Project Title: Best Management Practices for Control of Nuisance Flies Dispersing through the Ontario Grape and Wine Value-Added Industry Chain

Project Number 001000

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Final Report

Submitted: November 20, 2015

To: Eleanor Hawthorn (Program Coordinator - OGWRI)

1. Executive Summary

The house fly is of concern in rural and urban areas in part as it can be a nuisance to people and has the potential to spread diseases to humans. House flies may cause public health issues, loss of business income due to diminishing clientele and legal actions. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) began receiving fly nuisance complaints from neighbours living near poultry facilities during the summer of 2010. The complaints from the Niagara peninsula peaked during the summer of 2012. Efforts were put in place to find out the best methods to mitigate the nuisance problem given that poultry operations and rural residential areas must co-exist in Ontario. The objective was to limit dispersal from poultry operations (sources) to the Ontario grape and wine value-added industry chain receptors (grape growers, wineries, restaurants, client neighbours, client businesses) in the local area. The project also included the investigation of outdoor sampling methods to correlate the abundance of flies at the source to flies dispersing to receptors; the identification of potential breeding and resting sites for house flies at receptors; and the estimation of the potential risks of disease transmission to humans from house flies.

Various control methods were implemented at the source (poultry operations), and their efficiency were evaluated. Flies were captured, identified and counted sugin sticky cards at several locations (inside the poultry barns, outside the barns and at a broad range of receptors) from early May to September 2014, and again from July until end of August 2015. In 2014, fly numbers inside the poultry barns were highest between mid-June to end of July, with average adult flies per sticky card reaching a peak of 87.4 flies for one barn during the week of June 18th. The fly numbers outside the barns followed a similar pattern, with two visible peaks of fly numbers (June 18th and July 20th) but the number captured per sticky card was less than eight adult flies/card. The number of flies captured at receptors, including restaurants and wineries, was very low, partly due to a low number of flies at the source. However, the flies captured at the receptors followed a similar trend as the source, with receptor sites catching more flies during the period of mid-June to end of July than the rest of the period.

Flies were collected by sweepnet inside the barn and at four outside locations beside the barns and tested for the presence of coliforms/*E. coli*, Enterobacteriaceae and aerobic bacteria. The flies were found to transport bacteria of the group Enterobacteriaceae and coliforms (including *E. coli*) on their bodies, in addition to other non-identified aerobic bacteria. Since the flies were found to carry some pathogenic bacteria, precautionary principle should apply and contact of the flies with food and beverage should be avoided.

Visual surveys of potential breeding and resting sites of house flies were performed at the end of August and early September 2014 and 2015. This coincided with peak adult fly activity periods at the 3 wineries and restaurants within 1.5 km of the source barns. The overall number of flies observed was low for both seasons,

but empirical observations showed that the flies were more present and active in areas where food and food waste was prepared or handled. The flies present were not only house flies, but also comprised species of Calliphoridae (blow flies, cluster flies) and other calyptrate Diptera, likely attracted by protein sources and nutrient volatiles.

Four outdoor traps were evaluated during trial. The Big Bag Fly trap with attractant proved to be valuable as an option for outdoor trapping provided it is installed away from food handling areas. For food handling areas, inside and outside, a non-baited trap is recommended, so additional flies are not attracted to the area while food is being handled.

Rural homeowners can expect to have some house flies during the warmer months of the year since no control strategy will be 100% effective and flies are a part of the natural environment. Fly management should begin early at the source farm and the focus should be the elimination of potential sources for egg-laying and development of flies, such as organic matter. Many different control methods must be used together to limit fly abundance. The project resulted in the publication of a comprehensive manual for the control of house flies in poultry production barns (Fall 2015). Following recommendations described in the manual should alleviate fly problems at neighbouring properties. Commercial and agricultural businesses can also contribute in decreasing house fly numbers by limiting access to organic matter sources for the female flies to lay eggs and larvae to grow.

2. Detailed Description of the Project

a) Objectives and Project Input

The general goal of the project was to evaluate control methods to decrease house fly density at the source and dispersal of flies to neighbours living near poultry facilities.

The specific goals were to:

1. Establish outdoor sampling methods appropriate for receptors in the Ontario grape and wine value-added industry chain;

2. Establish how dispersal plumes of house flies occur from source farms;

3. Investigate preferential breeding/resting sites at receptors in the Ontario grape and wine value-added industry chain;

4. Study the level of pathogenic bacteria on flies;

5. Investigate antibiotic resistance levels of pathogenic bacteria collected from flies; and,

6. Evaluate the risks of pathogenic bacteria transmission.

The project is led by Dr. Simon Lachance, in collaboration with staff members at OMAFRA (Daniel Ward, Hugh Fraser and Al Dam) and University of Guelph (Drs. Cynthia Scott-Dupree and Michele Guerin). Graduate student Justine Shiell was involved in the project for the past 2.5 years, as well as 4 summer students. OMAFRA committed $100,000 cash, as well as an approximately similar amount in-kind, and the Town of Lincoln provided $10,000 cash.

b) Project Activities / Methodology and Outputs

Objectives 1-3. In 2013, six preliminary monitoring locations at neighbouring houses in the Beamsville area were established, plus eight external locations on the farm site surrounding the source barns. It provided preliminary data permitting the fine-tuning of surveillance methods using sticky cards.

In 2014, the sampling effort was expanded to 25 locations. The sticky cards were placed weekly in afternoon sun-protected areas at 1.5 m high above ground level (Gerry et al. 2011). The cards consisted of a double coated 10 x16 cm yellow sticky card (Silvandersson Sweden AB, Catch-it, no. 3411) attached vertically. All fly monitoring material was attached to a post using a 5 cm wide black paper clip screwed to the post. The posts were placed, if possible, at approximately 5 meters from the North-East corner of a building (winery, house, shed, etc.), but this siting was not always possible at every location due to owners requirements and variability in the buildings present at each of the location.

The sampling started in mid-May 2014 and continued until the end of August, at which point the number of flies observed in the barns was very low. The number of flies during the summer at the source (poultry barns) was also monitored to serve as comparisons and to determine source-levels.

The twenty-five locations were established at various distances and directions from the source operation. The list of the locations is provided in Table 1, and consisted of grape growers, wineries, restaurants, businesses and neighbours, within about 1.5 km of source barns (Fig. 1).

Table 1. List of sampling locations for the 2014 season.

KING MONITORING					
	Contact	Address	Coordinates	Contact	Phone Number
1	Fielding Estates Winery	4017 Mountainview Rd, Beamsville, ON L0R 1B2	43.153 N, 79.496 W	Curtis Fielding	(905) 563-0668
2	Thirty Bench Winery	4281 Mountainview Rd, Beamsville, ON L0R 1B2	43.184 N, 79.479 W	Fiona Muckle	(905) 328-2640
3	Peninsula Ridge Estates Winery	5600 King St, Beamsville, ON L0R 1B3	43.177 N, 79.509 W	Norm Beal	(905) 563-0900
4	August Restaurant	5204 King St, Beamsville, ON L0R 1B2	34.169 N, 79.487 W	Clayton Gillies	(905) 563-0200
5	Fleming Chick Hatchery (Back)	4412 Ontario, Beamsville, ON L0R 1B5	43.172 N, 79.478 W	Ed Marchuk	(905) 563-4914
6	Fleming Chick Hatchery (Side)	4412 Ontario, Beamsville, ON L0R 1B5	43.172 N, 79.477 W	Ed Marchuk	(905) 563-4914
7	Residential - Bill Pacherva	4339 Lincoln Street, Beamsville, ON L0R 1B2	43.168 N, 79.487 W	Bill Pacherva	(905) 563-3105
8	Residential - Theresa Haynes	4238 Stadelbauer Dr, Beamsville, ON L0R 1B8	43.164 N, 79.485 W	Theresa Haynes	(905) 563-0799
9	Residential - Randy Wilson	4468 Lincoln Street, Beamsville, ON L0R 1B3	43.184 N, 79.479 W	Randy Wilson	(905) 563-6516
10	Residential - John and Theresa Deyfeter	4482 Lincoln Street, Beamsville, ON L0R 1B3	43.179 N, 79.506 W	John and Teresa Deyfeter	--
11/11A	Good Earth Winery	4556 Lincoln Ave, Beamsville, ON L0R 1B3	43.184 N, 79.479 W	Nicolette Novak	(905) 563-6333
12	Residential - John Kralt	4646 Lincoln Drive, Beamsville, ON L0R 1B3	43.184 N, 79.479 W	John Kralt	(905) 563-4769
13	Westbrook Greenhouses	5150 South Service Road, Beamsville, ON L0R1B1	43.184 N, 79.479 W	--	(905) 563-4740
14	Residential - JJ Berard	4936 Hickory Lane, Beamsville, ON L0R 1B5	43.179 N, 79.473 W	JJ Berard	--
15	The Chestnut Tree Pre-school	5407 King Street, Beamsville, ON L0R 1B3	43.173 N, 79.498 W	--	(905) 563-1113
16	Residential - OAC Grad Fruit Farmer	5361 Greenlane, Beamsville, ON L0R 1B3	43.180 N, 79.495 W	--	--
17	Residential - Ted and Cathy Koudys	4554 Mountainview Road, Beamsville, ON L0R 1B3	43.179 N, 79.506 W	Ted and Cathy Koudys	(905) 563-4364
18	Angel's Gate Winery	4260 Mountainview Rd, Lincoln, ON L0R 1B2	43.184 N, 79.479 W	AJ McLaughlin	(905) 563-3942
19	Residential - Theo Koudys	5480 King Street, Beamsville, ON L0R 1B3	43.175 N, 79.503 W	Theo Koudys	--
20	Ericway Tire	5253 King Street, Beamsville, ON L0R 1B3	43.170 N, 79.490 W	Chris	(905) 563-4787
21	Lincoln Public Library	4996 Beam St., Beamsville, ON L0R 1B3	43.165 N, 79.496 W	--	(905) 563-7014
22	Residential - Bains Hobby Farm	5225 Greenlane, Beamsville, ON L0R 1B3	43.179 N, 79.506 W	D. Bains	(905) 563-0245
23	Residential - Nancy Arruda	4575 Cedarbrook Lane, Beamsville, ON L0R 1B3	43.183 N, 79.478 W	Nancy Arruda	(905) 566-9225
24	Residential - Dave	5140 Oakwood Ave, Beamsville, ON L0R 1B8	43.171 N, 79.486 W	Dave	--
25	Residential - Penny Keller	5046 Hartwood Ave, Beamville, ON L0R 1B5	43.173 N, 79.478 W	Penny Keller	(905) 563-8314
26	Drost King Street Barns - Shed 2	5297 King Street, Beamsville, ON L0R 1B3	43.171 N, 79.492 W	Don Drost	
27	Drost King Street Barns - Shed 5		43.180 N, 79.506 W		
28	Drost King Street Barns - North Solar Panel		43.178 N, 79.506 W		
29	Drost King Street Barns - South Solar Panel		43.172 N, 79.492 W		
30	Drost King Street Barns - Between Nicolette's		43.178 N, 79.506 W		

In 2015, the sampling locations were restricted to shorter distances from the source barns, as number of adult flies the previous year, and number of flies in the Spring (2015) were unexpectedly low at the source barns. The adult flies were collected inside the barns and at three distances outside the barns (Fig. 2) at various cardinal points to try to determine how dispersal plumes of house flies occur from source farms (Objective 2). Unfortunately, the number of flies was very low during the first 12 weeks of the duck production cycles (May through July). It was therefore decided to monitor the flies only during the last three weeks of the poultry production growout cycle, as fly nuisance complaints are usually received when the barns are being emptied of birds and manure. The shipping of birds from the barn and the removal of manure usually favor dispersal of flies from the source (barn) to the surrounding environment.

