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**2021**  
**LDD Moth Monitoring Program**  
Town of Pelham  
2021 Population Assessments and 2022 Defoliation Forecasts

Prepared For:

JASON MARR  
DIRECTOR, PUBLIC WORKS  
20 PELHAM TOWN SQUARE, PO BOX 400  
FONTHILL, ON L0S 1E0

Prepared By:

LALLEMAND INC./BIOFOREST  
151 SKYWAY AVENUE, TORONTO ON M9W 4Z5  
PHONE: (705) 942-5824 EXT. 218  
EMAIL: [ACRAIG@BIOFOREST.CA](mailto:ACRAIG@BIOFOREST.CA)  
WEBSITE: [WWW.BIOFOREST.CA](http://WWW.BIOFOREST.CA)

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# Introduction

## LDD Moth in North America

LDD moth (*Lymantria dispar dispar*), formerly known as “gypsy moth”, is native to Europe and was introduced to North America in 1869. Interested in developing a silkworm industry in North America by crossing LDD moths with North American silkworms, Professor L. Trouvelot brought LDD moths from France to Massachusetts. In 1870, a small number of LDD moths escaped, and, within 20 years, LDD moth had become a serious regional pest.

Although the United States government has had a quarantine in place since the early 1900s, LDD moth has been advancing slowly westward from the northeastern United States. In the United States, LDD moth has spread from western Pennsylvania, through Ohio, Michigan, and Illinois and is now in central Wisconsin. It is estimated that LDD moth is currently spreading at a rate of 21 km/year (USDA 2003).

Since 1955, LDD moth has become established in southern Ontario, Quebec, Prince Edward Island, New Brunswick, and Nova Scotia (Natural Resources Canada 2003). In Canada, the Canadian Food Inspection Agency (CFIA) is responsible for preventing the introduction and spread of invasive pest species, including LDD moth. Figure 1 (below) shows the areas of Canada that CFIA regulates for LDD moth. This map was updated, and the regulated area was significantly expanded on January 11, 2021.

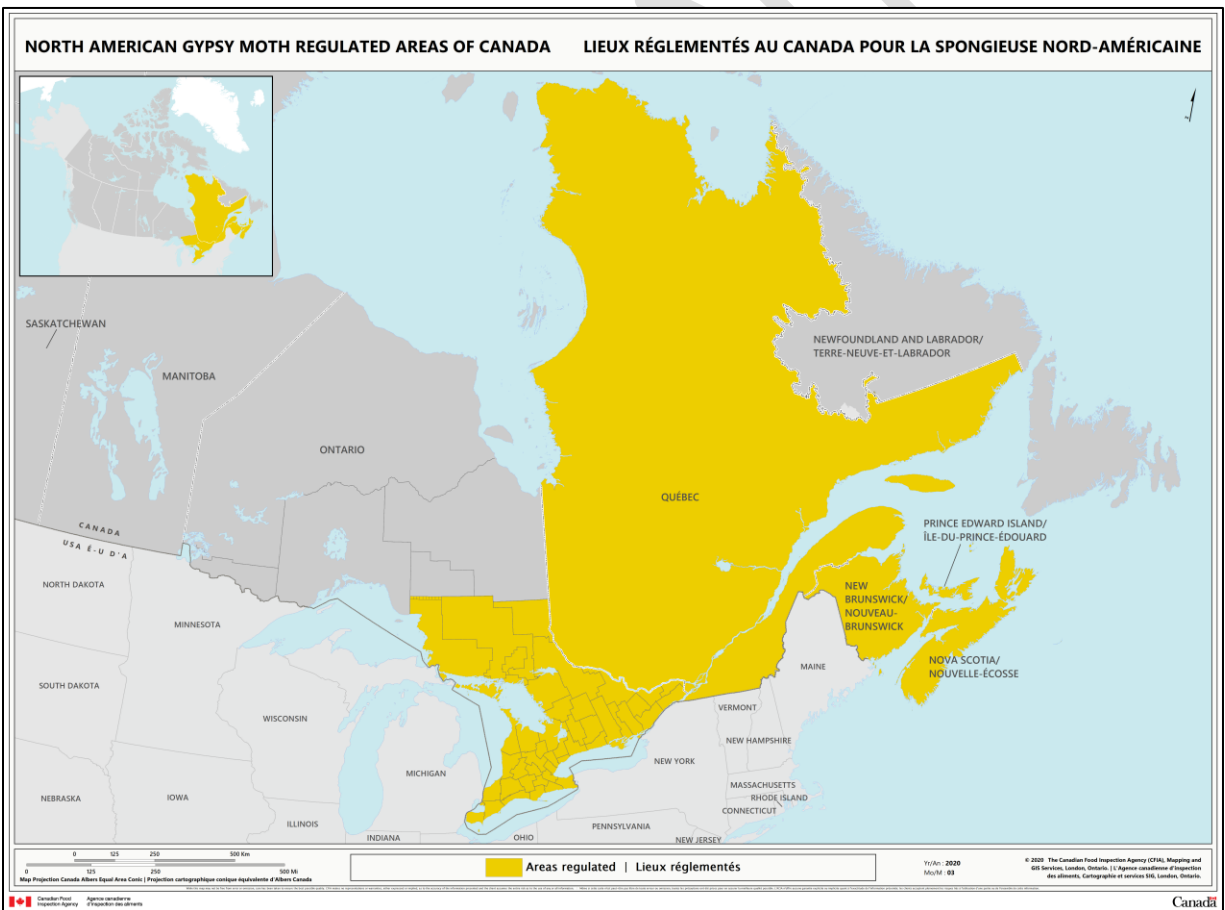


Figure 1. Areas in Canada currently regulated for LDD moth by the Canadian Food Inspection Agency (Source: CFIA 2021).

## LDD Moth in Ontario

Results from provincial forest health surveys conducted by the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry (OMNDMNRF) showed mostly light defoliation in 2017, with the largest populations concentrated in the Hamilton area and eastwards along the Niagara Peninsula (Rowlinson 2017). Provincial forest health survey data from 2018 showed an increase in the LDD moth population, with most activity concentrated in the Golden Horseshoe area of southern Ontario (Francis 2018). In 2019, approximately 41,000 hectares experienced moderate to severe defoliation, mostly in areas southwest of Oakville (Rowlinson 2019). In 2020, moderate to severe LDD moth defoliation was observed across approximately 570,000 hectares in Ontario. Provincial monitoring crews also observed high levels of egg mass parasitism and a high level of viral infection with nucleopolyhedrosis virus (NPV) among larvae in 2020 (Rowlinson 2020). In 2021, moderate to severe LDD moth defoliation was observed to have tripled to approximately 1.8 million hectares in Ontario (Figure 2). The largest increase in moderate to severe defoliation is observed in the Peterborough district, increasing from 160,000 to roughly 374,000 hectares. In southwestern Ontario, areas of moderate to severe defoliation are more fragmented and seem to be pushing north to the Parry Sound District. (Rowlinson 2021).

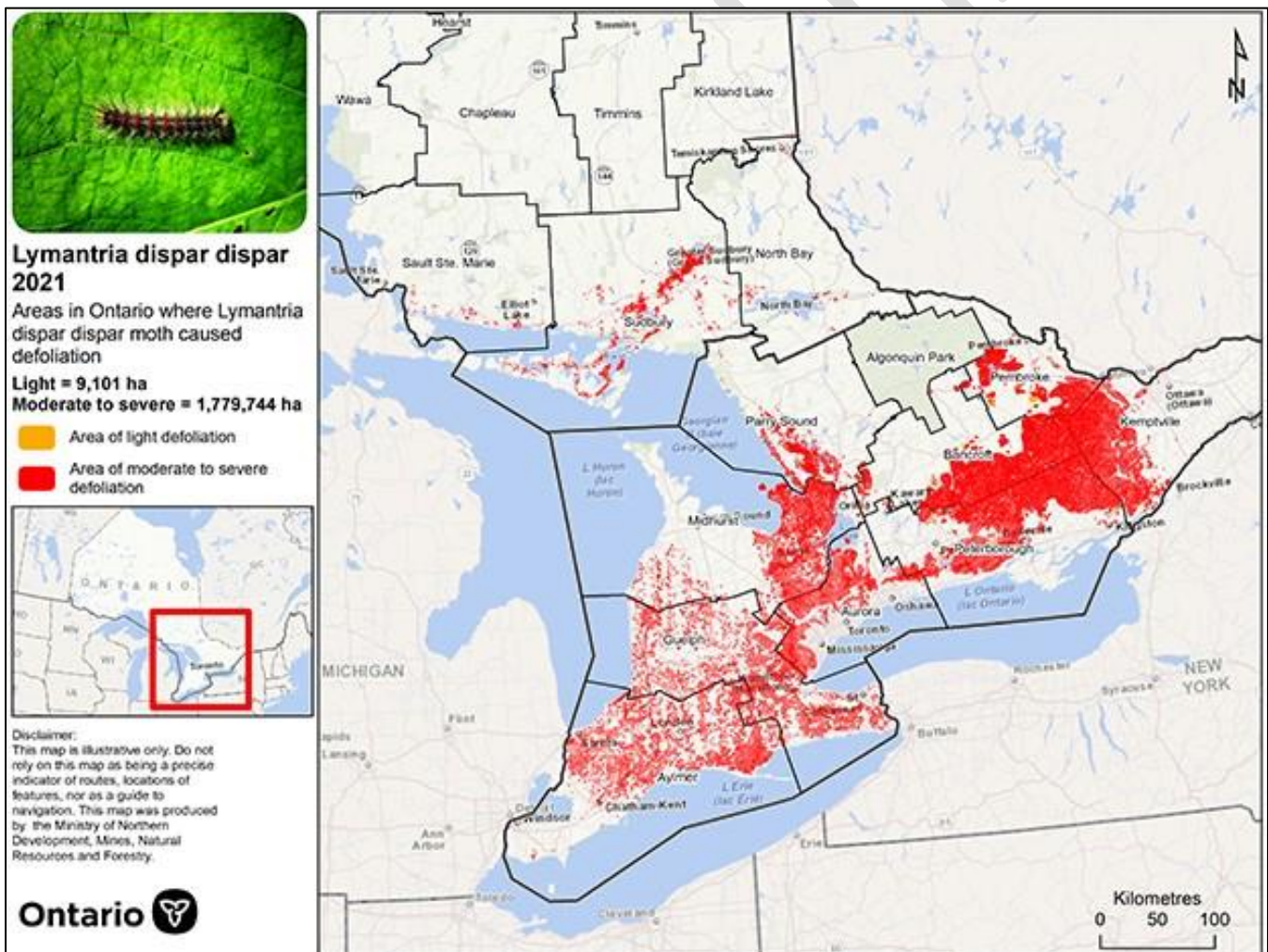


Figure 2. Map of areas defoliated by LDD moth in 2021 across Ontario (Source: Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry).

