur on July 24 and August 9. The concern was that 2012 and larvae may have already pupated. It was thought by doing weekly counts this problem would be avoided. Another change from the 2012 protocol was that the number of quadrats used was increase to 12 from the 6 used in 2012. The number of larvae found was low again in 2013 on both July 24 and August 9.

Larval sampling was done in areas that fell into each risk category (low, uncertain, moderate, high) based on SKPPMN moth counts (Table 10). At each risk area 6 fields were selected at random for larval counts. 3 of these fields were located near the SKPPMN trap location (near) and 3 were farther away from the trap (far). Larval counts were done at 12 locations within the selected field compared to 6 in 2012. The canola plants were shaken and BAW larvae that fell within a ¼ m^2 quadrat were counted (Table 11). Larvae were collected and supplied to Martin Erlandson's genomic study. Maps showing the location of the fields for each risk category can be found in Appendix 2. Larvae found were almost all in the high risk RM 286 with the one exception of the one larva found in the low risk RM 343.

Table 9: Mean number of larvae per $1/4^{m2}$ at the 5 study site locations in RM 252 on July 24 & August 9

Site	Jul-24	Aug-09
1	0.33	0
2	0	0
3	0	0.33
4	0.33	0.17
5	0.33	0

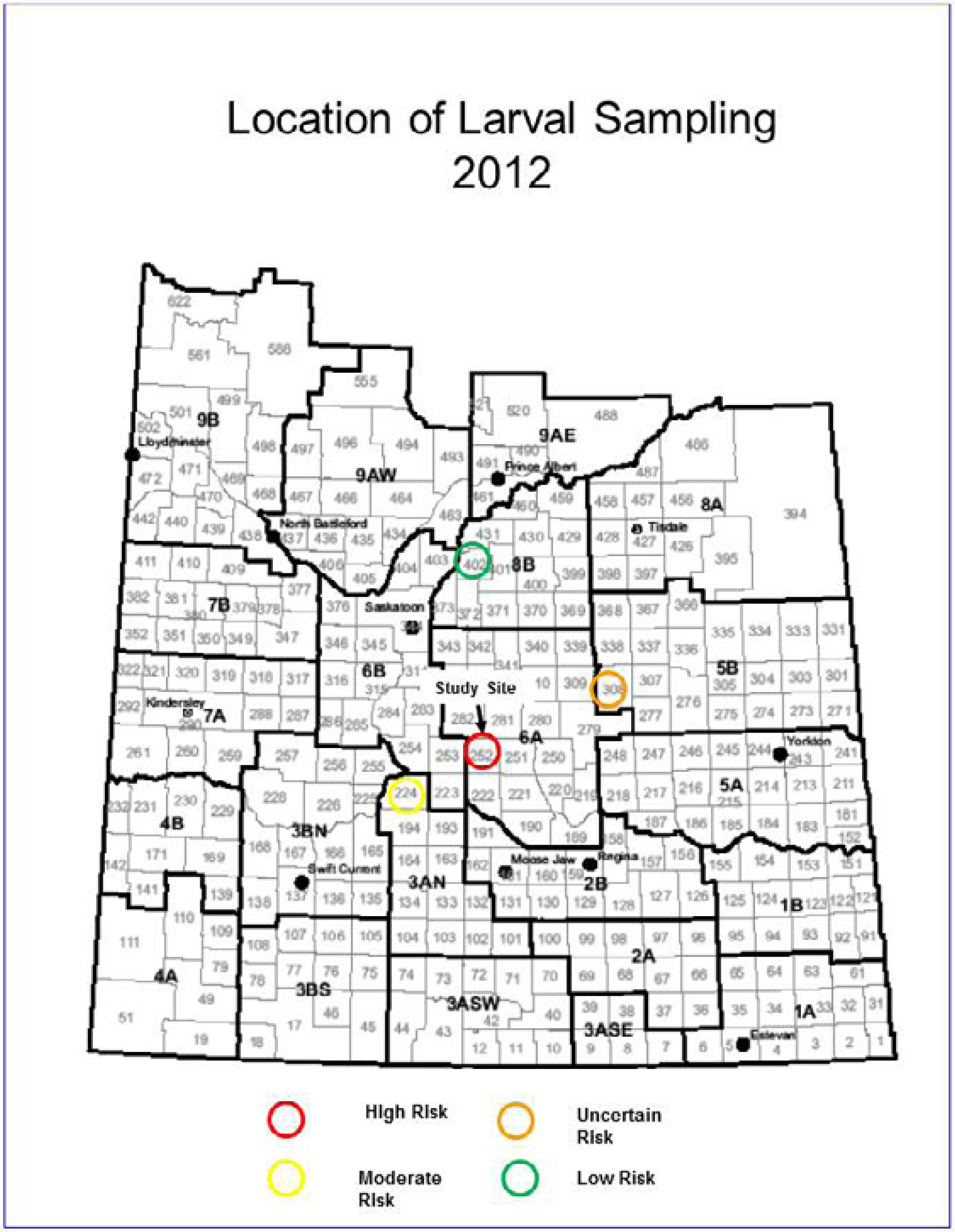
Table 10: GPS coordinates of the four PPMN traps in each RM surveyed and the risk category of each RM according to the cumulative moth counts

RM	Lat.	Long.	Cumulative Moth Total	Risk Category
343	51.9908	-106.2067	82	Low
318	51.6849	-108.2839	608	Uncertain
401	52.4856	-105.6386	1024	Moderate
286	51.5985	-107.6327	2308	High