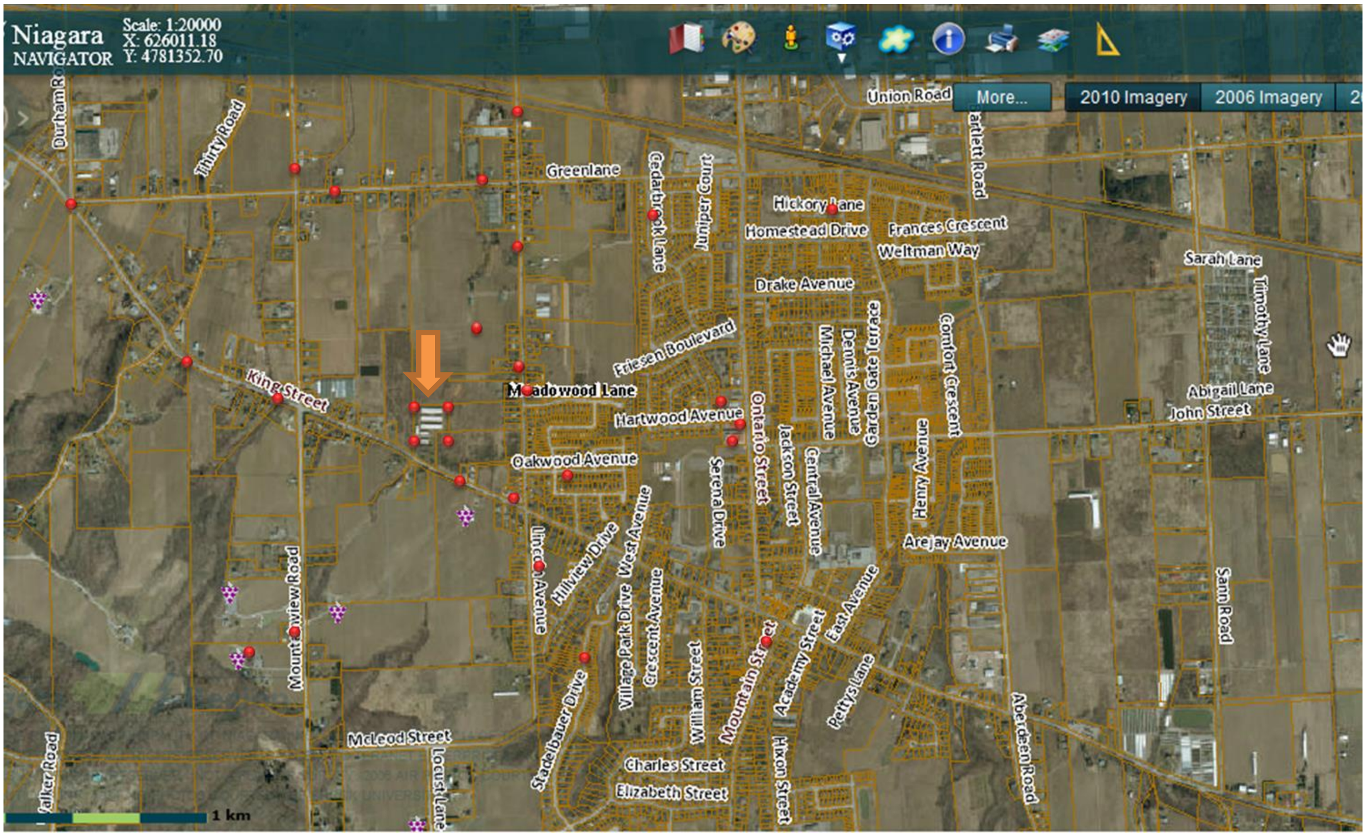

Figure 1. Sampling locations (red dots) around Beamsville area for 2014. Sites 1 (South-West) and 13 (North near QEW) are off the map. Arrow indicates the possible source of flies (poultry barn) and 4 sampling points outside the barn.

The sticky cards were installed inside the barns (5 cards/floor for a total of 30 cards), just outside the perimeter walls of the barns (9 cards), at about 25 meters from the barns (15 traps) and at about 75 meters from the barns (8 cards) (Fig. 2). The cards were installed to cover all the cardinal directions and most of the intercardinal directions (NE, NW, SE, SW), and house flies were counted weekly on all the cards.

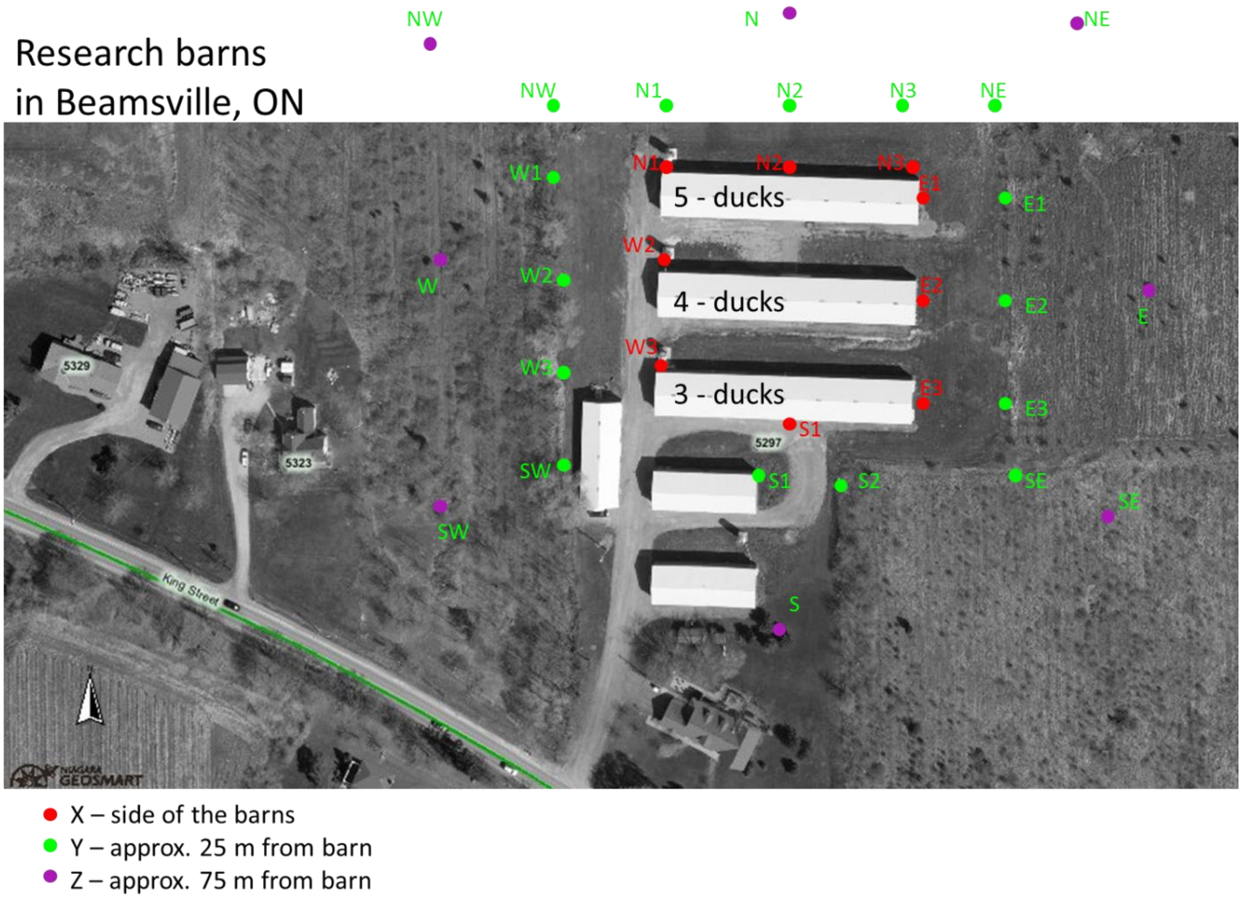

Figure 2. Sampling locations (red, green and purple dots) around the poultry barns for 2015. The barns are located on King Street in Beamsville, at the border of the town and at close proximity to vineyards, restaurants and houses.

Surveys of potential breeding and resting sites of house flies were performed by visual observations on a) visible organic substrates (potential breeding sites) and b) structural surfaces. The visual surveys were performed six times during warm weather (> 23 °C) in July-August 2014 and 2015, at wineries, restaurants and at the source barns. Locations with larger amount of waste organic matter storage (garbage bins, recycling bins) were targeted. The goal was to correlate the abundance of adult flies to site characteristics, such as surface type, orientation (N, S, E, W), proximity to breeding sites, color and other factors.

Four commercial outdoor trapping devices for flies, such as the ones commonly used by restaurants and businesses, were tested in 2015 to determine the most efficient ones and recommend proper selection. The traps selected for testing were: Advantage Flying Insect Trap (JF Oakes LLC, Yazoo City, MS), Rescue

Reusable Fly Trap (Sterling International Inc., Spokane, WA), Rescue Big Bag Fly Trap (Sterling International Inc., Spokane, WA), Catchmaster Gold Stick with Fly attractant (AP&G Co., Inc., Brooklyn, NY). All the traps were installed according to manufacturer's recommendation along the side of the poultry barn (Fig. 3). Individual traps were installed at a distance of 8-10 meters from each other. Trap location was randomly selected and three replicates were performed at the site. The traps were visited after 7 days had elapsed to retrieve the captured flies. Flies were counted and divided into two categories: house flies (*M. domestica*) or other large flies.