## Biology and Life Cycle

LDD moth is in the order Lepidoptera, which consists of moths and butterflies, and has one generation per year with four life stages: egg, larva, pupa, adult (Figure 3). LDD moth eggs are laid in late July or early August. Weather, food sources, and factors such as diseases all affect the exact time that eggs are laid. Eggs are usually laid in dark, sheltered areas such as in bark crevices, on the underside of branches, or in leaf litter, although they can also be found on a wide variety of surfaces such as rocks, buildings, lawn furniture, and automobiles. The eggs are covered with fine brown hairs from the female’s abdomen, giving the egg mass the appearance of a small piece of chamois (OMNR, undated). Egg masses can vary in size from being about the size of a dime to being larger than a one-dollar coin and may contain from 100 to 1,000 eggs. Smaller egg masses tend to indicate that a LDD moth population is in decline, while larger egg masses indicate a stable or growing population.

Fully formed, dormant larvae, or caterpillars, spend the winter inside the eggs. Generally, egg masses are resistant to drying and cold temperatures. However, if temperatures drop below  $-25^{\circ}\text{C}$  for an extended period, egg masses above the snow line may be susceptible to winter kill (Benoit and Lachance 1990). Eggs below the snow line are likely able to avoid winter mortality (Leonard 1974). When temperatures are warm enough in late April or early May, buff-coloured larvae chew through the egg mass coverings and emerge. Shortly after emerging, the larvae turn black. If conditions are favourable, larvae, attracted by light, begin moving upward towards foliage. If conditions are not favourable, the larvae will remain clustered on the egg mass until conditions improve.





		Month												
Stage		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Egg		█								█				
Larva						█								
Pupa							█							
Adult								█						

Figure 3. LDD moth life cycle in Ontario.

Of the four life stages of the LDD moth, the larval stage is the only one that feeds. As a larva develops, it passes through stages called instars, separated by molts during which the larva’s skin is shed and replaced with a new one. The male LDD moth has five larval instars, while the female has six. Depending on weather, the first larval instar lasts five to 10 days, the next three (male) or four (female) instars last about a week, and the fifth (male) and sixth (female) instars last about 10 to 15 days (OMNR, undated). First instar larvae are approximately 4 mm long. Full-grown larvae are hairy and range in length from 35 to 90mm and have pairs of five blue and six red dots along their backs.

First instar larvae are very lightweight and covered with an abundance of fine hairs. While feeding throughout the crown of a tree, the larvae spin silken threads that can be caught by the wind, dispersing the larvae to new host trees. This form of dispersal is known as “ballooning.” Some larvae balloon several times before they start feeding (Liebhold et al. 1992). Ballooning generally transports larvae short distances, moving LDD moth larvae up to 1km. LDD moth are generally dispersed greater distances by people moving objects such as firewood, recreational vehicles, Christmas trees, and boats that have larvae, pupae, or egg masses on them. Although people can inadvertently disperse all LDD moth life stages, they most commonly transport egg masses.



Figure 4. LDD moth defoliation (Source: Ontario Ministry of Natural Resources and Forestry).

First instar larvae begin feeding by cutting small holes in the surface of leaves. As the larvae develop, they feed on the edge of leaves (Figure 4). The first three larval instars remain on the foliage and feed day and night. When populations are very low (i.e., fewer than 250 egg masses/ha), larvae in instars four through six feed at night and at dawn look for shelter where they spend the day protected from the sun and predators. At higher populations (i.e., more than 1,250 egg masses/ha), shelter becomes less important and all larvae feed in the day and night (Brooks and Hall 2005). When the host plant is depleted, larvae crawl to find another suitable host (USDA 1995a).

LDD moth larvae are active from approximately mid-May to mid-July. During that time, one larva is able to consume an average of 1m<sup>2</sup> of foliage, which is roughly the equivalent of 10 to 15 entire red oak leaves (Nealis and Erb 1993). Males generally eat slightly less than 1m<sup>2</sup> and females eat slightly more. Larvae in the last instar cause the most defoliation, consuming three quarters of the total amount of foliage that they eat (OMNR, undated). Sixth instar female larvae are the most ravenous feeders and are often twice the size of full-grown male larvae. After feeding is complete around mid-July, pupation occurs in a cocoon that can be found in many places including trees, rocks, houses, boats, trailers, fences, picnic tables, and firewood. In 13 to 17 days, the moths emerge. Male moths usually emerge one to two days before females (USDA 1995a). Both sexes have wings, but only the male can fly. The female is too heavy bodied to fly, so LDD moth relies on the larval stage for dispersal. The male moth is dark brown to beige, is medium-sized, flies during the day, and is a very erratic flyer. Dark wavy lines cross the male moth’s forewings and its wingspan ranges from 35 to 40mm. The female is mostly white and has a wingspan between 60 to 70mm. Dark wavy lines also cross the female moth’s forewings but, because the female is lighter in colour, these lines are more prominent.



Figure 5. Female LDD moth laying eggs.

To attract males, female moths emit a powerful pheromone, or sex attractant. Males have large feathery antennae for detecting the pheromone and can do so from about 1.5km away. Within about 24 hours of mating, the female lays eggs in a mass of 100 to 1,000 on tree trunks, branches, houses, and fences and under rocks and forest floor debris (Figure 5). Since the female cannot fly, eggs are laid close to where pupation occurred. The female dies about one day after egg laying and the male survives about one week, after mating with several different females (Nealis and Erb 1993).

Although in Europe there is evidence of cyclical outbreaks of LDD moth, a clear pattern of outbreaks in North America has not yet been established (Liebhold et al 1994). However, LDD moth populations do appear to exist in one of four phases: innocuous, release, outbreak, decline (Elkinton and Liebhold 1990). The innocuous phase is characterized by very low population levels. The release phase usually takes place over the course of one or two years and can result in population density increases of several orders of magnitude. During the outbreak phase, populations are high enough to cause noticeable defoliation and damage to host trees. After this point, high levels of LDD moth mortality are observed usually due to starvation or disease and the population crashes. This is considered the decline phase.

Area-wide outbreaks can last up to ten years, but generally population densities in localized areas remain high for two to three years (Cloyd and Nixon 2001).

## Assessment of LDD Moth Populations in Pelham

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### History of LDD Moth Monitoring and Management in Pelham

#### 2009 – 2020

In 2009, the Town of Pelham partnered with Trees Unlimited and Zimmer Air to implement control measures when LDD moth populations reached outbreak levels. Those measures were successful in reducing the population to acceptable levels.

In 2017, the Town began receiving reports from citizens regarding the re-emergence of LDD moths and in the spring of 2018 the Town conducted an aerial spray in Hillcrest Park (6.47 hectares) using Btk, an insecticide product containing the naturally occurring bacterium *Bacillus thuringiensis* var. *kurstaki*. Throughout the summer of 2018, staff continued to receive reports and hear of concerns regarding LDD moth activity throughout the urban boundary. Trees Unlimited was again contracted to conduct egg mass surveys in early 2019, and 17 residential, park and cemetery properties were surveyed. Six of the properties surveyed had severe defoliation forecasts (Canboro Road at Concord Street, Hillcrest Park, Pancake Lane south to Beechnut Court, Oak Lane, Kunda Park, and Fonthill Cemetery). In response, the Town sprayed 161.2 hectares of public and private property within the urban boundary. Post spray surveys conducted in all treated areas indicated a significant reduction in larvae and tree defoliation (with some exceptions). In 2019, BioForest was contracted by the Town and established a grid-based surveying approach, with the objective of obtaining good coverage and fair representation through the areas of concern for the Town of Pelham. In the spring of 2020, the Town sprayed approximately 120 hectares of public and private property within the urban boundaries of Fenwick and Fonthill, including a corridor along Canboro Road between both urban areas. Post spray defoliation surveys indicated there was a significant reduction in tree defoliation compared to the previous year.

#### 2021

In the spring of 2021, the Town sprayed approximately 113 hectares of public and private property within the urban boundaries of Fenwick and Fonthill, including a corridor along Balfour Street and Foss Road, just south of Fenwick. The first application of Btk took place on May 20<sup>th</sup>, followed by the second on May 31<sup>st</sup>. Host defoliation rates were assessed upon completion of LDD moth larval feeding on Jun 30<sup>th</sup>. Based on these surveys, the 2021 Town of Pelham aerial spray program was effective at significantly reducing forecasted defoliation and maintaining a healthy tree canopy. 2021 LDD Moth Egg Mass Surveys

The 2021 LDD moth egg mass surveys were conducted from November 26<sup>th</sup> – December 15<sup>th</sup>, 2021. All but one of the plots established in 2019 were resurveyed. The remaining plot was located on private property and was excluded at the request of the landowner (plot 86.2). One new plot was added on the corner of Stella and John Streets. For a detailed description of plot establishment and distribution, see the 2019 LDD Moth Monitoring Program report



(BioForest 2020). Plot trees were surveyed by examining the trunk and scanning the entire tree, from base to crown, using binoculars. All egg masses observed on the tree, both old and new, were recorded.