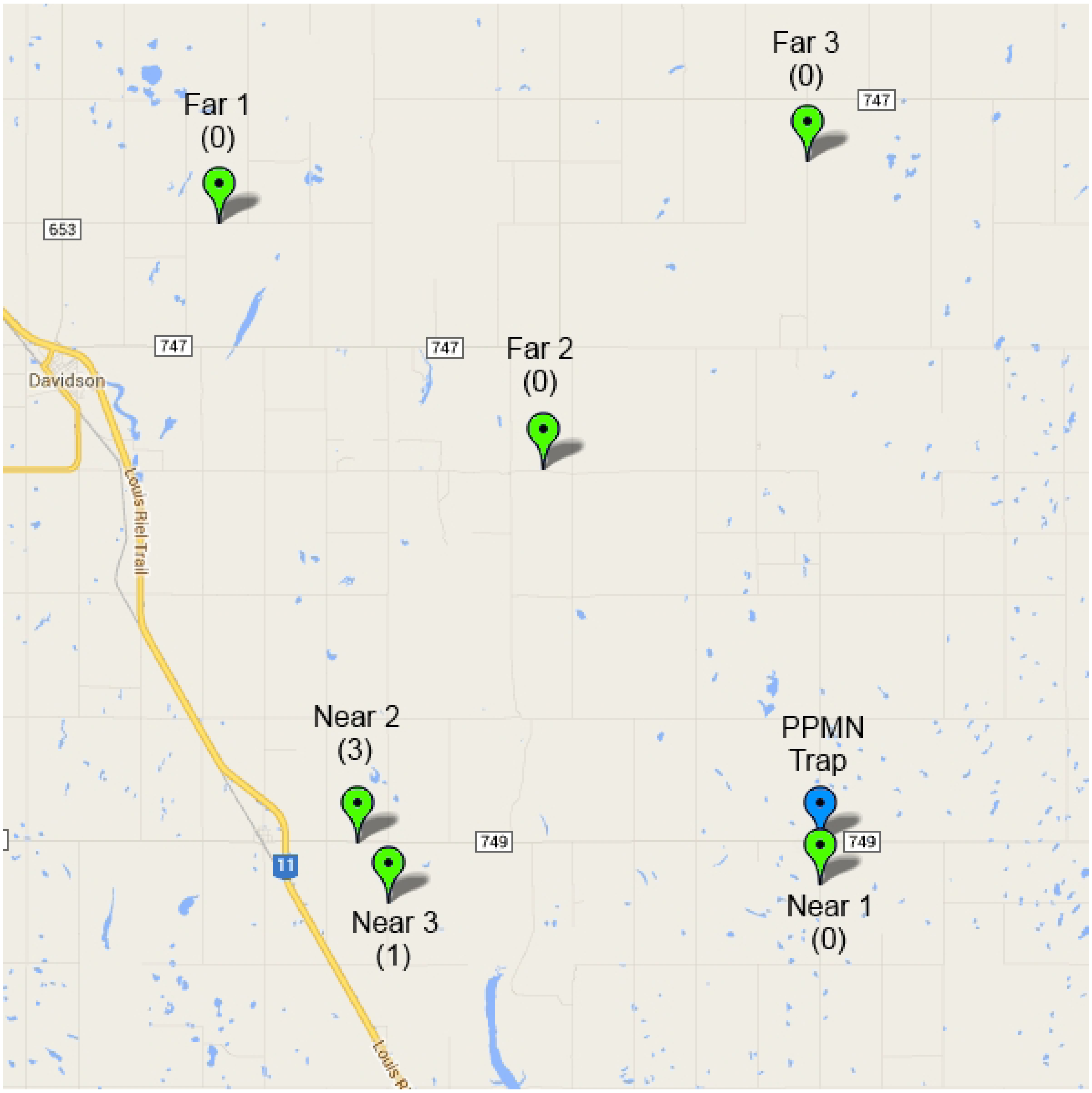
Table 11: Mean number of bertha armyworm per 1/4^{m2} for fields near (N1-3) and far (F1-3) from the SKPPMN trap for each risk category.

Field	RM 286 (High Risk) 06-Aug-13	RM 401 (Moderate Risk) 10-Aug-12	RM 318 (Uncertain Risk) 9-Aug-12	RM 343 (Low Risk) 8-Aug-12
N1	0.08	0	0	0
N1	0.67	0	0	0
N1	0.17	0	0	0
F1	0.08	0	0	0.08
F1	0	0	0	0
F1	0	0	0	0

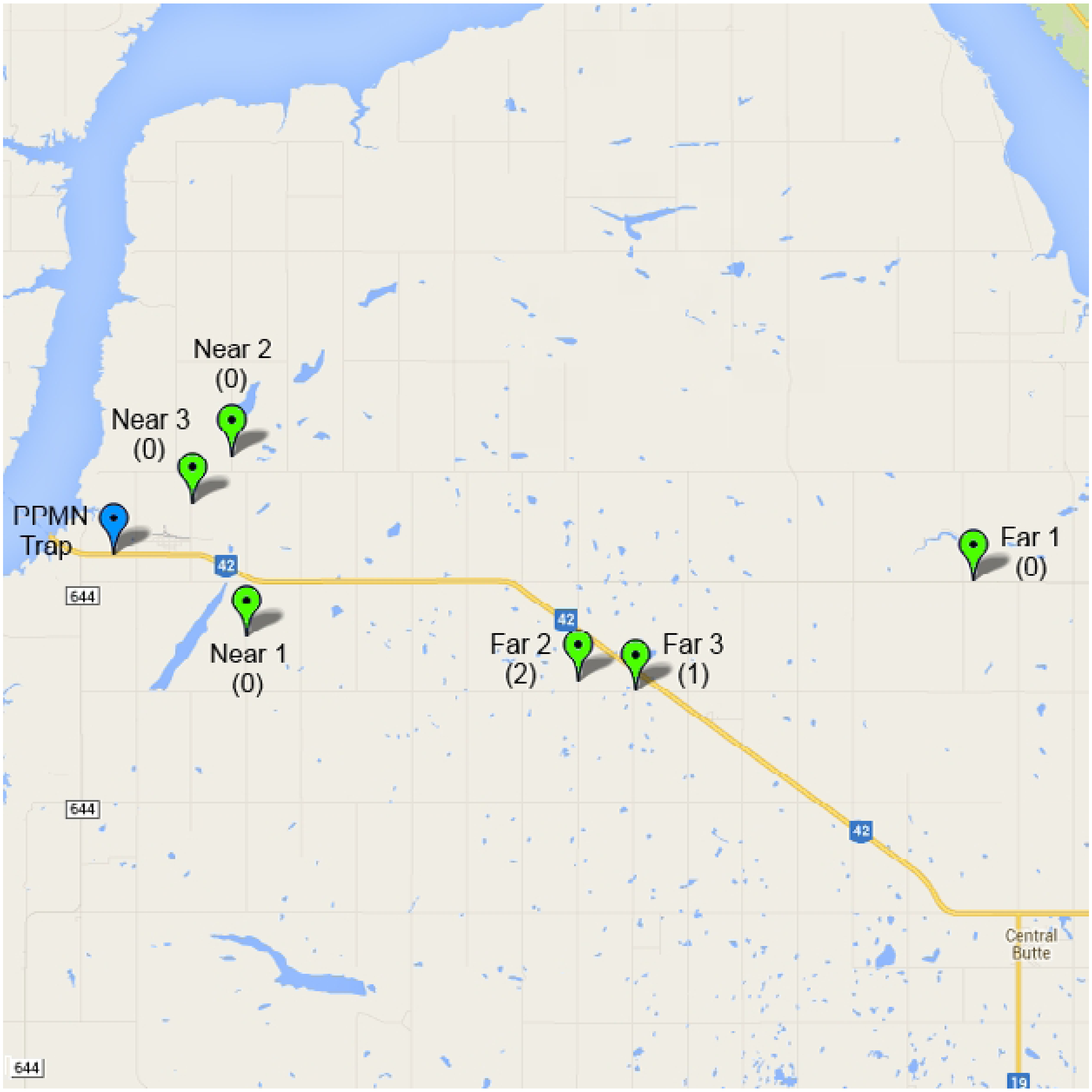
Appendix 1 – Maps showing location of larval sampling locations 2012