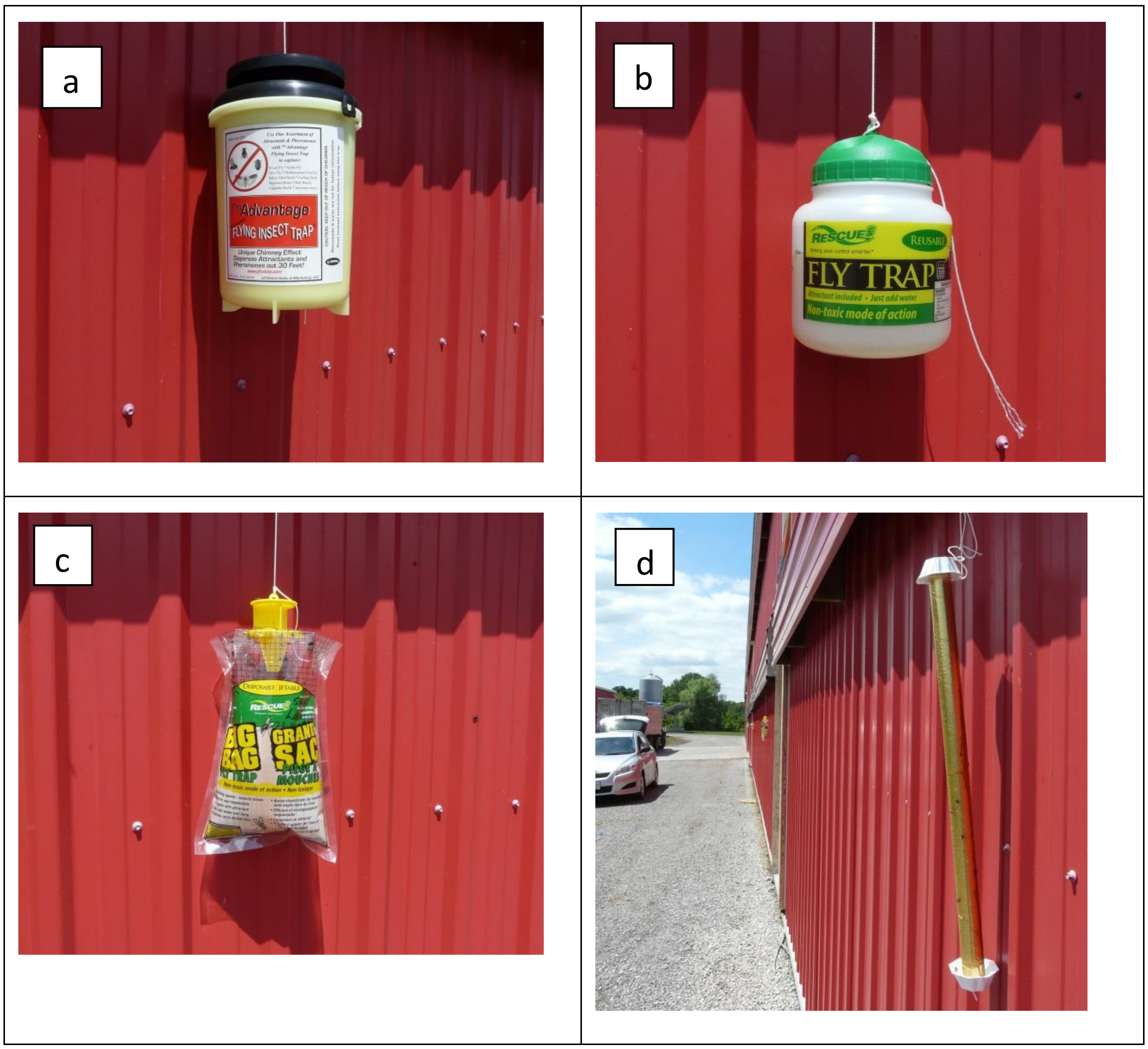

Figure 3. Outdoor traps tested for house fly control (2015). a) Advantage Flying Insect Trap, b) Rescue Reusable Fly Trap, c) Rescue Big Bag Fly Trap, d) Catchmaster Gold Stick with Fly attractant.

Objectives 4-6. Three times each year, flies were collected from inside the barns during July – Sept 2014 and again during same period in 2015. They were tested for the presence of potential pathogenic Enterobacteria, coliforms and *E. coli* and total aerobic bacteria. As well in 2015, flies were collected three times directly outside the barns, outside at August's restaurant (King Street) and outside and inside at Good Earth Winery (Lincoln Avenue). These locations were selected based on 2014 monitoring data and the proximity to the poultry barns to the restaurants and the likelihood of flies traveling from the barn.

Methods used by Chakrabarti et al. (2010) were adapted. Briefly, 10 flies were collected from a site, kept on ice, homogenized in 10 ml saline buffer and dilutions made to 10^{-4} concentration. One millilitre of each dilution was spread on a coliform/*E. coli* petrifilm plate, an Enterobacteriaceae petrifilm plate and a total aerobic petrifilm plate. All plates were incubated for 48 h at 37°C. Counts of colonies were performed using the 3M Petrifilms information sheets provided.

Due to very low fly numbers in the month of July and August at the receptor sites in 2014, it was not possible to collect enough flies to test for bacteria presence at numerous locations in 2014. The number of flies was low as well in 2015, but it was possible to collect at least three groups of 10 flies from the selected locations (closer to source barn) for bacteria testing.

Due to the low number of flies, and the relatively low pathogenic bacteria counts, no inhibition test following incubation was performed to assess the bacterial resistance to antibiotics added to poultry feed (Objective 5).

The fly counts during the 2014 and 2015 seasons were lower than previous years in the Beamsville area, likely due in part to environmental conditions less conducive to fly reproduction and development, but also because the poultry producers were more proactive in implementing fly control methods. While this is excellent for the neighbouring property owners, it was challenging for the research activities planned. It is generally considered that when the number of house flies within a livestock barn reach the threshold of 100 flies/sticky card over a 7 day period, a control action is necessary. For both years (2014-2015), the numbers were far below this threshold. The number of complaints for the past five years in the Beamsville area is included in the Results as a comparative.

c) Reach and Communication

The project was well publicised within the agricultural industry and involved major stakeholders (OMAFRA, UoG, Poultry Industry Council, the Grape and Wine industry, municipalities, residents, businesses). Flies are a concern not only for the agri-food sector, but also for surrounding residents and businesses. Many farmers in Ontario are being proactive and putting methods in place to reduce flies. A detailed publication (Pub. 849 –

House fly control in poultry barns, 34 pp.) was developed by Daniel Ward (OMAFRA) and Dr. Simon Lachance as part of the project, and published in September 2015. While it is primarily targeted at poultry producers, it provides methods that can be used in other agricultural settings. It contains a section on House fly identification and life cycle (Appendix 1). The document is available in both English and French and will be distributed to all poultry producers across Ontario. The hopes is that by limiting fly numbers within the barns, it will decrease the number of conflict situations between neighbours related to nuisance flies.

During this trial, poultry producers and stakeholders learned that there was no one solution to fly control. It takes an integrated, site specific program for every farm, or even for every barn situation. Although each method used may only slightly reduce fly numbers, the cumulative impacts may be significant.

Total number of people reached by the project is estimated to be more than 350 directly though presentations (2014-1015) and sampling during the summers at 25 locations, and many others due to the publication of several articles in the popular press (2013 and 2014) and website information about the project (Town of Lincoln - http://www.lincoln.ca/content/nuisance-flies).

Papers published, seminars or conferences presented:

Lachance, Simon, Shiell, Justine, Cynthia Scott-Dupree, Michel Guerin, Al Dam, Hugh Fraser, Dan Ward. Control of flies in poultry production. Poultry Industry Council Producer Update, *London*, Ontario, 25 Feb. 2015

Lachance, Simon, Shiell, Justine, Cynthia Scott-Dupree, Michel Guerin, Al Dam, Hugh Fraser, Dan Ward. Control of flies in poultry production. Poultry Industry Council Producer Update, *Jordan*, Ontario, 11 Feb. 2015

Shiell, Justine, Cynthia Scott-Dupree, Michel Guerin, Simon Lachance. Controlling house fly (*Musca domestica* L.) pressure in duck production facilities using management techniques to reduce manure suitability, Entomological Society of Canada annual meeting. *Saskatoon*, SK, 29 Sept. 2014.

Shiell, Justine, Cynthia Scott-Dupree, Michel Guerin, Simon Lachance. Controlling house fly (*Musca domestica* L.) pressure in duck production facilities using management techniques to reduce manure suitability, Ontario Pest Management Conference, *Guelph*, 13 Nov. 2014.

Shiell, Justine, Cynthia Scott-Dupree, Michel Guerin, Simon Lachance. Manure characteristics affecting the management of house fly (*Musca domestica* L.) populations in duck production facilities. Poultry Industry Council Research Day, *Guelph*, ON, 6 May 2014.

Justine Shiell, C. Scott-Dupree and S. Lachance. Treatment of duck manure with naturally-occurring substances to reduce suitability for house fly (*Musca domestica*) landing and breeding. , Ontario Pest Management Conference, *Guelph*, 7 Nov. 2013.

Shiell, J., Scott-Dupree, C, and S. Lachance. 2015. Manure characteristics affecting the management of house fly (*Musca domestica* L.) populations in duck production facilities. M. Sc. Thesis, University of Guelph. 126 pp.

Ward, D. and Lachance, S. 2015. House fly control in poultry barns / Lutte contre la mouche domestique dans les élevages de volailles, Publication 849/849F. Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA).

OGWRI was identified as a supporter for all presentations listed above, and for the 8 technical committee reports prepared and online at the Town of Lincoln website (below).

Technical Committee Report #1 - April 11, 2013. Available at http://www.lincoln.ca/content/nuisance-flies.
Technical Committee Report #2 - May 15, 2013. Available at http://www.lincoln.ca/content/nuisance-flies.
Technical Committee Report #3 - June 7, 2013. Available at http://www.lincoln.ca/content/nuisance-flies.
Technical Committee Report #4 - July 5, 2013. Available at http://www.lincoln.ca/content/nuisance-flies.
Technical Committee Report #5 - August 19, 2013. Available at http://www.lincoln.ca/content/nuisance-flies.
Technical Committee Report #6 - October 11, 2013. Available at http://www.lincoln.ca/content/nuisance-flies.
Technical Committee Report #7 - March 3, 2014. Available at http://www.lincoln.ca/content/nuisance-flies.
Technical Committee Report #8 - July 8, 2014. Available at http://www.lincoln.ca/content/nuisance-flies.