The total number of egg masses on each tree were summed. In a separate count, egg masses that were easily distinguishable as old or new were tallied. As many intact new egg masses within reach were measured and recorded, in order to obtain 2021 egg mass size data.

All LDD moth egg mass survey data was entered and managed in a Microsoft Excel database. In addition, a point shapefile of all plots was created in ArcMap. All plot centers were drawn in ArcMap and categorized based on the adjusted number of egg masses present within that plot and the defoliation forecast for 2022.

LDD moth egg mass age (new vs. old ratio): The proportion of new and old egg masses is an indicator of population vigor. A low proportion of old egg masses (i.e. less than 25% old) indicates a healthy, building population while a high proportion of old egg masses (i.e. more than 50% old) suggests a population in decline (Liebhold et al. 1994). Crews distinguished the age of all egg masses on each tree trunk and summed both old and new egg masses observed for each grid cell.

In 2021, approximately **50%** of egg masses surveyed by BioForest crews were new. This is a decrease of nearly 20 percentage points from 2020 (67%). The percentage of new egg masses observed in 2021 is well below the level for what is considered to be a healthy population, and has decreased fairly significantly from 2020, indicating that this population may have passed its peak and is now on the decline.

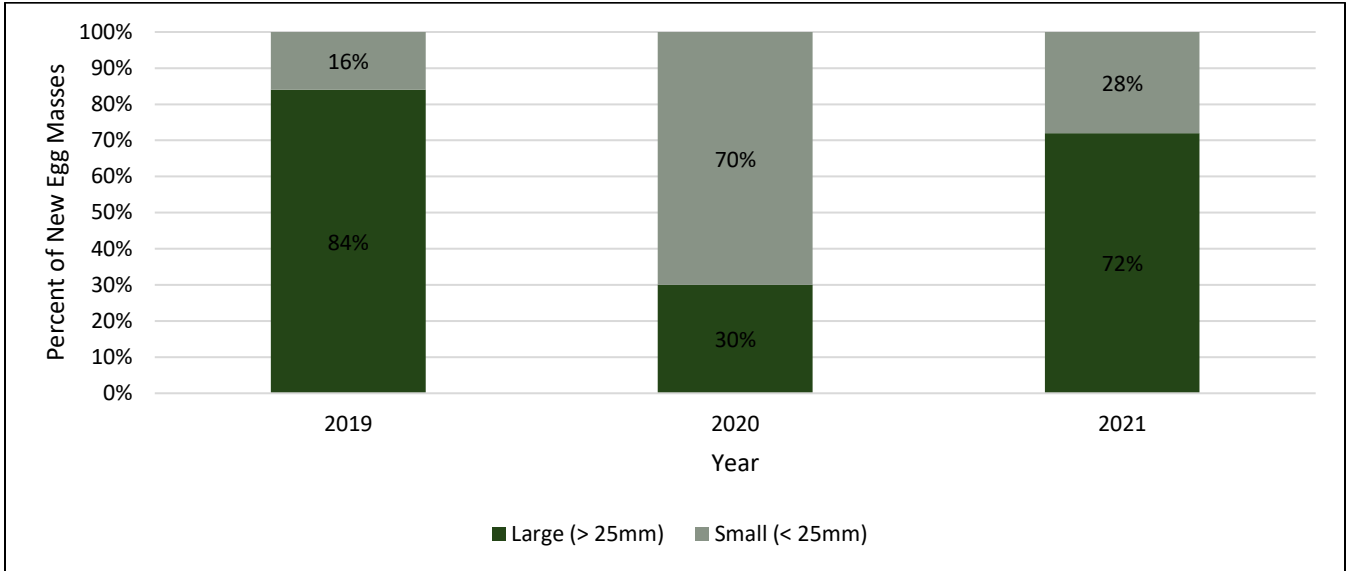
LDD moth egg mass size: The actual size of the egg mass is a vital statistic for assessing LDD moth populations. Larger egg masses (more than 500 eggs per mass, greater than 30mm) indicate a healthy, increasing population whereas smaller egg masses are characteristic of a decreasing population (less than 20mm in size) (Nealis and Erb 1993). 25mm, or the size of a quarter, is a commonly used threshold to categorize egg mass sizes as large (>25mm) or small (<25mm), therefore 25mm has been used as the cut-off for the purposes of this report.

Within each property surveyed, BioForest crews measured as many egg masses as possible to provide more information on the infestation status.

In 2021, **72%** of all new egg masses measured were considered to be “large” (25mm or greater) (Figure 7). Comparing relative size distribution of new egg masses in Pelham from 2019 to 2021. Compared to 2020 (30%), there is a significant increase in large egg masses. That being said, the average size of new egg masses in 2021 was 28.8mm (n=381), larger than in 2020 (24.9mm), but still remains below 30mm; this also potentially indicates that this population is past its peak and is in decline (Figure 8).

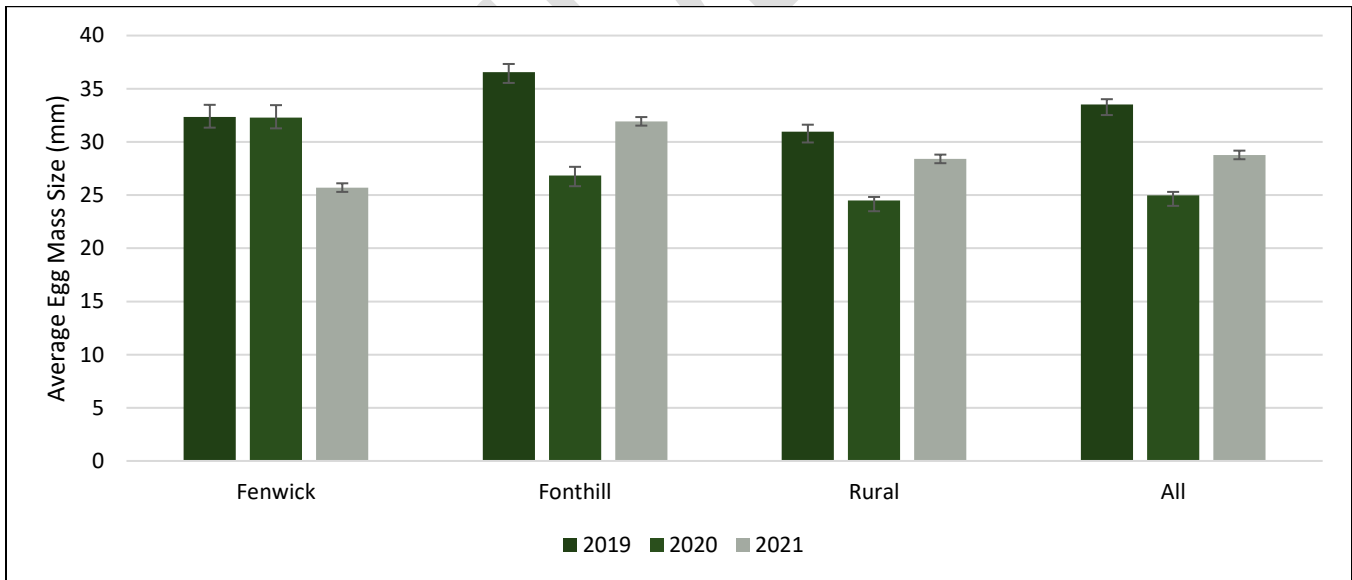


Figure 6. Large new egg mass measured by BioForest staff in plot 97.1 from 2021 surveys.



**Figure 7. Comparing relative size distribution of new egg masses in Pelham from 2019 to 2021.**

Fenwick saw the most significant decline in average egg mass size in 2021, whereas Fonthill and the rural areas experienced some increases in average egg mass size. However, across all plots the average new egg mass size remains below what is considered to be a healthy population. The slight increase in new egg mass size between 2020 and 2021 may be due to the possible decline in Pelham’s population and/or the 2021 aerial spray program, causing less competition among caterpillars for food sources, resulting in healthier adults who are able to lay larger egg masses. Continued annual monitoring will help to confirm this potential population decline.



**Figure 8. The average new egg mass size comparison 2019 to 2021.**

Natural controls: Egg mass predation (attacks) by birds and small mammals was evident at many locations throughout the survey, as well as evidence of parasitism. For example, small pinholes in egg masses indicated the presence of the tiny parasitic wasp, *Ooencyrtus kuvanae*. These predators and parasites will help to slightly reduce LDD moth populations, though not to an extent that would prevent severe defoliation.

## 2022 LDD Moth Defoliation Forecasts

It is difficult to use LDD moth forecast surveys that rely on egg mass density data to predict defoliation in the urban environment. Most of the methodologies developed to date are suitable for continuous natural forested environments and are not easily adapted to urban areas where tree species and tree densities can vary considerably and where access is often limited. In November and December 2021, BioForest crews conducted surveys in residential neighbourhoods on public trees, in a selection of parks and along rural roads to assess egg mass densities and egg mass size. A 2022 forecast map was developed based on a calculation of the density of LDD moth egg masses per hectare and egg masses per tree.

LDD moth defoliation is difficult to predict with a high degree of probability. As noted earlier, populations are subject to a wide variety of biotic and abiotic factors that complicate the forecasting process. Some degree of defoliation is likely to occur in all areas where egg masses have been observed. However, the data collected in the 2021 surveys does indicate clear areas that are likely to be affected in 2022. It should be noted that the forecasts presented in this report are based **only** on observed egg masses occurring on public trees in residential neighbourhoods, within those parks and along those rural roads that were surveyed. Private property was not surveyed, except for a few front yard or private woodlot trees where necessary.