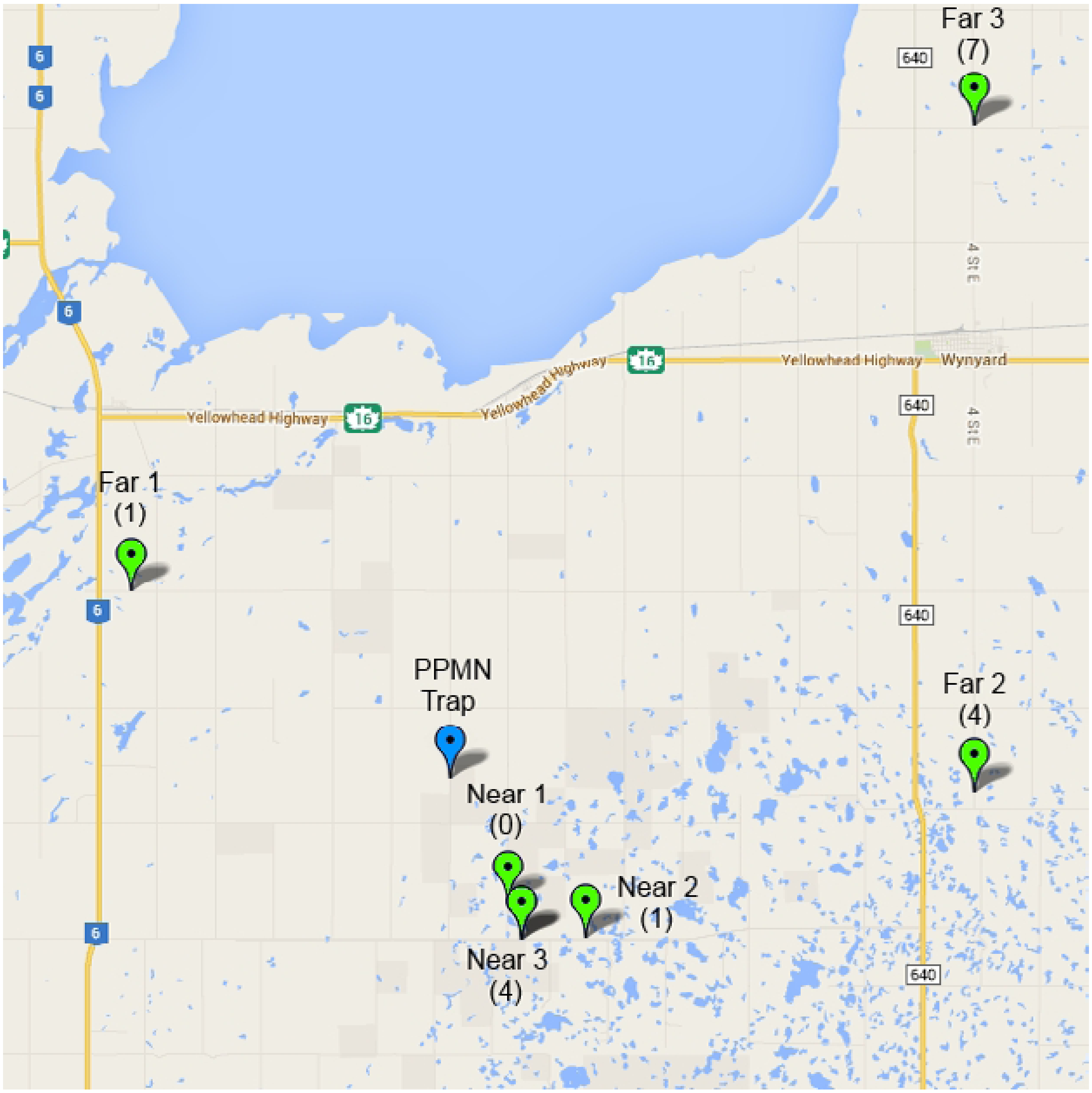
Larval collection Sites for RM 252 Davidson = HIGH RISK