A presentation “House flies and food-borne disease transmission: what do we know?” is being prepared for the agricultural community. To be presented at later meetings.

3. Results and Discussion (Project Outcomes)

General objective.

The general objective of the project was to control flies in poultry manure (and duck in particular), and Integrated Pest Management (IPM) programs were implemented for house fly control in Beamsville poultry barns located in proximity to the town, local wineries and businesses. Various control methods, targeting all life cycles of the flies, were tested and implemented in the poultry houses. The methods included the release of biological control agents, the use of barn management techniques such as increasing ventilation to reduce the moisture content of the manure and testing synthetic insecticides as control methods.

Adult house fly emergence rates from larvae reared in the different poultry manures (including duck) were between 90-98%. This demonstrates the suitable nature of this material for fly rearing and then need to apply control methods at the source to avoid dispersal of adult flies to the neighbourhood. Poultry manure is particularly suited for flies compared to any of the other host manures (buffalo, cow, nursing calf, dog, horse, sheep, and goat), as house fly larvae reared on poultry manure developed faster (Khan et al. 2012).

Laboratory tests involving duck manure treated with various concentrations of natural insecticidal substances acetic and boric acid significantly lowered adult fly emergence rates. The laboratory tests using treatments of citric acid, diatomaceous earth and hydrated lime did not decrease the adult fly emergence compare to the untreated control manure. The application of naturally-occurring substances to manure could potentially alter the pH of the manure, making it less suitable as a reproductive substrate for house flies, discouraging fly development, and potentially limiting the number of flies dispersing to neighbouring residents.

The use of the biological controls (parasitic wasps and hister beetles) was not found to be efficient at decreasing fly populations. Commercial insecticide baits were efficient, but only controlled the adult flies. Management techniques that render the manure less suitable for fly production, such as decreasing the moisture content or adding natural insecticidal products to the manure, were found to be potentially important in decreasing infestations by creating unfavourable conditions for house fly growth. Although not efficient in our specific case, appropriate ventilation throughout animal production facilities may help reduce moisture in the barns in certain circumstances, decreasing fly breeding.

Complaints of nuisance flies in Beamsville started in 2010 with at least one call being received and followed-up (Daniel Ward, OMAFRA, pers. comm.). In 2011, OMAFRA received 12 calls from neighbours around the barns on King Street. In 2012, more than 65 calls were received from two locations in Beamsville during late

July and early August. In 2013, there was only few nuisance fly call complaints received by OMAFRA from the Beamsville area. Some of the complaints may have been directed to the Town of Lincoln, as a webpage was created during the project to inform residents about nuisance flies and provide project updates on the "fly control" project. No complaints were received from the Beamsville area during the 2014 and 2015 seasons, as fly numbers were low.

Specific objectives.

The seasonal population of flies was monitored weekly in the Beamsville poultry barns during the summer of 2013 and 2014. Outdoor sampling stations were used to estimate if fly dispersal from the barns to neighbours, businesses, wineries and restaurants was happening. The number of flies captured outside the barns and at neighbouring sites seems to correlate with the number of flies observed inside the barns (Fig. 4). However, the number of flies captured was very low at the neighbour's location (average < 0.6 fly/card) (Fig. 4).

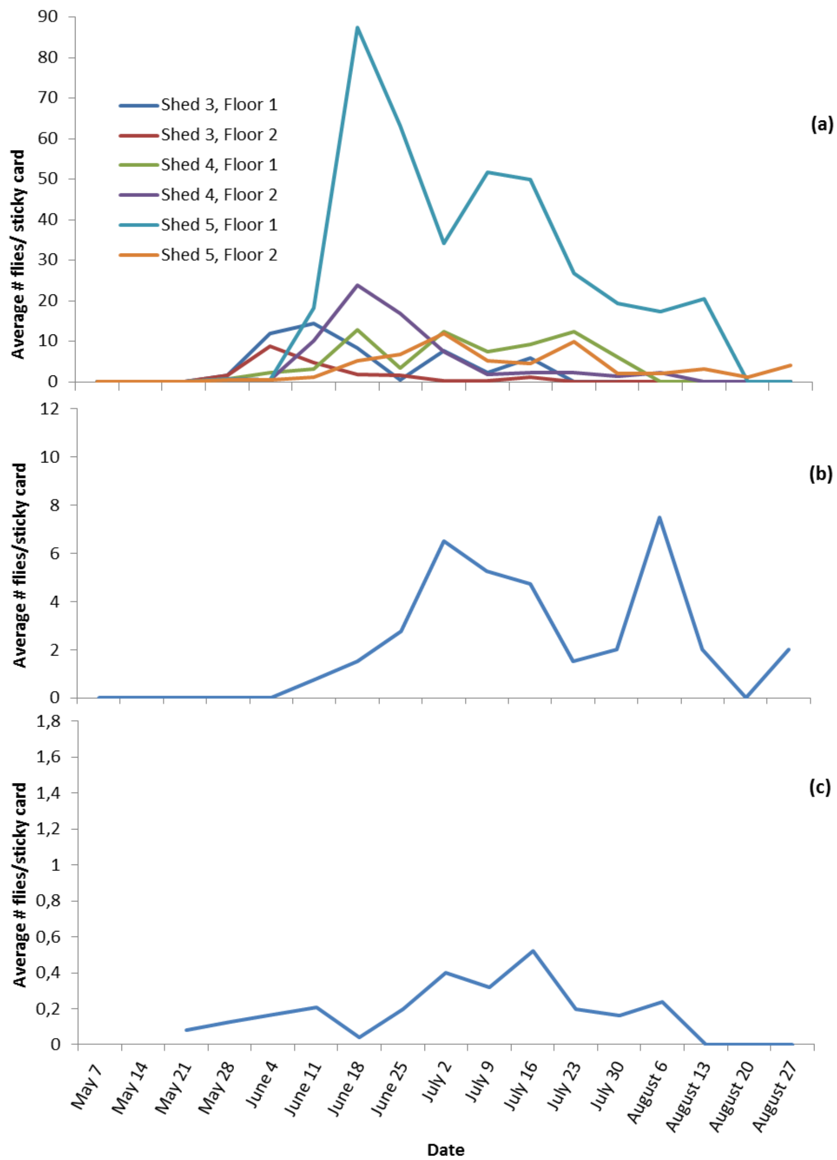

Figure 4. Average number of house flies captured per sticky card during the 2014 season, a) inside 6 poultry barns (source), b) outside the barns and, c) at 25 locations at distances up to 1 km from the source (c). Note the Y axis is not the same for all graphs, demonstrating the decrease in fly numbers as distance increases.

Flies inside the poultry barns were highest between mid-June to end of July 2014, with average adult flies per sticky card reaching a peak average of 87.4 flies for one floor of a barn during the week of June 18th (Fig. 4). The barn with highest fly numbers was the Control barn where no fly control measures were implemented during this experiment. The fly numbers immediately outside the barns followed a similar population pattern, although delayed, with two visible peaks of fly numbers (July 2nd and August 6th). The average number of flies captured per sticky card was always lower than 8 adult flies/card. Making correlations with densities at the 25 receptor sites was challenging, as the number of flies captured at receptors were very low and varied greatly (Fig. 4c), partly due to low number of flies at the source. However, the house flies captured followed a similar trend with more flies during the period of mid-June to early August.

Locations with larger amount of organic matter in the form of waste material (garbage bins, recycling bins) and serving food were empirically found to harbour more adult house flies than other locations (sites 4 and 11 – Fig. 5). These two sites are also located within 400-450 meters flight for an adult fly potentially emerging from the source barns. Resource-derived semiochemicals, usually volatiles, attract females flies and stimulate them to lay eggs in this substrate (Cosse and Baker, 1996). It is therefore likely that the adult flies were attracted by volatiles released by the food processing, handling and by-products at these locations serving food, although it is difficult to confirm where the flies were coming from.

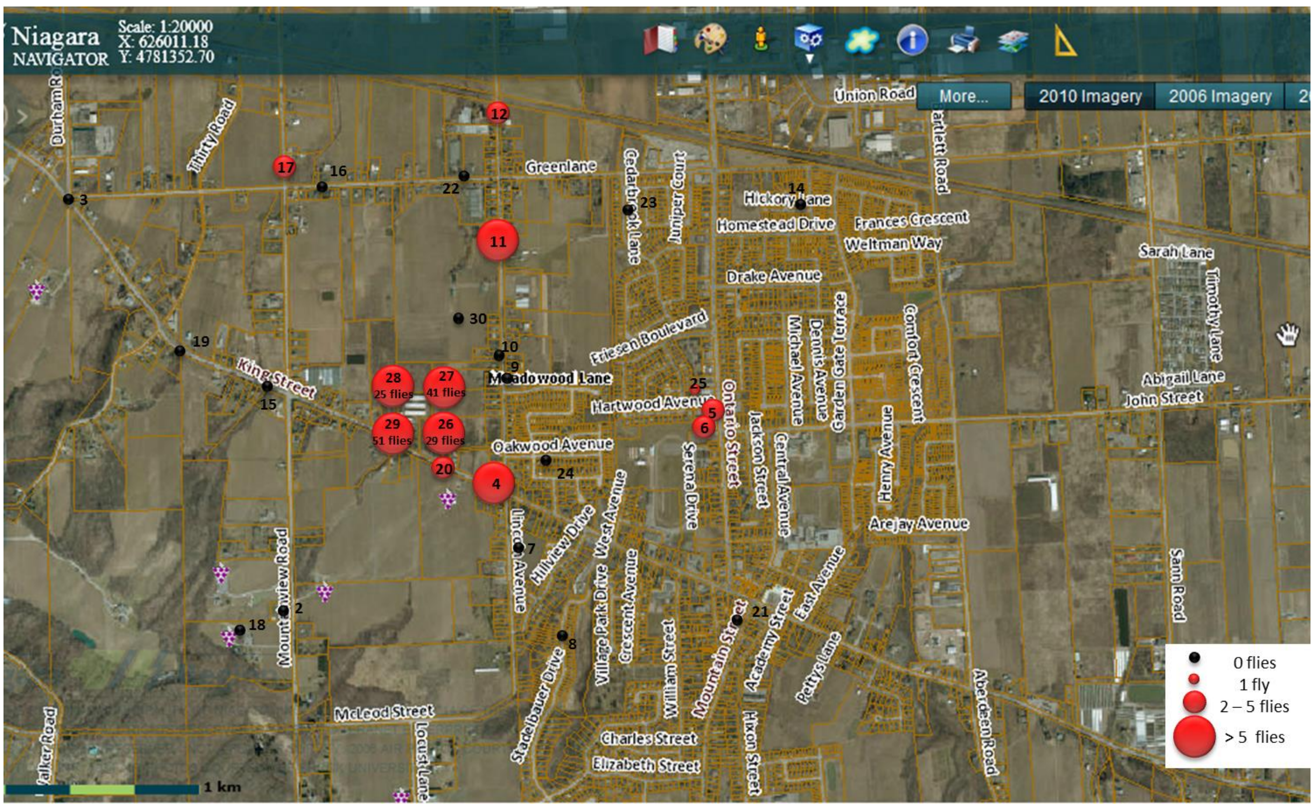

Figure 5. Number of flies collected at each sampling locations around Beamsville area for 2014. Sites 1 (South-West) and 13 (North near QEW) are off the map. The site number is included, and circle size represents fly pressure.