The 2021 survey focused on assessing all plots surveyed previously. It is likely that other areas of the Town, including parks, natural areas and large private properties that were not included in this survey are also harbouring LDD moth populations that have not yet been reported. Depending on the composition and geographic characteristics of these areas (i.e., species, age class, slopes, etc.), they could potentially be a breeding ground for LDD moth populations next year and into the future.

BioForest used two methods for determining defoliation forecasts in 2022, depending on plot settings. The first, in Table 1, which illustrates the egg mass density in egg masses per hectare, was used to calculate defoliation forecasts for woodlots. This is suited for forested environments where the canopy is continuous, and species composition is more uniform. The second, in Table 2, illustrates the egg mass density in egg masses per tree. This method is used to calculate defoliation forecasts for street trees and is suited for areas where canopies are not continuous, and the species composition and age class distribution are more diverse. It is important to remember, however, that both are just estimations and that the actual level of defoliation and damage is dependent on a variety of other factors such as tree condition, previous years' defoliation, presence of other pests, etc.

**Table 1. LDD moth defoliation predictions based on egg mass densities per hectare and associated management impacts. Thresholds derived from USDA defoliation prediction model developed by Gansner et al. 1985.**

Egg Mass Density (Em/Ha)	Defoliation Forecast	Defoliation Forecast Range (%)	Management Impacts
0	Nil	0 to 5	None
1 to 1,250	Light	6 to 25	Up to 20% Defoliation
1,251 to 3,750	Moderate	26 to 65	Nuisance and Aesthetics; Noticeable Defoliation
3,751 to 5,000	Heavy	66 to 90	Wildlife and Recreation; Growth Loss
> 5,001	Severe	91 to 100	Tree Mortality

**Table 2. LDD moth defoliation predictions based on egg mass densities per tree.**

<b>Egg Mass Density (Em/Tree)</b>	<b>Defoliation Forecast*</b>	<b>Defoliation Forecast Range (%)</b>
0	Nil	0 to 5
1 to 10	Light	6 to 25
11 to 40	Moderate	26 to 65
41 to 100	Heavy	66 to 90
> 100	Severe	91 to 100

\*Defoliation forecasts and associated management impacts in a street tree environment may vary significantly based on species composition, age-class diversity, differences in tree health, continuity of tree canopy, etc. In areas with greater host density, defoliation will likely be on the higher end of the range, as opposed to areas with low host density where defoliation may be patchier and/or concentrated on host trees.

### Results

Figure 9 and Figure 10 provide an overview of the location of all plots surveyed in 2021 and the 2022 defoliation forecasts for each plot surveyed. Figure 11 and Figure 12 show closeup maps of Fonthill and Fenwick, the urban areas within Pelham.

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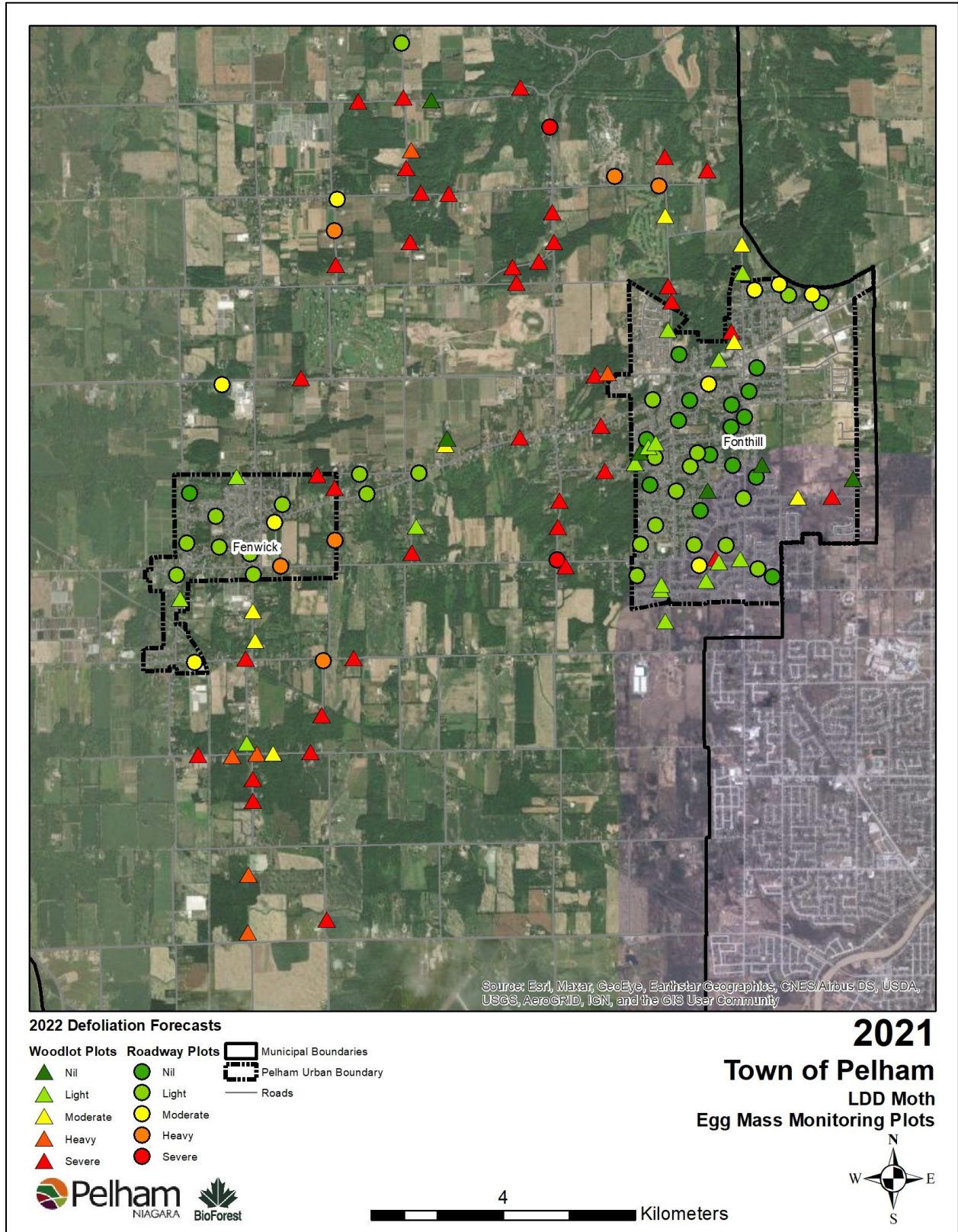


Figure 9. All LDD moth egg mass monitoring plots surveyed in November and December 2021, Town of Pelham.

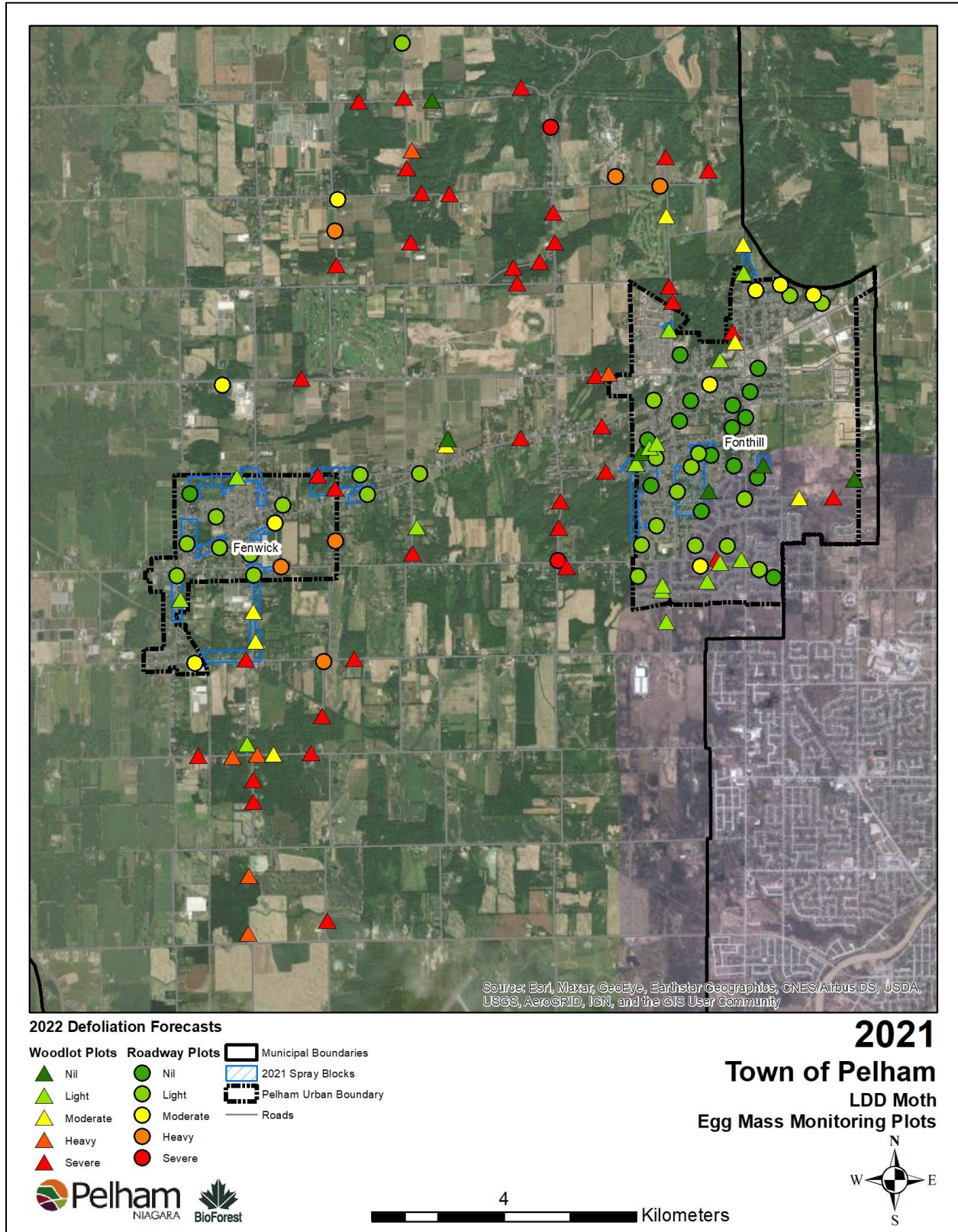


Figure 10. All LDD moth egg mass monitoring plots surveyed in November and December 2021 and all blocks sprayed in May-June 2021 (outlined in blue), Town of Pelham.