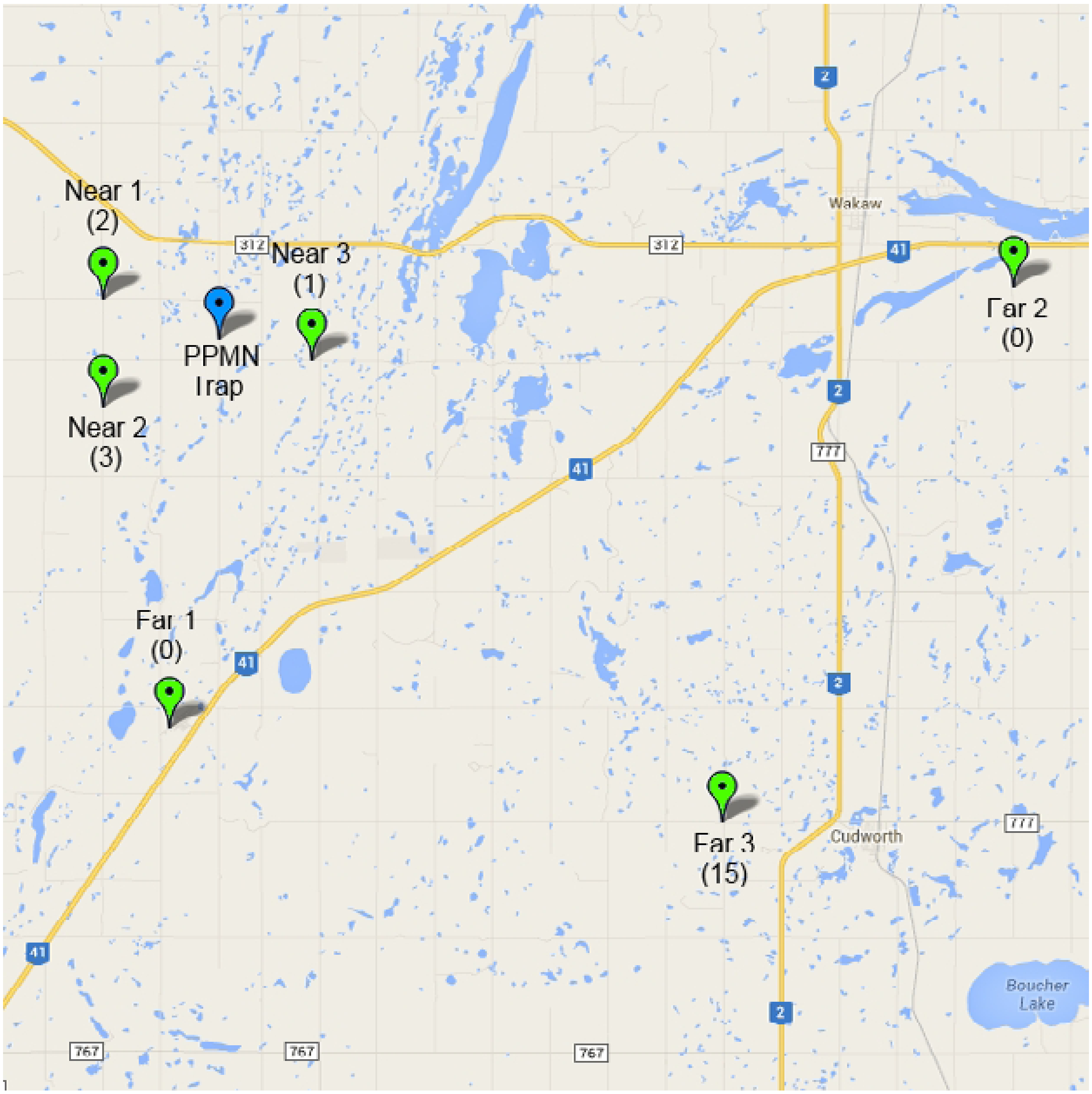
Larval collection sites for RM 224 Riverhurst = MODERATE RISK



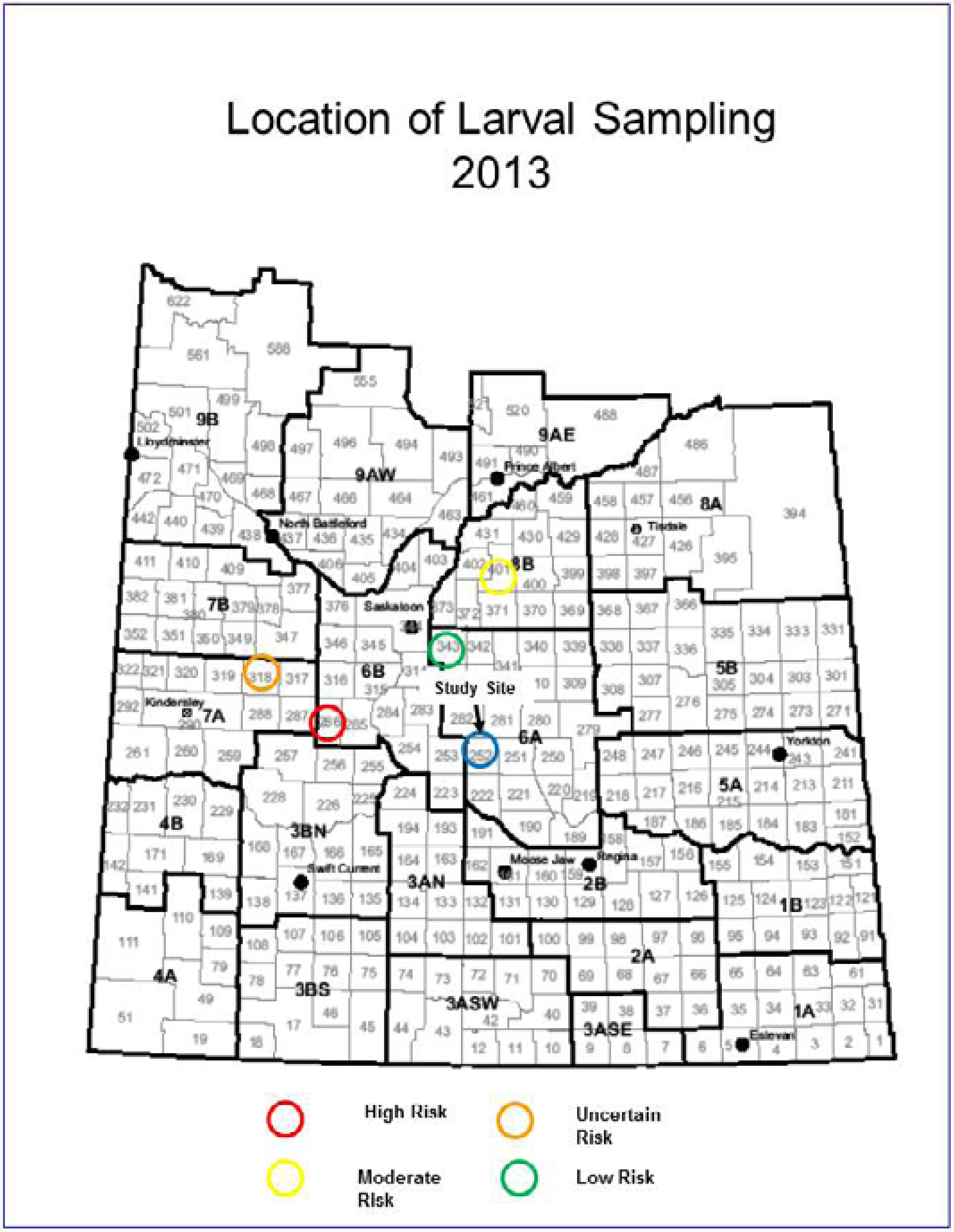
Larval Collection sites for RM 308 Wynyard = UNCERTAIN RISK