Larval house fly development is dependent on the presence of bacteria in the substrate, suggesting that fly development in a natural environment is supported by a complex microbial community in the organic matter

(Zurek at al., 2000). Although we did not search through organic matter to find maggots, it is clear that organic matter that can decompose or ferment should be removed from the farms and businesses on a weekly basis to avoid larvae development and adult fly emergence. A change in substrate characteristics can influence oviposition, attract more females, as microbial-derived stimuli are used by the female flies to select a suitable site for oviposition and larval development (Romero et al., 2006). It is important to note that the flies observed at the sites were not all house flies. They included flies from other family, genus and species (such as a few Calliphoridae) and should not be correlated with the proximity to poultry facilities. These flies were also likely attracted by some of the same volatile compounds produced by organic substances such as food and food by-products.

Fly sampling numbers for 2015 around the poultry barns are shown in Fig. 6. The air-inlets are located on the East side of the barns and the outlets with the ventilation fans are located on the West side. It appears that more flies were captured from these two directions, at close proximity to the barns (Fig. 6.). However, number of flies captured per sticky card was highly variable, and we could not statistically confirm a difference in fly number based on cardinal direction (Fig. 7).

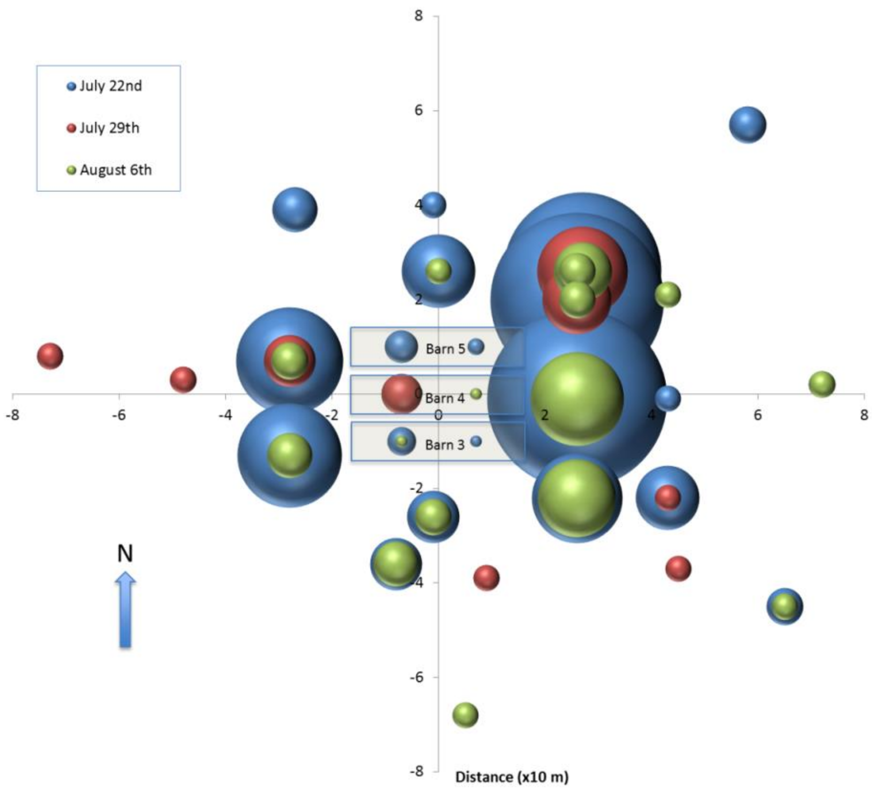

Figure 6. Number of house flies captured, for each trap locations, for 2015. Exhaust fans from the barns are located on the West side.

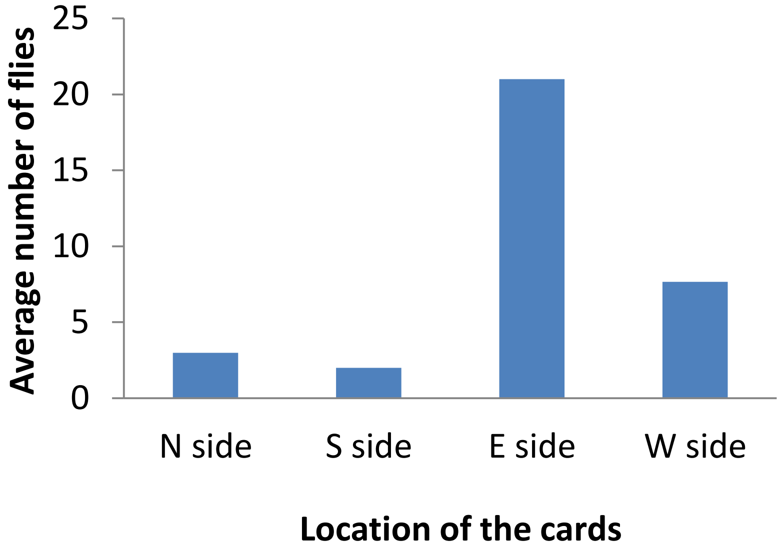

Figure 7. Average number of house flies collected from the cards situated at each of the four cardinal points, close to the poultry barns. No significant statistical differences were found between locations, using an ANOVA followed by a Tukey's test at $p < 0.05$, due to a high variability in the number of flies captured at each location.

The number of flies captured at the three distances from the barns (1, 25 and 75 meters) and inside the barns was compared. The average number was statistically higher outside the barns, at the shortest distances, than inside or at the other two distances (Fig. 8). At the time (July 22nd), about two-thirds of the barns were emptied of birds, and flies were free to travel from inside to outside of the barns, or leave the vicinity. It is clear that some environmental or biotic factor(s) were affecting the behavior of the flies and they were staying immediately outside the buildings and not moving inside the buildings. Many flies were observed basking on the outside walls of the barns. It is unclear how many may have been leaving to disperse to neighbouring locations, as a capture-mark-recapture study would be necessary to fully answer the question. However it is obvious that flies that were *inside* the barns earlier during the poultry production cycle were clearly staying *outside* when the birds were moved out of the barns and the barns kept empty.

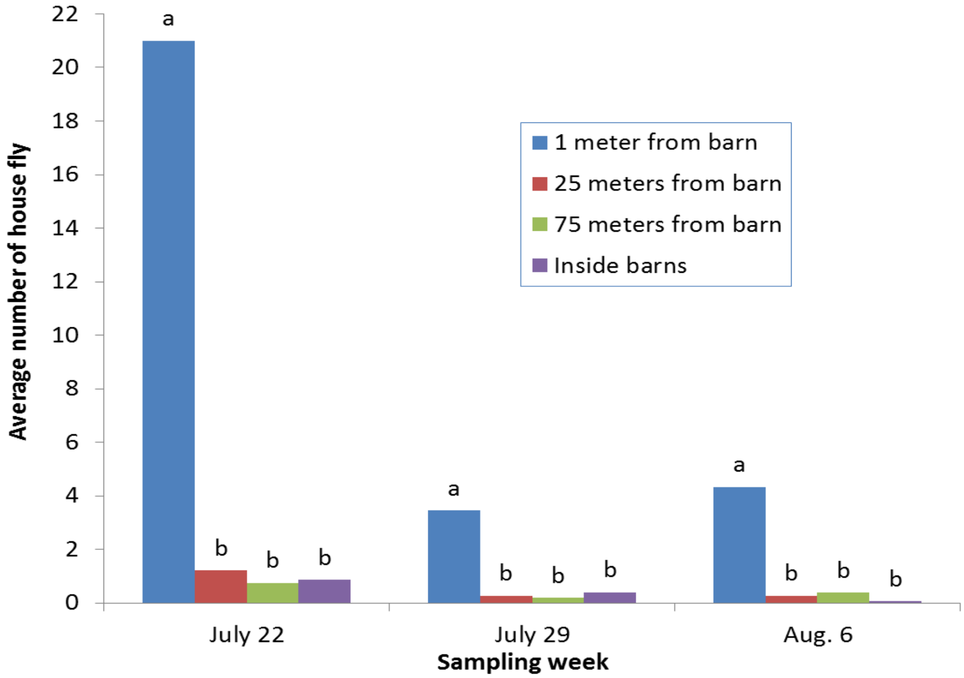

Figure 8. Average number of house flies collected outside barns at different distances and inside the poultry barns. Data with the same letter within the same week are not significantly different using a repeated-measure ANOVA followed by a Tukey's test at $p < 0.05$.

Since adult house fly numbers collected at the receptor sites were often very low, a trial using attractants was performed for four weeks in 2014 to try to increase the number captured at the neighbour locations. The number of flies caught with attractant at the neighbour locations was not higher than the number caught without the attractant (Figure 9). However, on the monitoring cards located immediately outside the poultry barns, the use of attractant did increase the number of flies caught on the sticky cards (Figure 9). It is likely that the effect of the volatile attractant is short range, and when used at the neighbour locations the volatile was not strong enough to attract flies from the barns. Since there were more flies in the proximity of the traps just outside the barns, they were reached by the volatile attractant and behavior changed. Designing a simple, easy to use and cheap trapping device that can be used to monitor flies in outside situations and relate the numbers to potential risks of disease transmission was the goal. However, more work is needed to develop an efficient outdoor monitoring method.