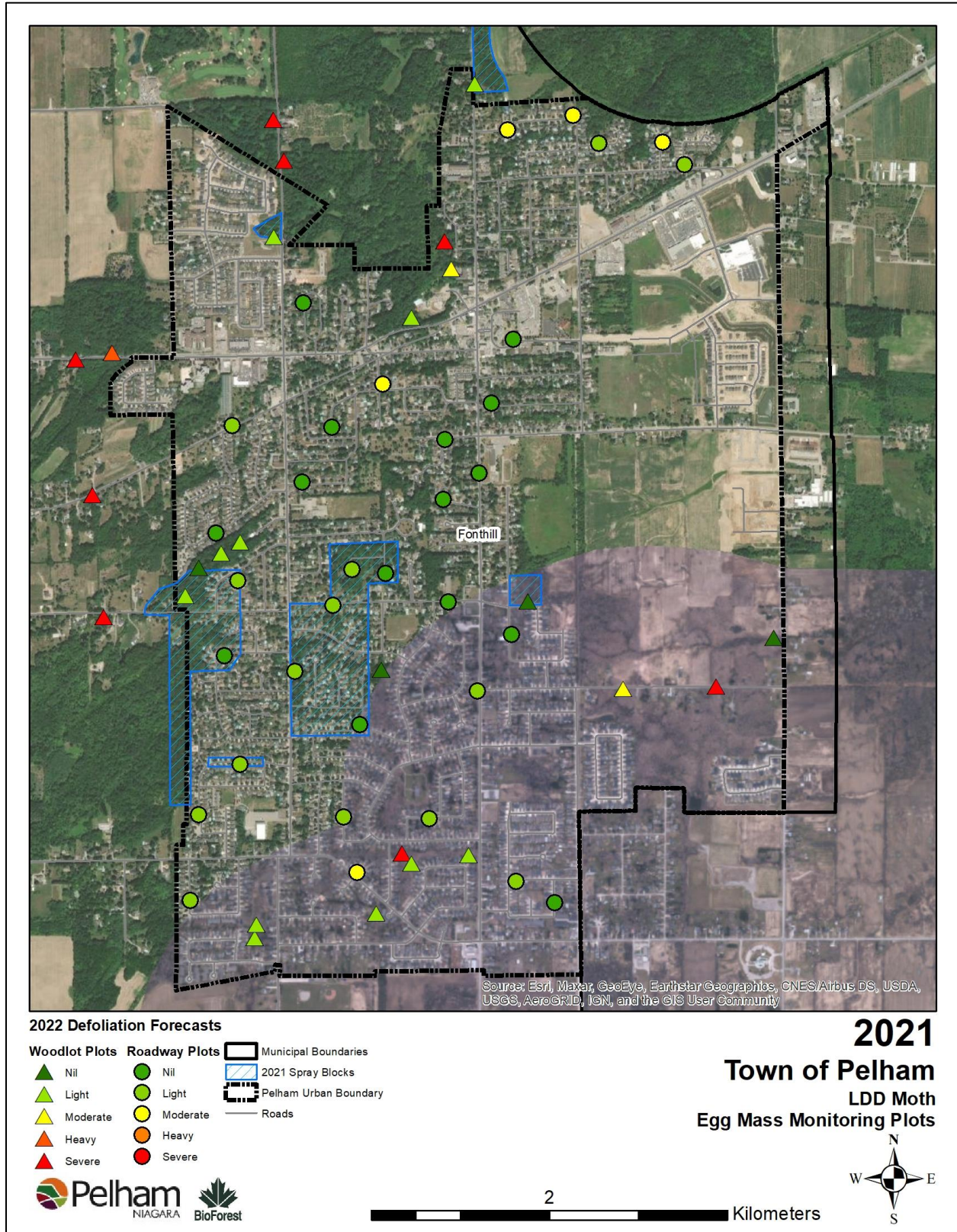


Figure 11. All LDD moth egg mass monitoring plots surveyed in November and December 2021 and all blocks sprayed in May-June 2021 (outlined in blue), Fonthill, Town of Pelham.

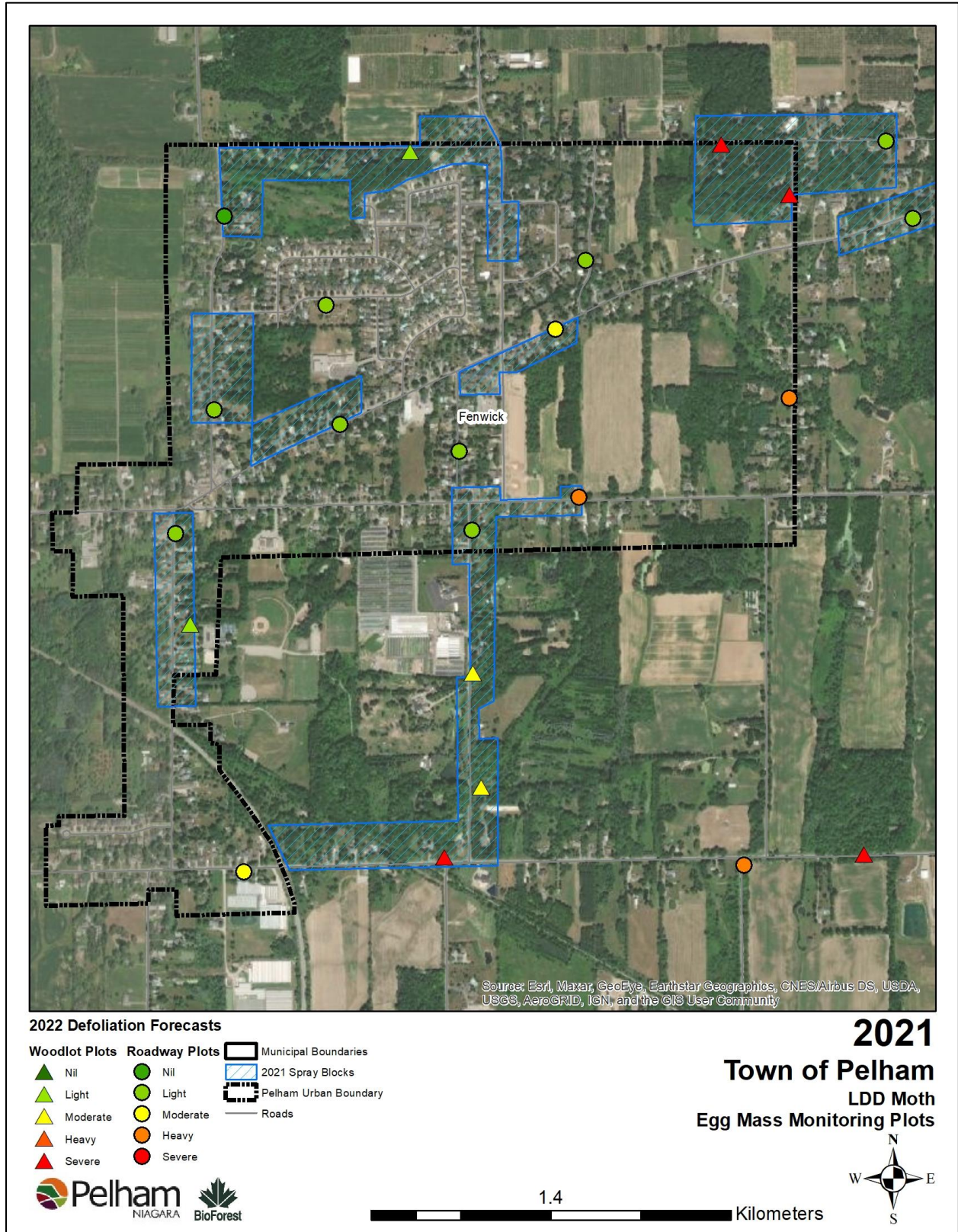


Figure 12. All LDD moth egg mass monitoring plots surveyed in November and December 2021 and all blocks sprayed in May-June 2021 (outlined in blue), Fenwick, Town of Pelham.



The 2022 defoliation forecast results for the entire area surveyed (Figure 10) show high LDD moth egg mass densities, or moderate to severe defoliation forecasts (represented by yellow, orange, and red dots or triangles on the map), occur in 71 plots out of 133, or 53% of plots, with the majority of those being severe (41 plots), and primarily located in the rural area. Light defoliation (represented by the light green dots on the map) is forecasted in 52 out of 133 plots, or 39%, and nil defoliation (represented by the dark green dots on the map) is forecasted in 10 plots, or 8%.