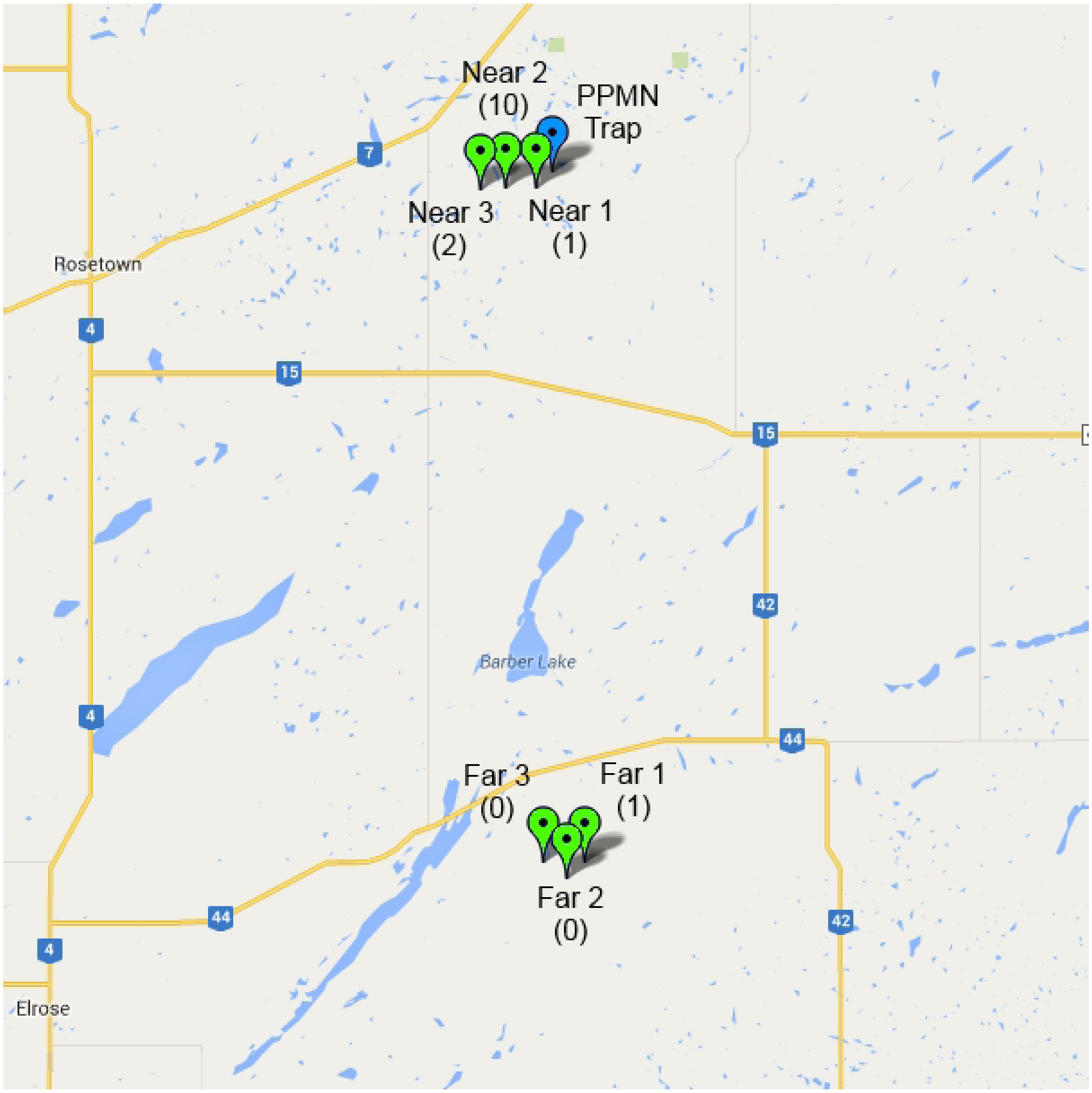
Larval collection sites for RM 402 Wakaw = LOW RISK