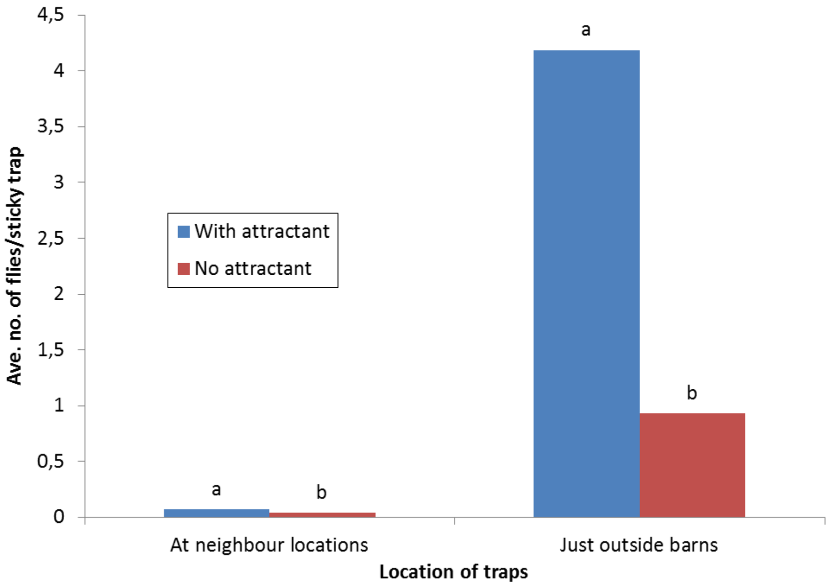

Figure 9. Average number of flies captured/sticky card at 25 neighbour locations and at 4 locations just outside the poultry barns, with or without attractant placed on the cards. Data with the same letter within the same location are not significantly different using an ANOVA followed by a LSD test at $p < 0.05$ (n=25 or 4 replicates; neighbour locations and outside barns, respectively).

It is often recommended to apply a knockdown spray in the barn if fly numbers average 100 flies captured per card over a 7-day period. This would be performed before manure cleanout, immediately after the last bird is loaded on the truck for shipping. This would prevent flies from escaping into the neighbourhood. The numbers during the 2014 and 2015 seasons were not high enough to justify a knock-down application. However, as part of the research project in 2013, we sprayed one barn at the end of the bird growout period as fly numbers were approaching the threshold, in order to reduce adult fly numbers and avoid fly dispersal during barn cleanout.

Fly numbers observed during 2013, 2014 and 2015 at the neighbours, including resident houses, restaurants and vineyards were drastically reduced compared to the summer before the trial was started, when no IPM was in place at the farm. The reduction of fly number at the neighbours is likely due to the reduction at the source, although the direct relationship is difficult to confirm. For example the one time knockdown spray treatment killed more than 3300 flies killed per 10 meter square of flooring inside the barns (Fig. 10). This translates to approximately 310,000 flies killed in the barn before doors of the barns were opened for manure cleanout and eliminated the dispersal of these flies to neighborhood.

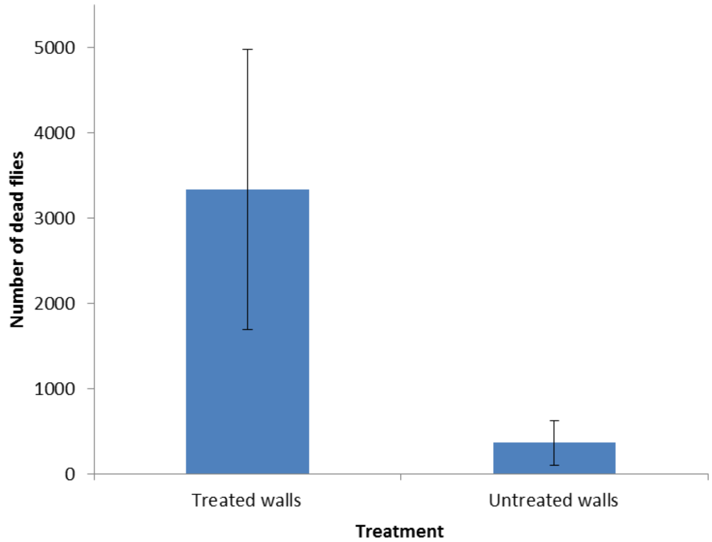

Figure 10. Number of dead flies on floor (10 m^2) after spraying with the insecticide Pounce just before cleanout. Threshold number of 100 flies/sticky card almost reached, but decision to apply was positive due to possibility of dispersal to neighbour (2013).

Another control method tested during the trial to control fly populations in the barns was the use of insecticide fly baits. Various quantities of insecticide baits and two delivery methods were tested. The impact on the number of flies killed is presented in Figure 11. The number of flies killed by the various treatments decreased during the poultry production cycle (Fig. 11), and less flies were present at the end of the cycle (Mid-August). All the insecticide bait treatments were efficient at killing the flies, compared to the control (the device not filled with the insecticide bait) (Fig. 11). On weeks 9 and 10 (August 13 and 20, 2014), the bait tray with 15 grams of newly placed insecticide was significantly better than the other treatments (Fig. 11).

As insecticide treatments may increase resistance development, it would be recommended to place the insecticide in the barns only if necessary, when the adult flies are starting to appear. It would be valuable to develop a threshold indicating when the placement of insecticide baits should occur.

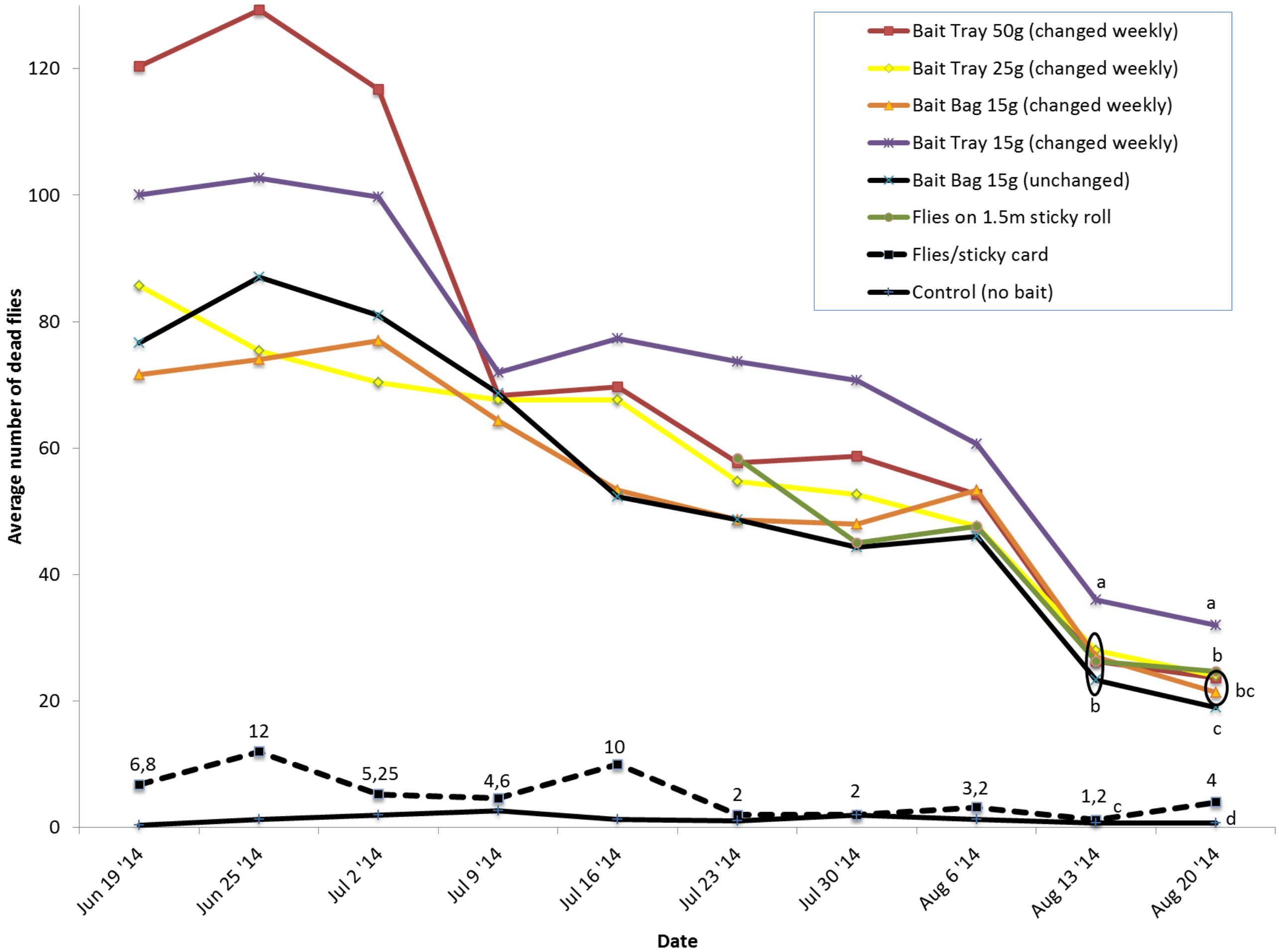

Figure 11. Average number of flies killed by each treatment over the course of a poultry production cycle in 2014. The insecticide bait used is Agita (active ingredient thiamethoxam). Data with the same letter within the same week are not significantly different using a repeated-measure ANOVA followed by a Tukes's test at $p < 0.05$. All treatments were significantly different than the control for the first 8 weeks but not within each other (no letters added). The dotted line represents the average value of flies on monitoring sticky cards.

As all flies at the source cannot be prevented from moving to other locations, trapping the adults in locations where they may congregate and become a nuisance (homes, restaurants, wineries and businesses) might sometimes be an alternative. Many outdoor traps are commercially available, but their efficacy varies. For the trial, four of the most common traps were selected, installed and flies captured during a one-week period. The most efficient trap at capturing adult house flies (although not significantly better than the Rescue Fly trap) was the Big Bag, with an average of 1306 adult house flies captured (Fig. 12). As well, it was capturing a higher number of other large fly species (Fig. 12), that can also be a nuisance to humans.