The most severe defoliation is anticipated to occur north of Fonthill (Effingham Street, Tice Road, and Metler Road area), in the area between Fenwick and Fonthill just outside the Fonthill urban boundary (along Effingham Street, Welland Road, Canboro Road and Pancake Lane), and south of Fenwick (Balfour Street south of Sumbler Road and along Cream Street south of Foss Road). Defoliation within the urban boundaries of Fenwick and Fonthill is expected to be predominantly light to moderate, with the exception of a few areas located near the urban/rural border.

**Table 3. Summary of woodlot plots surveyed in 2021. Egg mass counts are presented in average egg masses per hectare.**

Location	Grid	Plot	Plot Centre Address	Total Egg Masses	Adjusted Total Egg Masses	2020 New Egg Masses/Hectare (Em/Ha)	2021 New Egg Masses/Hectare (Em/Ha)	2022 Defoliation Forecast
Fenwick	74	74.1	612 Memorial Drive	185	72	14,360	7,237	Severe
	74	74.2	1284 Cream Street	136	53	15,120	5,320	Severe
	63	63.4	999 Church Street	166	11	21,656	1,145	Light
	73	73.4	726 Memorial Drive	76	5	6,611	456	Light
Fonthill	80	80.2	220 Merritt Road	1,250	1,246	4,300	124,600	Severe
	99	99.4	Trail behind 10 Elm Avenue	167	139	890	13,923	Severe
	68	68.5	88 Woodside Square	115	93	3,961	9,279	Severe
	99	99.5	Trail behind 1532 Pelham Avenue	44	37	274	3,668	Moderate
	79	79.6	90 Merritt Road	52	36	210	3,594	Moderate
	69	69.1	88 Woodside Square	21	11	477	1,145	Light
	99	99.7	33 Park Lane	13	11	411	1,084	Light
	98	98.4	16 Marlene Steward Drive	122	6	5,600	610	Light
	109	109.2	Across 1708 Pelham Street	49	6	5,657	592	Light
	68	68.1	1077 Edward Avenue	6	5	137	484	Light
	68	68.6	Along trail behind Maureen Court	5	4	478	403	Light
	88	88.2	Hillcrest Park	69	3	15,993	256	Light
	68	68.2	1077 Edward Avenue	3	2	683	242	Light
	69	69.4	Behind 52 Woodside Square	1	1	409	55	Light
	88	88.5	Hillcrest Park	12	0	256	44	Light
	88	88.4	Hillcrest Park	8	0	302	30	Light
	78	78.7	Behind 19 Parkhill Road	0	0	0	0	Nil
	79	79.1	43 Stella Street	0	0	7,428	0	Nil
80	80.1	1304 Rice Road	0	0	0	0	Nil	
88	88.3	Hillcrest Park	0	0	628	0	Nil	
Rural	118	118.2	1936 Haist Street	1,059	812	55,818	81,182	Severe
	77	77.1	1139 Effingham Street	961	669	70,438	66,859	Severe
	107	107.2	Across 307 Moore Drive	981	582	78,686	58,155	Severe
	106	106.2	345 Tice Road	520	495	12,750	49,545	Severe

Location	Grid	Plot	Plot Centre Address	Total Egg Masses	Adjusted Total Egg Masses	2020 New Egg Masses/Hectare (Em/Ha)	2021 New Egg Masses/Hectare (Em/Ha)	2022 Defoliation Forecast
Rural	87	87.1	250 Canboro Road	923	488	57,550	48,801	Severe
	77	77.3	230 Pancake Lane	643	447	37,353	44,735	Severe
	87	87.2	250 Hwy 20 West	783	414	17,640	41,399	Severe
	115	115.3	1951 Centre Street	900	364	57,360	36,442	Severe
	54	54.2	770 Groen Road	414	322	31,900	32,241	Severe
	54	54.3	586 Foss Road	372	290	16,225	28,971	Severe
	43	43.4	595 Balfour Street	505	282	45,900	28,188	Severe
	125	125.3	591 Kilman Road	464	281	27,061	28,110	Severe
	67	67.1	1005 Effingham Street	386	245	24,730	24,496	Severe
	77	77.2	1160 Effingham Street	345	240	43,191	24,002	Severe
	43	43.5	625 Balfour Street	367	205	24,500	20,485	Severe
	107	107.3	315 Moore Drive	338	200	21,686	20,037	Severe
	118	118.3	1925 Hansler Street	233	179	15,263	17,861	Severe
	44	44.1	617 Sumbler Road	410	163	116,800	16,291	Severe
	104	104.3	1732 Cream Street	190	151	17,308	15,072	Severe
	125	125.4	485 Kilman Road	248	150	5,826	15,024	Severe
	94	94.1	653 Hwy 20 W	159	149	720	14,900	Severe
	106	106.1	345 Tice Road	152	145	15,840	14,483	Severe
	54	54.1	Across 586 Foss Road	183	143	42,533	14,252	Severe
	116	116.1	1951 Centre Street	341	134	32,320	13,442	Severe
	98	98.3	1615 Haist Street	217	120	43,867	11,972	Severe
	115	115.2	1934 Centre Street	295	119	36,320	11,945	Severe
	34	34.1	Across 310 Cream Street	223	102	29,300	10,200	Severe
	107	107.1	1770 Effingham Street	157	93	50,914	9,307	Severe
	126	126.1	350 Kilman Road	355	90	44,320	8,999	Severe
	105	105.1	1797 Centre Street	89	78	4,500	7,788	Severe
	53	53.3	910 Foss Road	196	66	28,100	6,557	Severe
	98	98.2	1636 Haist Street	113	62	66,067	6,234	Severe
	75	75.5	Across 1116 Centre Road	312	61	37,890	6,058	Severe
	43	43.1	775 Sumbler Road	91	51	12,900	5,080	Severe
	33	33.2	Behind 701 Webber Road	76	47	3,600	4,669	Heavy
	43	43.3	725 Balfour Street	83	46	9,200	4,633	Heavy
	97	97.1	245 Hwy 20 West	108	42	26,560	4,200	Heavy
	33	33.1	Behind 700 Chantler Road	66	41	2,100	4,054	Heavy
	115	115.1	1951 Centre Street	235	40	26,640	3,994	Heavy
	43	43.2	716 Sumbler Road	68	38	14,600	3,796	Heavy
	108	108.1	Across 1861 Haist Street	122	28	18,050	2,800	Moderate
	63	63.3	925 Balfour Street	347	24	36,938	2,393	Moderate
	109	109.1	1747 Pelham Street	189	23	17,650	2,284	Moderate
	86	86.1	451 Canboro Road	23	16	3,245	1,609	Moderate
	44	44.2	631 Sumbler Road	37	15	29,400	1,470	Moderate

Location	Grid	Plot	Plot Centre Address	Total Egg Masses	Adjusted Total Egg Masses	2020 New Egg Masses/Hectare (Em/Ha)	2021 New Egg Masses/Hectare (Em/Ha)	2022 Defoliation Forecast
Rural	63	63.1	961 Balfour Street	186	13	5,906	1,283	Moderate
	53	53.2	725 Balfour Street	37	12	4,400	1,238	Light
	75	75.4	1165 Centre Street	24	5	1,350	466	Light
	68	68.7	940 Haist Street	5	4	0	403	Light
	125	125.2	461 Kilman Road	381	0	90,764	0	Nil

Table 4. Summary of roadway plots surveyed in 2021. Egg mass counts are presented in average egg masses per tree.

Location	Grid	Plot	Plot Centre Address	Total Egg Masses	Adjusted Total Egg Masses	2020 New Egg Masses/Tree (Em/Tree)	2021 New Egg Masses/Tree (Em/Tree)	2022 Defoliation Forecast
Fenwick	74	74.3	1144 Cream Street	362	328	2.8	65.7	Heavy
	64	64.1	663 Welland Road	336	302	59.7	60.5	Heavy
	74	74.4	688 Canboro Road	173	68	17.0	13.5	Moderate
	73	73.3	1159 Maple Street	629	38	86.6	7.6	Light
	63	63.5	1050 Church Street	178	12	62.8	2.5	Light
	73	73.2	746 Canboro Road	178	11	27.8	2.1	Light
	74	74.5	1160 Sunset Drive	13	5	1.4	1.0	Light
	63	63.2	1090 Balfour Street	62	4	44.1	0.9	Light
	73	73.1	90 Sandra Drive	63	4	4.6	0.8	Light
	73	73.5	1115 Garner Ave	53	3	10.1	0.6	Light
	73	73.6	1229 Maple Street	20	1	10.2	0.2	Light
	Fonthill	99	99.3	6 Shorthill Place	155	129	30.3	25.8
88		88.12	7 Highland Avenue	249	123	8.4	24.7	Moderate
79		79.7	43 Stella Street	150	104	N/A	20.7	Moderate
68		68.4	1 Arbor Circle	127	102	6.0	20.5	Moderate
100		100.2	11 Scottdale Court	71	64	5.0	12.7	Moderate
99		99.2	23 Shorthill Place	74	62	21.1	12.3	Moderate
78		78.5	38 Pancake Lane	198	44	47.0	8.9	Light
99		99.1	5 Leslie Place	47	39	9.3	7.8	Light
68		68.3	1081 Deborah Street	47	38	8.6	7.6	Light
79		79.4	11 Fallingbrook Drive	39	27	3.9	5.4	Light
78		78.4	1183 Haist Street	93	21	24.9	4.2	Light
100		100.1	1 Stonegate Place	17	15	0.6	3.1	Light
78		78.8	13 Deer Park Crescent	58	13	5.2	2.6	Light
78		78.1	55 Rolling Meadows Boulevard	49	11	5.5	2.2	Light
88		88.1	15 Blackwood Crescent	263	10	20.4	1.9	Light
88		88.11	173 Canboro Road	229	8	25.3	1.7	Light
79		79.3	Across 1253 Pelham Street	12	8	0.2	1.7	Light
69	69.3	27 Tanner Drive	11	6	4.5	1.2	Light	