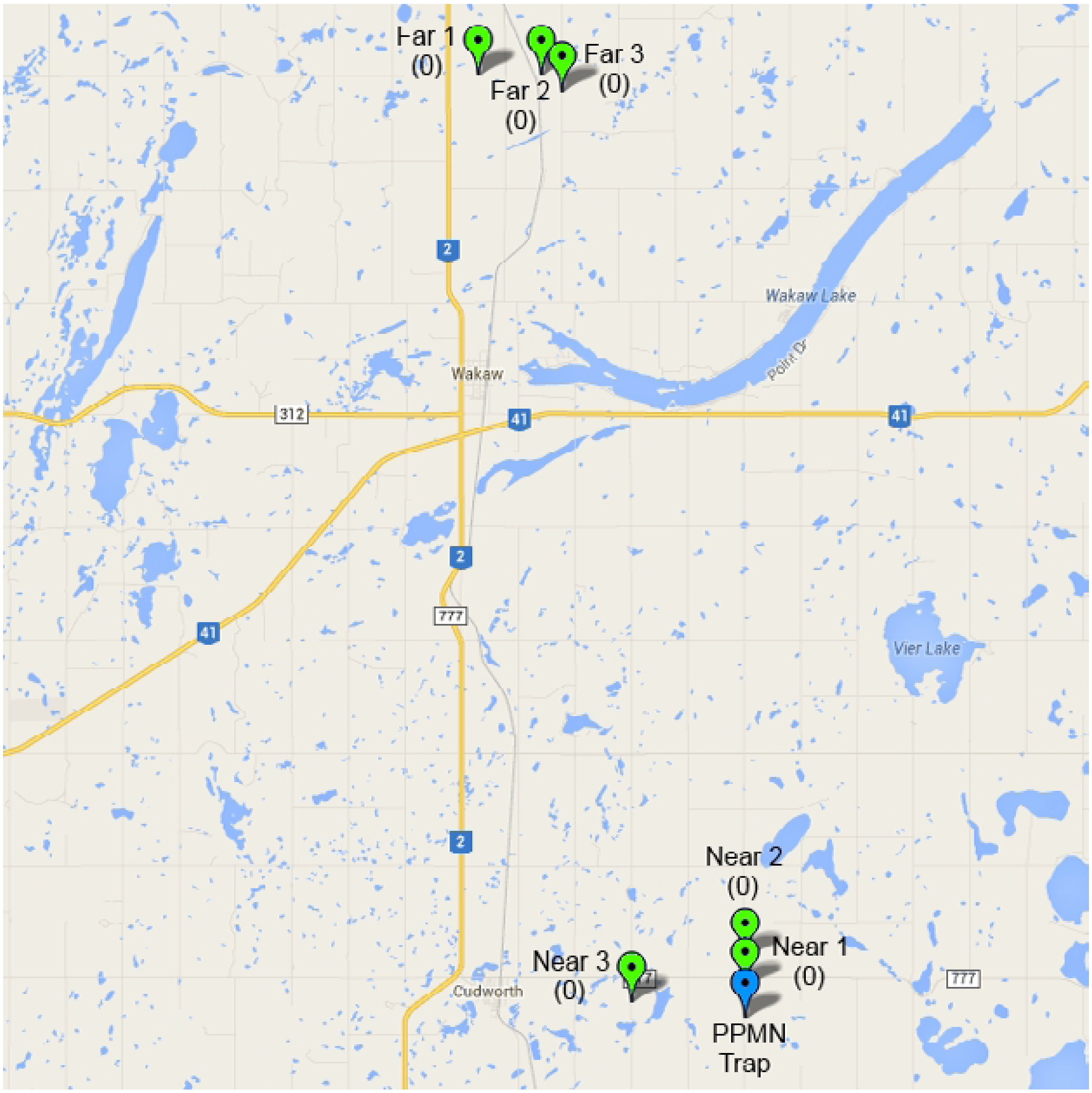
Appendix 2 - Maps showing location of larval sampling locations 2013



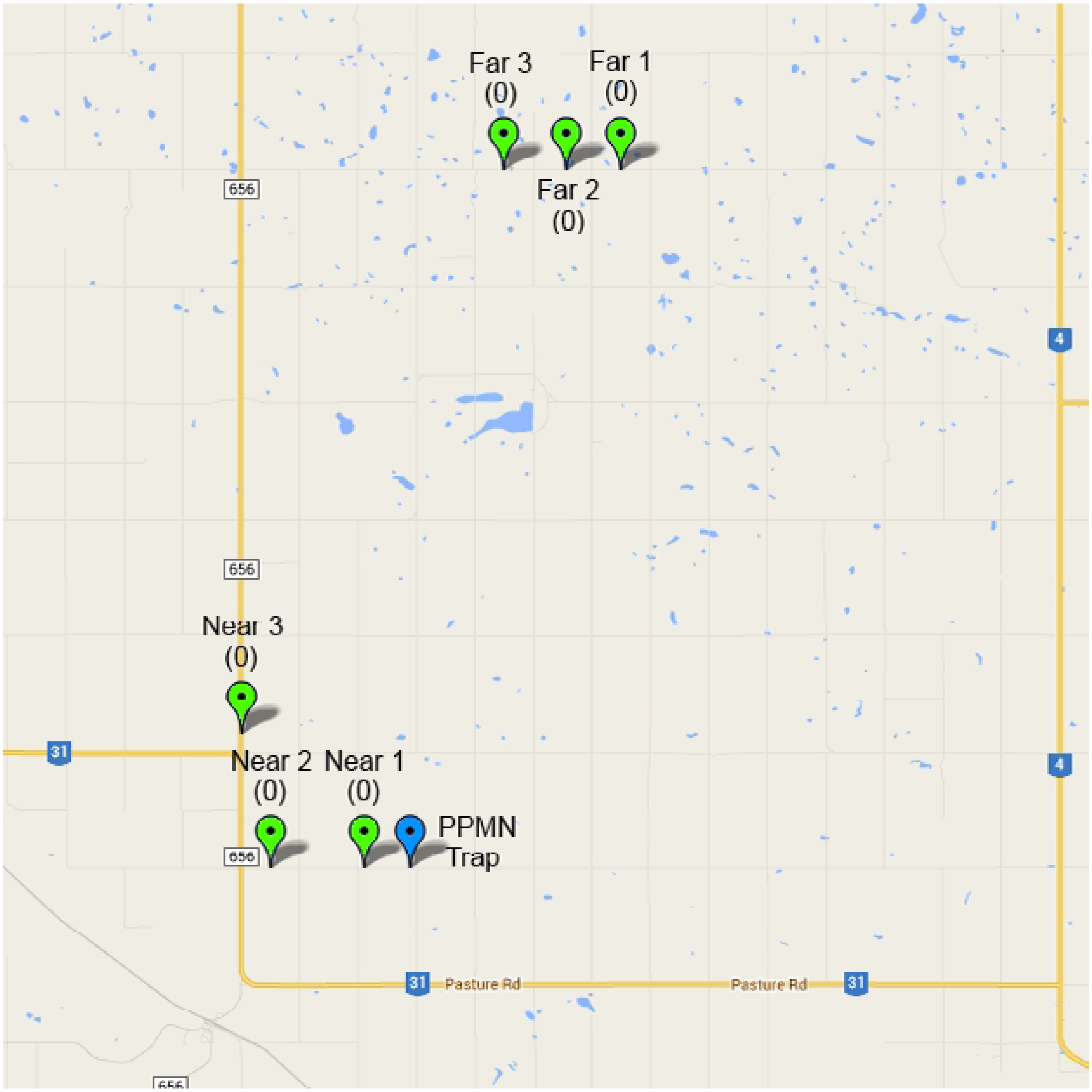
Larval collection sites for RM 286 Rosetown = HIGH RISK