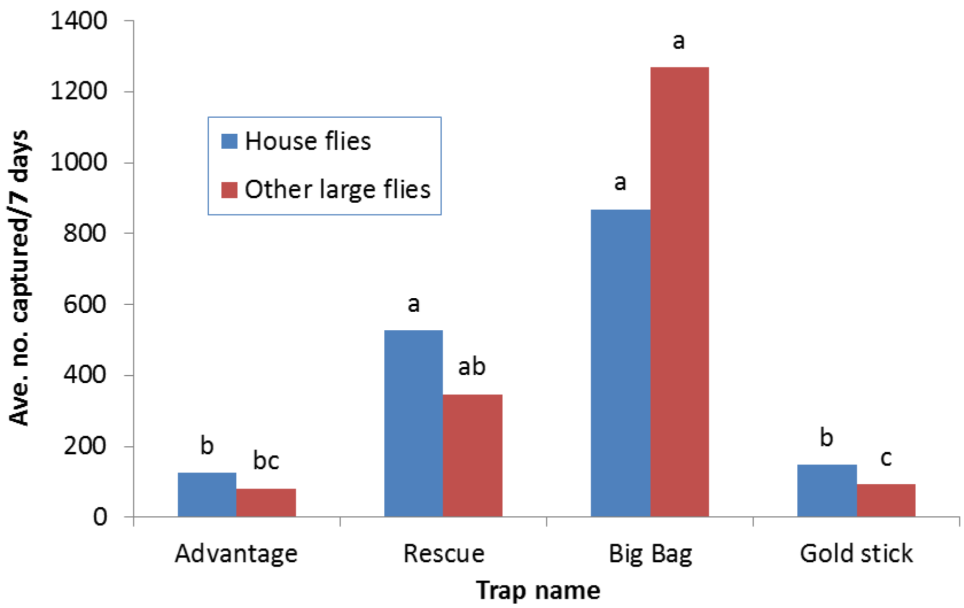

Figure 12. Number of house flies (*M. domestica*) and other large flies captured by four different trap types. Data with the same letter within the same group of flies are not significantly different using an ANOVA followed by a LSD test at $p < 0.05$ (n=3 replicates).

For 2014 and 2015, flies were collected by sweep nets inside and outside the barn and at four other locations away from farm and tested for the presence of coliforms/*E. coli*, Enterobacteriaceae and aerobic bacteria. It was not possible to collect enough flies to test for bacteria at all the locations where traps were installed around Beamsville (25 locations), due to very low fly numbers and time limitations. External locations where food was handled (e.g. restaurants) and at close proximity to the source poultry barns were selected for this trial.

The total number of bacteria per fly was higher than the number of pathogenic bacteria (Enteriobacteriaceae and coliforms/*E.coli*), indicative that the flies harbour a bacterial fauna that is likely not all pathogenic (Table 3). Bacterial tests were also performed with groups of 10 flies collected from the house fly colony at the University of Guelph, to compare bacteria number, and these also harboured pathogenic bacteria. All the fly samples collected from the barn and outside the barn tested positive for at least one of the potential pathogenic bacteria (coliforms/*E. coli* and Enterobacteriaceae) in 2014, although no *E. coli* was detected.

Table 3. Minimum and maximum number of colony forming units (CFU) per fly found on fly samples collected inside the barns, outside the barns and in the colony for 2014.

Location of fly sample	**Bacteria group**	**Minimum CFU/fly**	**Maximum CFU/fly**
Outside barn (n=3)	Total Aerobic	288	>250,000
	Enterobacteriae	0	5000
	Coliforms	315	3400
	Escherichia coli	0	1900
Inside barn (n=8)	Total Aerobic	0	>250,000
	Enterobacteriae	0	3500
	Coliforms	0	30000
	Escherichia coli	0	21050
Colony (n=2)	Total Aerobic	2815	6150
	Enterobacteriae	80	495
	Coliforms	830	2360
	Escherichia coli	0	0

For 2015, four locations were tested for microbial counts on adult house flies, for a total of 150 adult flies, tested in groups of 10. The flies were captured at the end of the poultry production cycle. Total number of bacteria per fly was lower than in 2014, and no flies were tested positive for Enterobacteriae. However, many flies tested positive for *E. coli*, one of the potentially most harmful bacteria. The presence of *E. coli* is an indicator of fecal contamination, but its presence does not necessarily indicate the presence of a pathogenic strain (many *E. coli* are not pathogenic). In 2015, the average coliforms per fly was 73 (range 0-1000), the average *E. coli* per fly was 73 (range 0-1000) and the average aerobic bacteria was 1060 per fly (range 0-3000). Flies found to carry *E. coli* were collected from one location away from the poultry barns, but at close proximity of food-serving areas.

It is difficult to extrapolate the direct risk of bacterial transmission from the source barns to receptors without a more in-depth study on bacterial *deposition* to food by flies. However, as it was found that many of the flies were able to carry pathogenic bacteria, and possibly deposit some of the bacteria on other substrates such as food, the precautionary principle should apply and contact of flies with food and beverage should be avoided. Efforts should be placed to limit the *number* of flies landing on food, as well as the *duration* of the contact to food sources.

The pathogenic bacteria present on the adult flies can possibly come from the poultry barns, if the fly has dispersed from this source. However, flies can also pick-up bacteria, pathogenic or not, while landing on many other organic substrates such as garbage or various surfaces outside of the poultry operations.

4. Final Comments and Conclusions

The results presented here are part of a larger project aiming at reducing flies in poultry production facilities and the surrounding environment. Flies can compromise the health and well-being of livestock animals, as well as of workers, neighboring residents and visitors, and can potentially be vectors for pathogenic bacteria. Innovative, simple, safe and economically sound technologies were evaluated and developed to provide recommendations within a best management program and a surveillance program. House fly control is not just important for livestock and poultry farms, but for the rural community in general. As urbanization continues to expand into rural areas, such as in the Niagara Peninsula, public health concerns arise; the risk of disease transmission may increases as residential areas move closer to poultry operations.

It is clear that reducing the *source* of flies, such as growing sites for maggots, should be the focus of any management project. In poultry operations, managing flies at the source can be challenging due to the high density of birds and the resulting accumulated manure at these sites. The nuisance impact of flies may be important when different land uses are located side by side, such as agri-tourism in an area with commercial poultry barns.

As a response to the high densities of flies being observed in proximity to poultry production facilities within the Niagara/Beamsville area (and also observed at other locations in Southwestern Ontario), the research project tested several control methods. The end result was the development of some best management practices and the publication of a comprehensive manual for the control of house flies in poultry production barns. If the recommendations are followed by poultry producers, this should alleviate fly problems at neighbouring properties.

Once house flies are in a neighbourhood, they will search out sources of food and places to live, breed and survive. It is therefore essential for anyone with a backyard composter, a waste bin, a pile of lawn clippings, pet droppings sitting on their lawn or any other source of organic matter, to take action to prevent flies from breeding in this material. Commercial, agricultural and industrial businesses can contribute to lowering the fly number by limiting the source of organic matter (for example wine processing residues) for flies to breed and feed.

The correlation between endemic disease outbreaks and the seasonal abundance of house flies has been examined, mostly in developing countries, and a reduction in disease prevalence in both urban and rural areas was observed when house fly control was implemented (Graczyk et al., 2001). Pathogens can be transmitted by house flies using their mouthparts, hair, vomit or feces (Malik et al., 2007). Although the number of bacteria found on flies collected during this project was low, specific environmental situations may increase the number of pathogenic bacteria present on flies, the mechanical transmission and the risks of human food-borne diseases if the pathogens are deposited on food. Precautionary principle should apply and contact of flies with food and beverage should be avoided, as flies were found to carry some pathogenic bacteria.

From both sampling data inside and outside the barns and at neighbouring locations during a three year period we can hypothesized the following may happen in relation to fly densities and fly behavior, in somewhat chronological order, at proximity of poultry production facilities:

1) Adult flies will slowly move inside building (barns) at the beginning of a normal duck production cycle (duration about 12 weeks).
2) The female flies inside the building will start laying eggs as soon as manure conditions will be appropriate, usually when bedding (manure and wood chips) will reach about 70% humidity.
3) At weeks 5-8, a high number of maggots will be present in the bedding.
4) Adults will be starting to emerge from the fly pupae formed by the maggots about 2 weeks following egg-laying, and therefore a peak adult emergence from the first egg-laying period should happen during weeks 7-10.
5) The new adults will start laying eggs themselves, or leave the premises if they find openings to the outside. During the warmer parts of the season, due to the high rate of air exchange required to manage the environment for the birds, the inlet and outlets vents are open most of the time.
6) Continual emergence of adults from the litter should then be observed if conditions in the bedding remain suitable during the latter part of the poultry production cycle.
7) When birds are ready for markets, doors are opened, birds are shipped and manure is usually quickly removed.
8) Remaining adult flies will leave the building and search for new suitable environment for feeding and laying eggs, which is usually NOT back into an empty barn because the food sources are gone and the bedding conditions are not appropriate anymore for maggot growth. *This is when the flies can move in large numbers to neighbours, vineyards, businesses, restaurants, etc. and cause nuisance issues.*

It takes an integrated, site specific program for every farm. For animal operations in close proximity to sensitive areas, it is important to use a variety of management methods including moisture and ventilation control, exclusion of adult flies from the barn, mechanical control with sticky traps, biological control methods and insecticide spray or baits as needed. Although each method used may only slightly reduce fly numbers, the cumulative impact of all the methods will have an overall beneficial result on reducing flies in the barn available to disperse to nearby residences, farms and businesses.

Rural homeowners can expect to have some house flies during the warmer months of the year since no control strategy is 100 percent effective and flies are a part of the natural environment. Control strategies should be implemented early to ensure an environment not conducive to fly breeding. It is important to take the time to locate where flies breed, and eliminate the source or make the conditions less than ideal for fly breeding.

Nonetheless, if flies are present around businesses, wineries and restaurants, the use of exclusion techniques (screens for windows, keeping door closed) can be implemented, as well as trapping. Of the traps tested, the Rescue Big Bag Fly Trap (Sterling International Inc., Spokane, WA) prove to be the most efficient at trapping house flies in outdoor situations.

5. References

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Appendix 1. House fly life cycle (from Ward and Lachance, 2015).

In order to effectively control fly populations, it is important to understand their life cycle, preferred habitat and what they need to survive and reproduce. Use this knowledge to monitor and select the most effect control strategies.

The most common fly found in Ontario poultry facilities is the house fly (*Musca domestica L.*). It is a non-biting, 6–9 mm long fly, with four black stripes on the thorax. The sides of the abdomen are beige in colour (Figures 32 and 33).

Figures 32. House fly.

Figure 33. House fly.