Location	Grid	Plot	Plot Centre Address	Total Egg Masses	Adjusted Total Egg Masses	2020 New Egg Masses/Tree (Em/Tree)	2021 New Egg Masses/Tree (Em/Tree)	2022 Defoliation Forecast
Fonthill	78	78.2	18 Rolling Meadows Boulevard	26	6	9.4	1.2	Light
	88	88.7	10 Oak Lane	81	3	9.3	0.6	Light
	79	79.2	57 Stella Street	3	2	0.9	0.4	Light
	79	79.5	2 Pancake Lane	3	2	1.4	0.4	Light
	78	78.6	72 Millbridge Crescent	7	2	10.1	0.3	Light
	78	78.3	22 Berkwood Place	6	1	26.1	0.3	Light
	99	99.6	20 Pelham Town Square	1	1	0.3	0.2	Light
	98	98.1	18 Peachtree Park	1	1	6.5	0.1	Light
	88	88.13	127 Daleview Crescent	7	0	2.0	0.1	Light
	88	88.6	8 Brucewood Street	5	0	3.5	0.0	Light
	88	88.9	28 Concord Street	5	0	0.9	0.0	Light
	88	88.8	42 Strathcona Drive	4	0	0.9	0.0	Light
	69	69.2	15 Manson Drive	0	0	0.0	0.0	Nil
	89	89.1	1 Petronella Parkway	2	0	1.7	0.0	Nil
	89	89.2	14 Donahugh Drive	6	0	0.7	0.0	Nil
	89	89.3	1353 Pelham Street	0	0	0.1	0.0	Nil
	89	89.4	1 Emmett Street	0	0	0.4	0.0	Nil
Rural	67	67.2	273 Welland Road	1,952	1,239	226.4	247.7	Severe
	117	117.1	1974 Effingham Street	1,057	632	205.2	126.4	Severe
	117	117.2	205 Metler Road	729	436	64.3	87.2	Heavy
	104	104.2	1780 Cream Street	459	364	42.7	72.8	Heavy
	118	118.1	Across 155 Metler Road	339	260	106.0	52.0	Heavy
	86	86.3	353 Canboro Road	184	129	11.5	25.7	Moderate
	53	53.1	764 Foss Road	348	116	37.6	23.3	Moderate
	83	83.1	740 Hwy 20 W	132	68	5.0	13.6	Moderate
	104	104.1	1895 Cream Street	80	63	18.4	12.7	Moderate
	75	75.2	491 Canboro Road	121	23	2.4	4.7	Light
	125	125.1	2180 Centre Street	11	7	1.7	1.3	Light
	75	75.1	546 Memorial Drive	648	6	138.2	1.3	Light
	75	75.3	554 Canboro Road	435	4	104.5	0.9	Light

*Fonthill*

In Fonthill, three woodlot plots are forecasted to experience severe defoliation in 2022: plot 80.2 along Merritt Road, plot 99.4 along the trail behind Elm Avenue and Giles Crescent, and plot 68.5 located in the wooded area behind Spruceside Crescent (Figure 11). In all three of these plots, there has been a significant increase in egg mass density. The severe defoliation forecast for plot 68.5 is likely due to two red oaks on which the majority of egg masses are located. The remaining plots within Fonthill have nil to moderate 2022 defoliation forecasts. The average proportion of new egg masses in Fonthill was 55%. The average new egg mass size in Fonthill in 2021 was 31.9mm (n=61), which represents an increase in size from 2020 (26.8mm). Of the new egg masses measured, 84% of them were large (greater than 25mm). While the egg mass populations within the urban boundary have declined and are now at much lower

levels than previous years, the extreme egg mass populations persisting in the surrounding rural areas may still cause defoliation within Fonthill; early instar larvae may be dispersed by wind or may migrate into the urban area in search of host trees on which to feed.

#### *Fenwick*

In Fenwick, two woodlot plots are forecasted to experience severe defoliation in 2022: plots 74.1 and 74.2, located in the wooded area south of Memorial Drive and west of Cream Street (Figure 12. All LDD moth egg mass monitoring plots surveyed in November and December 2021 and all blocks sprayed in May-June 2021 (outlined in blue), Fenwick, Town of Pelham.). That being said, egg mass density in both plots has declined significantly between 2020 and 2021. Two roadway plots in Fenwick are forecasted to have heavy defoliation in 2022: along Cream Street north of Welland Road (plot 74.3) located on private land, and the streets trees on Welland Road just west of Balfour Street (plot 64.1). The remaining plots in Fenwick are forecasted to have light to moderate defoliation. The average proportion of new egg masses in Fenwick was 36%. The average new egg mass size for Fenwick in 2021 was 25.7mm (n=27) a significant decrease from the average size in 2020 (32.3mm). Of the new egg masses measured in 2021, 63% of them were large (greater than 25mm). While the egg mass populations within the urban boundary have declined and are now at much lower levels than previous years, the extreme egg mass populations persisting in the surrounding rural areas may still cause defoliation within Fenwick; early instar larvae may be dispersed by wind or may migrate into the urban area in search of host trees on which to feed.

#### *Rural Areas*

Rural areas contained the majority of plots with heavy to severe defoliation forecasts (36 plots severe and nine plots heavy). These included properties north and northwest of Fonthill (Effingham Street, Tice Road, and Metler Road area); the area between Fenwick and Fonthill just outside the Fonthill urban boundary (along Effingham Street, Welland Road, Canboro Road and Pancake Lane); and south of Fenwick (Balfour Street south of Sumbler Road and along Cream Street south of Foss Road). Surveys in these areas were conducted primarily along the perimeter of these properties, so as not to trespass on private land. As a result, the forecasts are representative of edge populations, which can be higher than those found in forest interiors (Bellinger et al 1989). Therefore, it is possible that these perimeter plots are an over-representation of the counts present throughout the property, however the counts are so extreme (ranging from 0 all the way up to 81,182 egg masses per hectare) that it is very possible that interior counts are also high. The average proportion of new egg masses in the rural areas was 50%. The average new egg mass size for the rural areas in 2021 was 28.4mm (n=293) a slight increase from 2020 (24.5mm). Of the new egg masses measured in 2021, 71% of them were large (greater than 25mm).

#### *Weather*

Cool, wet conditions tend to favour the build-up of *Entomophaga maimaiga*. Evidence of larvae killed by this fungal disease is often associated with a decrease in LDD moth populations in the following year. Conversely, hot, dry conditions typically suppress the build-up of this natural pathogen. Environment Canada weather data from the Welland-Pelham area indicate that in 2021, spring and summer temperatures were above normal in March, April, and June; and below normal in May and July (Figure 13. Twenty-nine-year historical temperature normals (1981-2010) and 2021 monthly temperature averages for Town of Pelham area.). Precipitation was well below normal in all spring and summer months, except for July (Figure 14. Twenty-nine-year historical precipitation normals (1981-2010) and 2021 monthly totals for the Town of Pelham area.), when total precipitation was nearly double the normal total. The lower-than-normal precipitation and higher than normal temperatures would not be favourable to *E. maimaiga*, therefore, it is likely that 2021 larval mortality due to this natural pathogen was low. This is likely a contributing factor to the continued high levels of LDD moth seen throughout the rural areas of Pelham, and the province in general. A few days of -25°C temperatures would have a significant effect on those larvae; however, this is very rare in southern Ontario. A

late frost (post-larval emergence) could also reduce the population, but it is impossible to predict the likelihood of this occurring.

Extreme larval populations, as seen throughout Pelham, are not sustainable. In combination with the right environmental conditions, such high host presence allows the nucleopolyhedrosis virus (NPV), which is density-dependent, to proliferate and spread more effectively throughout the LDD moth population. This could potentially lead to a population crash in 2022 if weather conditions are right.

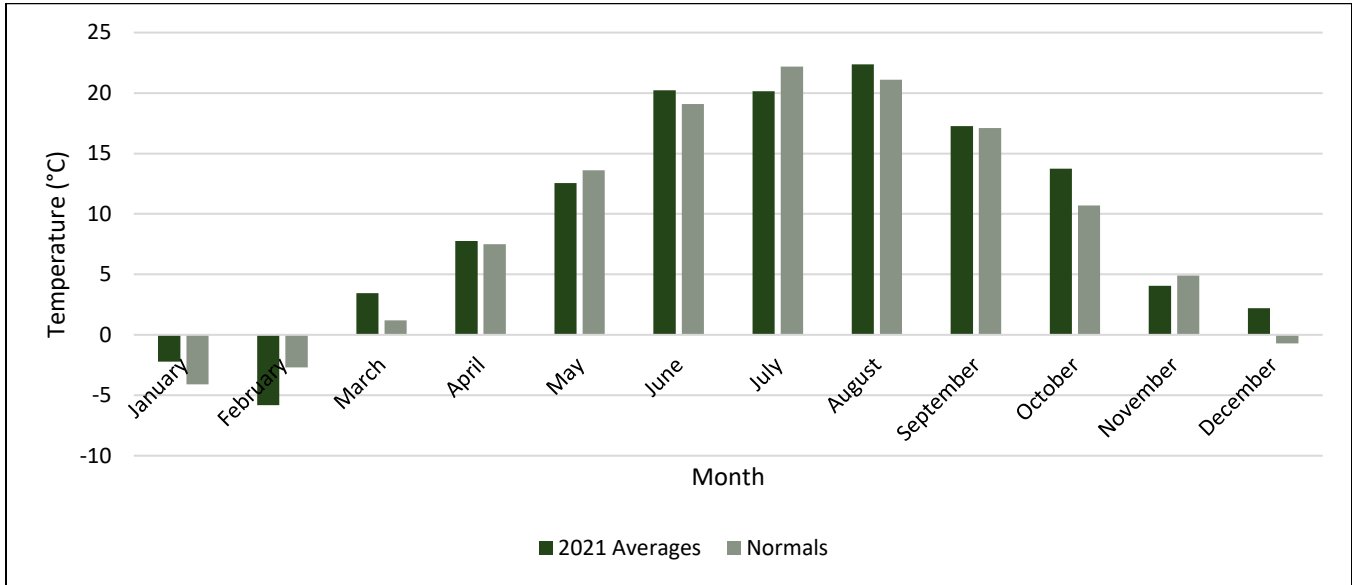


Figure 13. Twenty-nine-year historical temperature normals (1981-2010) and 2021 monthly temperature averages for Town of Pelham area.