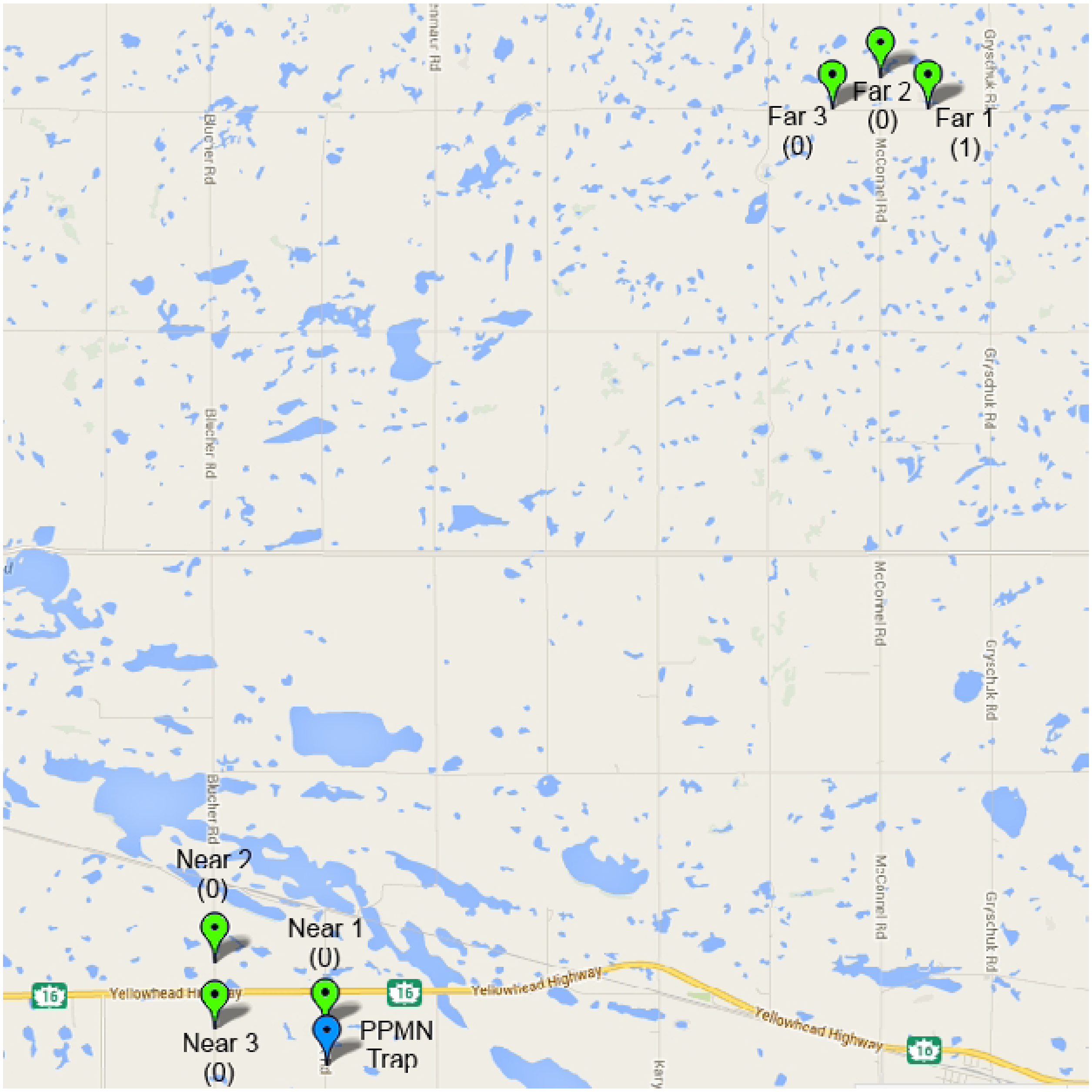
Larval collection sites for RM 401 Cudworth = MODERATE RISK



Larval collection sites for RM 318 Herschel = UNCERTAIN RISK



RM 343 – LOW RISK



Saskatchewan Study Site Data 2012

Study Site = RM 252 Arm River					
Trap Deployment = June 12, 2012					
Trap removed = July 31, 2012					
Trap site	trap id	Lat	Long	# 2012 Canola fields in approx 1.6 km radius	# 2011 Canola stubble fields approx 1.6 km radius
1	12-24	51.2994	-105.2994	5	2
	12-17	51.2998	-105.2998		
2	12-20	51.2407	-105.2407	1	2
	128	51.2412	-105.8055		
3	12-19	51.3192	-105.7098	3	0
	12-23	51.3147	-105.7100		
4	12-21	51.1541	-105.7122	1	2
	12-22	51.1540	-105.7172		
5	135	51.1540	-105.8740	1	1
	12-18	51.1539	-105.8793		

Canola Stage for Collection Dates					
Site:	1	2	3	4	5
19-Jun-12	Rosette	Rosette	Rosette	Rosette	Rosette
26-Jun-12	Bolting	Bolting	Bolting	Bolting	Bolting some early bud formation
3-Jul-12	Bolting	Bolting	Bolting	50% Bud	50% Bud some early flowering
10-Jul-12	50% Bloom	80% Bloom	20% Bloom	50% Bloom	not recorded
18-Jul-12	Full Bloom	Full Bloom	Full Bloom	Full Bloom	Full Bloom
24-Jul-12	Bloom with pods	Bloom with pods	Bloom with pods	Bloom with pods	Bloom with pods
31-Jul-12	Pods	Pods	Pods	Pods	Pods

Davidson Area Larval Counts	August 7, 2012		N 51.13835	W -107.86862		
Within field count	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6*
N	52.51649	52.62769	52.49297	52.6249	52.59765	52.60931
W	-106.02518	-105.67462	-105.79573	-106.05206	-106.05214	-105.96622
A1	0	0	0	0	0	0
A2	0	0	0	0	2	0
B1	0	0	0	0	0	0
B2	0	0	0	0	0	0
C1	0	0	0	1	1	0
C2	0	0	0	0	0	1
*Location 6 = extra field in the RM no trap was at this location.						