House flies absorb liquid or semi-liquid foods and feed on solid material by softening it with regurgitate. They spit out saliva on solid foods to predigest it then suck up the liquefied materials with their mouth. Flies are especially attracted to foods that contain sugars (e.g., molasses) and protein (e.g. poultry feed). Because of their high intake of food, they deposit feces constantly.

Other flies in agricultural settings that resemble house flies include the Face Fly (*Musca autumnalis*), which is 6–10 mm (0.24–0.40 in.) long and very similar to the house fly (Figure 34). It is also a non-biting fly found mostly around pastured animals. It feeds on animal secretions around the eyes, mouth and muzzle.

Figure 34. Face fly.

The Stable Fly (*Stomoxys calcitrans*) is 5–8 mm (0.20–0.32 in.) long with a gray abdomen and biting mouthparts. It often bites the legs of animals and sometimes humans (Figure 35).

Figure 35. Stable fly.

The Cluster Fly (*Pollenia* spp.) is 8–10 mm (0.32–0.40 in.) long, has a checkered abdomen and its wings overlap and lay flat at rest (Figure 36). It often congregates in large numbers on buildings during the fall to find overwintering places. It is often seen in the spring as well, when sunny days warm up their hiding places. The larvae of the cluster fly are parasitic on earthworms.

Figure 36. Cluster fly.

Blow Flies are metallic green or blue and are sometimes mistakenly identified as "house flies" (Figure 37). Blow flies are attracted to dead animals and their maggots devour the carcasses.

Figure 37. Green Bottle Blow fly.

Life Cycle

The fly life cycle is divided into four distinct stages: egg, larva (maggot), pupa and adult (Figures 38 and 39). Adult flies represent a small percentage of the total fly population present as the eggs, maggots and pupae are located in the bedding or organic matter and out of sight. Adult flies tend to spend their entire lives within 1 km (3,280 ft.) of where they emerged, if there is food and the right conditions for breeding and laying eggs. Adults will move if they have to find food and the right environment.

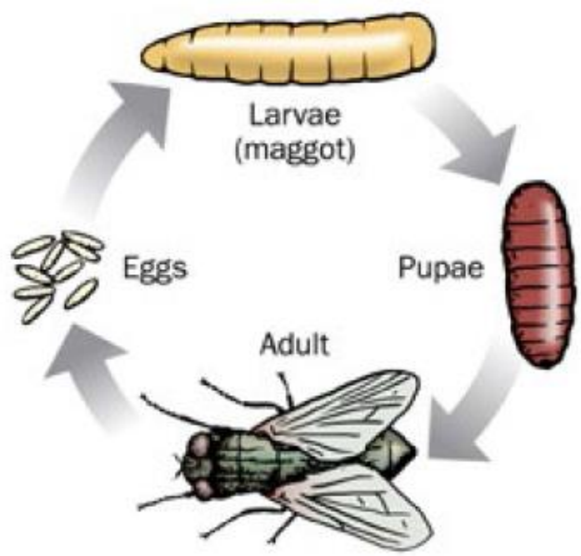


Figure 38. Life cycle of the house fly.

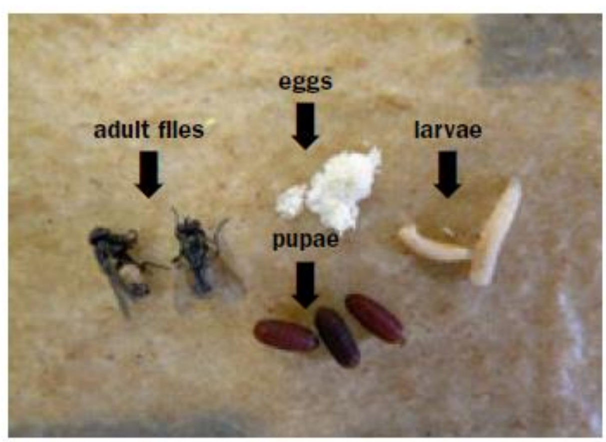


Figure 39. Life stages of the House fly, moving clockwise — adult flies, eggs (white), larvae (brownish-grey) and pupae (reddish-brown).

Adult (Egg Laying Stage)

Female flies like moist areas to lay their eggs. If conditions are too dry, the eggs dry up and die. Female flies prefer to lay their eggs in material with moisture content between 60%–80%. The sex ratio of adult house flies produced is approximately 50:50.

Male house flies can begin mating as early as 10–12 hours post emergence. Females only mate once, however males are capable of mating with 4–8 females in a 24-hour period. A female fly will start laying eggs 3–4 days after its emergence from the pupae. Eggs are laid in areas with the most attractive odour and moisture content (e.g., manure).

The eggs are individually laid and piled in small groups. Normally the female house fly lays 75–150 eggs at a time and she will repeat this process several times for about 500 eggs total in her lifetime. Often, several flies will lay their eggs close together, creating large numbers of larvae and pupae in one particular area. Female flies need access to suitable food to allow them to produce eggs.

Egg

House fly eggs are white, and approximately 1.2 mm (0.05 in.) in length. During warm weather the eggs normally hatch within 8–20 hours after being laid.

Larva (Maggot)

After the eggs hatch the larvae or maggots grow rapidly through three progressively larger larvae stages. Nutrient rich organic materials such as rotting vegetation, garbage, spilled feed and livestock manure are ideal food sources for the growing larvae (Figure 40). Larvae require a relatively moist environment to survive. A 65%–85% moisture content range is ideal.

Figure 40. House fly larvae in manure.

Research shows that 75% moisture content is ideal for larvae survival. In each of the trials, all of the fly larvae (100%), emerged as adults. Above and below this moisture content there was some death loss observed in the fly larvae. Litter moisture content below 60% showed a thirty percent reduction in larval survival, which is significant. Farmers could use ways to reduce moisture, as a partial control method. Targeting a moisture level below 55% will give the best results in fly reduction (Figure 41).

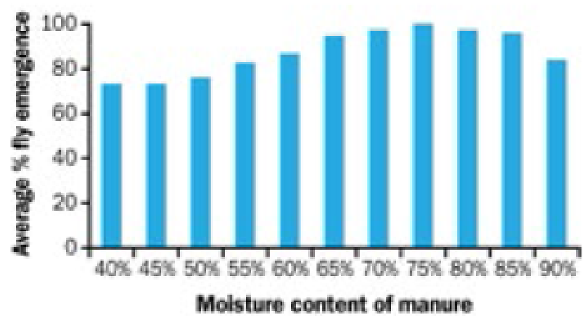


Figure 41. Adult emergence from duck manure of different moisture contents. *(Source: Shiell, 2015)*

Fly development and activity is temperature dependent. Maggots grow faster in warmer temperatures, and adults will emerge sooner. The fastest development occurs in organic material at 30ºC–38ºC. This temperature is often found in litter and fermenting organic materials. Larvae will develop in material having a temperature as low as 12ºC, but at a slower rate of growth. If material temperatures exceed 55ºC, the larvae will die. This is the temperature found in a good composting pile of organic materials. Note that air temperatures are not the same as the litter temperature because of the fermentation process happening in organic material.

Pupa

The pupa is the last stage before the adult emerges. Fly larva stop eating and crawl as far as a few meters to find drier areas to pupate. The larva forms a hard outer shell to prevent moisture loss and protect the developing adult fly. The shell is light orange to brown to almost black as time progresses. The time to complete the pupa stage in the fly life cycle is dependent on the temperature of the materials surrounding them, but usually lasts about 6–7 days at room temperature (Figure 42).

Figure 42. Close up of fly pupae.

Fly Lifespan

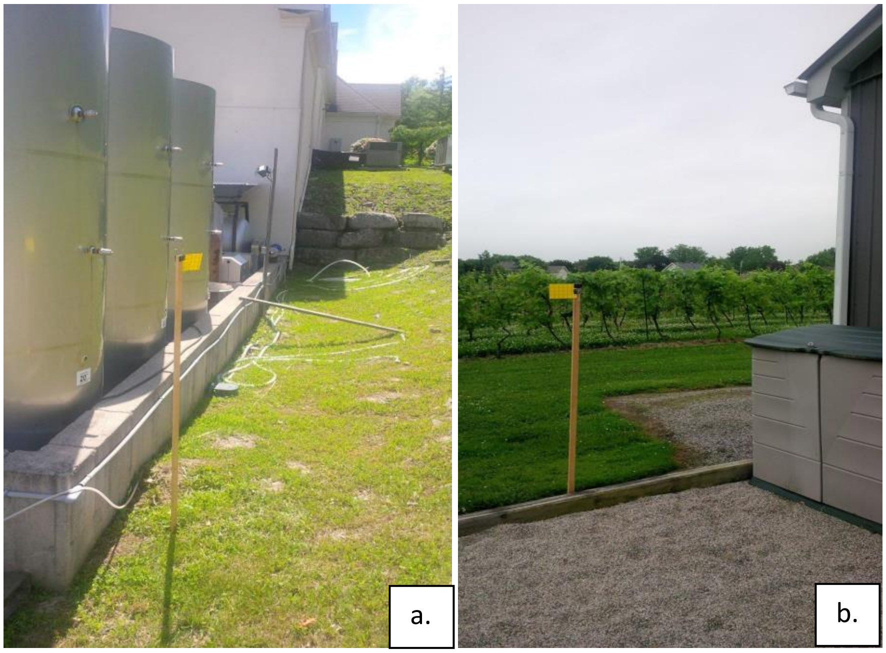
The complete life span, from egg to sexually mature adult, can take as long as 50 days at 16°C or as little as 11 days at 30°C. Adult house flies normally live 15–25 days but may survive up to 70 days. Their longevity is enhanced by cooler temperatures and by the availability of suitable food, especially sugar. Without food they will only survive two to three days.

Flies are diurnal (they are active during daylight hours). As night-time approaches they tend to look for places to rest.

As colder weather and shorter day length approaches (Fall), adult flies that are outside, slow their metabolic process, stop laying eggs and seek shelter. They crawl inside cracks and small openings of buildings to overwinter until temperatures warm up in the spring. The management of poultry barns with controlled temperature and long photoperiods (>14 hours light), allows for year-long reproduction of flies, without this overwintering period.

Under ideal conditions fly populations can increase rapidly. As many as 10–12 generations of flies can occur in one year in climates like Ontario.

Appendix 2. Sticky card for weekly sampling at: a) Angel's Gate Winery and b) a residential home (Bill Pacherva).



Appendix 3. Petrifilms for bacteria sampling. Red for coliforms/E. coli, purple for Enterobacteriaceae, yellow for total aerobic.