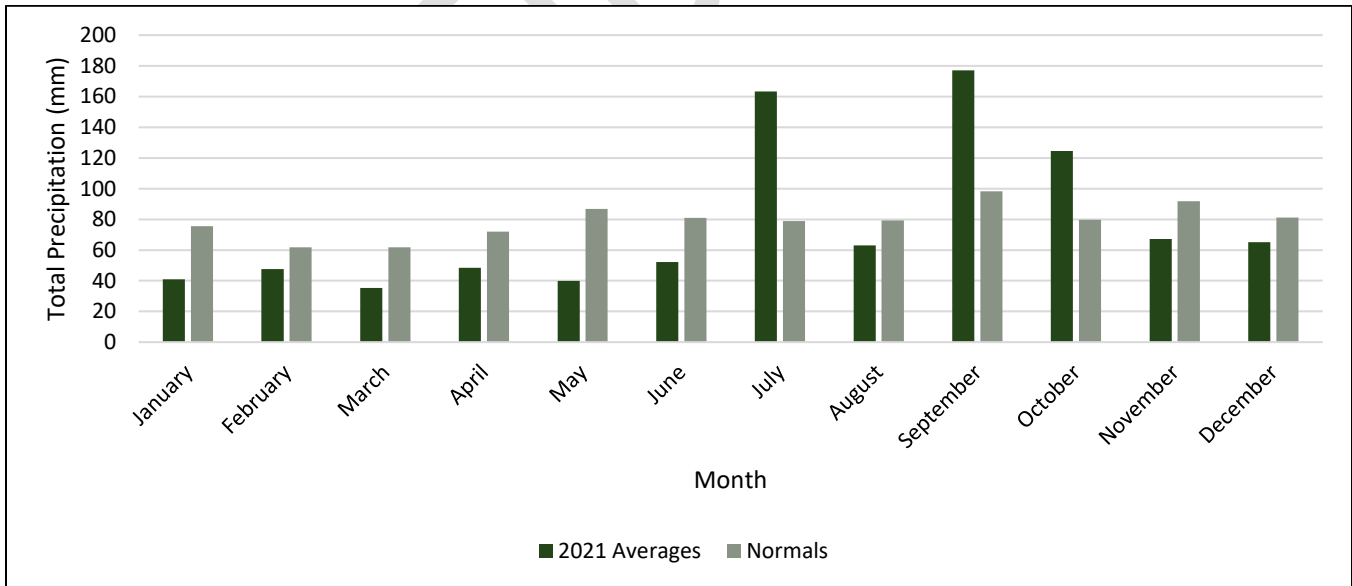


Figure 14. Twenty-nine-year historical precipitation normals (1981-2010) and 2021 monthly totals for the Town of Pelham area.

## Conclusions and Recommendations

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The objectives of this report are to provide the Town of Pelham with 1) an assessment of 2021 LDD moth egg mass densities and use these to determine forecasts of expected host damage and defoliation for 2022, 2) short- and long-term management options, applying a philosophy of Integrated Pest Management (IPM), and 3) specific recommendations for management in the affected areas in 2022.

Based on the LDD moth data collected during November and December 2021, the Town has the potential to experience heavy to severe levels of defoliation, primarily in rural areas north of Fonthill (Effingham Street, Tice Road, and Metler Road area); the area between Fenwick and Fonthill just outside the Fonthill urban boundary (along Effingham Street, Welland Road, Canboro Road and Pancake Lane); and south of Fenwick (Balfour Street south of Sumbler Road and along Cream Street south of Foss Road). In Fenwick, heavy to severe defoliation is forecast to occur in the wooded area south of Memorial Drive and west of Cream Street, along Cream Street north of Welland Road, and on Welland Road just west of Balfour Street. In Fonthill, heavy to severe defoliation is forecast to occur in the wooded area along Merritt Road just west of Rice Road, along the trail behind Elm Avenue and Giles Crescent, and in the wooded area behind Spruceside Crescent. It is possible the defoliation will extend beyond the areas surveyed, especially north of Kilman Road west of Effingham Street throughout these continuous, heavily forested areas of the Natural Heritage Environmental Conservation areas.

At a high-level comparison, 2022 defoliation forecasts have decreased from 2021 forecasts in the urban centres of Fenwick and Fonthill, especially within the areas that were treated in the spring of 2021. However, as previously mentioned, rural areas along with isolated areas within the urban boundaries are forecast to experience heavy to severe defoliation in 2022.

A moderate proportion (50%) of LDD moth egg masses observed in November and December of 2021 were new, which was a significant decrease from 2020 (67%) and remains well below the level of what is considered a healthy population (75% new egg masses). A large proportion (72%) of new egg masses were large (greater than 25mm), which was a significant increase from 2020. However, it was a decrease from baseline data collected in 2019 (84%) and may be the result of less feeding competition due to a collapsing population and/or aerial spray program intervention. Additionally, the average new egg mass size in 2021 (28.8mm) remains below the threshold of what is considered a healthy, building population (30mm). Given the low proportion of new egg masses and moderate average new egg mass size, Pelham's LDD moth population may have passed its peak and may be on the decline, though the evidence is not yet conclusive.

### Recommendations

The Town has two management options for 2022 which are outlined below: 1) **Community Outreach**, where the Town runs a public outreach campaign but does not intervene with a treatment program, allowing the LDD moth population to run its natural course, or 2) **Targeted Treatment**, focusing on the small areas within the urban boundaries of Fonthill and Fenwick.

**Community Outreach:** The Town takes no action on public trees and executes a strong communication and engagement program throughout the communities of Fenwick and Fonthill, as well as rural areas, and Pelham's Forest Health Volunteers. Pelham's Forest Health Volunteers have been educated in detecting LDD moths throughout 2021 and can help educate their community networks to identify new populations, thereby supporting formal monitoring surveys. Landowners should be educated on what their treatment options are (ground treatments with Btk or TreeAzin®, manual egg mass removal, and/or burlap banding) as well as the pros and cons associated with each option, focusing on cost and efficacy, and include information on why the Town has chosen this particular course of action for 2022. Communication should be executed through a variety of avenues to reach as many people as possible. With this option,

varying levels of defoliation will still occur and there is the risk that the LDD moth population will persist in certain areas of the Town, possibly prolonging the need for management and the associated costs.

During the 2021 LDD Moth Egg Mass Surveys, BioForest crews encountered numerous enthusiastic residents eager to learn about LDD moth and tell stories about their efforts to protect trees on their property. Using the community as a resource to report on LDD activity and to participate in LDD moth management on private property, can be an inexpensive management option and will help to generate overall awareness of urban forestry programs.

The consequences associated with foregoing active treatment of public trees may result in overall tree health decline and further expenses required due to hazard tree removal, service requests, pruning, etc. as a result of a persisting and severe LDD moth population. The upside of this approach is the reduced immediate cost to the Town in 2022.

**Targeted Treatment:** The Town implements a targeted program within the urban boundaries of Fonthill and Fenwick using ground spray with Btk, tree injections, burlap banding, and manual egg mass scraping for individual trees. This option would be supported by a strong public outreach and communications program as described in Option 1, targeted towards private landowners with moderate-to-severe defoliation forecast plots located on or near their property.

Plot 68.5 located in Fonthill is a good candidate for tree injections with TreeAzin<sup>®</sup> Systemic Insecticide as the severe forecast is likely due to two individual red oak trees. Ground spray with Btk could prove a challenge in this location due to the height of the canopy and narrow trails for transporting spray equipment. The street trees located in plot 64.1 (two Norway maples and two sugar maples), would be excellent candidates for ground application of Btk, tree injections, and/or burlap banding.

The forested area in Fenwick's northeast has been sprayed for the last two years, providing the canopy a reprieve from LDD moth defoliation and thus can be excluded from this year's program, despite its severe defoliation forecast. Plot 99.4, located on the north end of Fonthill, is connected to a large woodlot that continues beyond the urban boundary and would be inappropriate for a targeted program. Finally, plot 80.2 in Fonthill and plot 74.3 in Fenwick, would also be inappropriate for a targeted approach as they are both located on private land.

Private landowners located outside of the urban centres, especially those with moderate-to-severe forecast plots on their property, should receive targeted communications in a similar manner as described above in Option 1. Treatment in the rural areas would not be feasible due to an abundance of private land but landowners should be encouraged to take action on their property using one of the management options available to the public.

### Continued Monitoring

It is recommended that egg mass surveys be continued on an annual basis to monitor LDD moth population trends, especially to confirm the potential decline that Pelham is currently experiencing. Annual surveys will help to identify new populations, initiate control activities in a timely manner, and mitigate the impact of a potential outbreak. Additionally, defoliation surveys conducted during the summer would supplement egg mass surveys by recording actual damage to the urban canopy and assessing the efficacy of treatment programs, if applicable.

It is also recommended that the current LDD Moth Activity Database be kept up to date with information from Pelham Forestry staff (and other municipal departments), residents, and Forest Health Volunteers. This practice has proven to be useful for identifying new areas of concern and targeting new sites to monitor annually.



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