Bumble Bee Counts										
Site:	1	1	2	2	3	3	4	4	5	5
Trap:	12-24	12-17	12-20	128	12-19	12-23	12-21	12-22	135	12-18
19-Jun-12	1	7	1	0	0	3	0	1	0	0
26-Jun-12	1	4	1	0	1	2	1	0	1	4
3-Jul-12	6	13	13	5	2	0	4	2	19	11
10-Jul-12	10	10	2	1	8	4	1	6	2	4
18-Jul-12	0	0	6	1	0	3	1	0	3	2
24-Jul-12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31-Jul-12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Alvena Area Larval Counts from PPMN Traps						
	FAR=5-10 k from trap			NEAR=1-5 k from trap site		
Within field count	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
N	52.51649	52.62769	52.49297	52.6249	52.59765	52.60931
W	-106.02518	-105.67462	-105.79573	-106.05206	-106.05214	-105.96622
A1	0	0	1	2	0	0
A2	0	0	4	0	0	0
B1	0	0	6	0	1	0
B2	0	0	2	0	1	0
C1	0	0	1	0	1	1
C2	0	0	1	0	0	0

Riverhurst area						
	FAR=5-10 k from trap			NEAR=1-5 k from trap site		
Within field count	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
N	51.70704	51.65667	51.82388	51.6288	51.6201	51.6199
W	-104.52079	-104.17908	-104.17914	-104.3682	-104.3363	-104.3625
A1	0	0	0	0	0	0
A2	0	0	0	0	0	0
B1	0	0	0	0	0	0
B2	0	0	1	0	0	0
C1	0	2	0	0	0	0
C2	0	0	0	0	0	0

Wynyard area						
	FAR=5-10 k from trap			NEAR=1-5 k from trap site		
Within field count	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
N	50.89248	50.86619	50.8634	50.87789	50.92551	50.91286
W	-106.53151	-106.69701	-106.67298	-106.83591	-106.84176	-106.8586
A1	1	2	0	0	0	0
A2	0	1	1	0	0	0
B1	0	0	2	0	0	1
B2	0	1	3	0	0	0
C1	0	0	1	0	1	3
C2	0	0	0	0	0	0

Apendix 2

Plans for the Opening and Closing Traps Blue prints available on request

MecE 460 Capstone Design Project: Closing Insect Trap

Alberta Agriculture and Rural Development

High Velocity Engineering Inc.	Year
Josh Coyne, Krista Janzen, Anita Kalitsky, Nick Stukoski, Faline Tan	Fall 2012

Background:

Bertha Armyworms pose a significant risk to canola crops, reducing crop yields by as much as 50% in the event of a mild infestation.

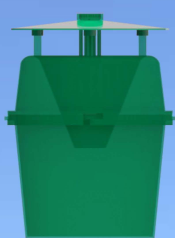


Figure 2: Existing Trap–Funnel View

Armyworm populations are determined by on-site tracking of adult male moth populations. Data is collected for 6-8 weeks in June and July by farmers and researchers across Alberta. Cumulative moth counts in traps during these months help determine the level of risk for August. Insecticide is then applied as required.

Currently, the use of pheromone-baited traps result in the capture of Bertha Armyworm moths as well as Bumblebees. On average, 150 Bumblebees are caught each week, most of which are queen bees. This poses a significant threat to Bumblebee populations and future crop pollination.

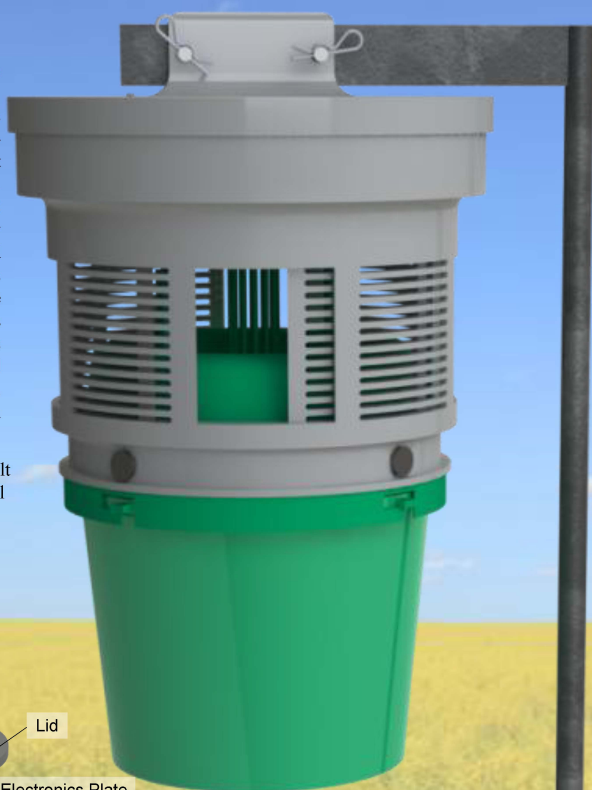


Figure 1: Trap and Closing Mechanism in Environment

Design Objective:

To modify the existing Bertha Armyworm moth trap such that it:

-Excludes Bumblebee catches during daytime

-Allows Bertha Armyworm catches at night

-Is economically feasible

-Can be easily assembled and used

-Is durable in adverse weather conditions

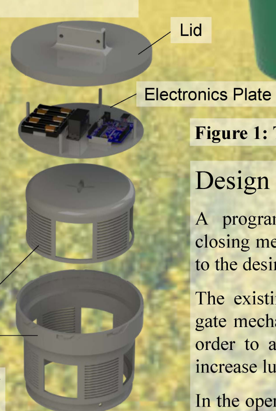


Figure 3: Exploded View of Mechanism

Design Solution:

A programmable microcontroller and motor rotate the closing mechanism. The inner cylinder rotates at a 45° angle to the desired open or closed state.

The existing trap is encompassed within the new rotating gate mechanism. Thus, several slots have been machined in order to allow air flow. Creating an air tight design may increase lure potency and adversely affect moth counts.

In the open position, four large gaps align to maximize moth accessibility while retaining product integrity.

University of Alberta

Department of Mechanical Engineering

HVE INC.