# Assessment of Gypsy Moth Populations and Potential Impacts within the City of Mississauga and Recommendations for Management

**Prepared for**
**City of Mississauga**


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# Executive Summary


- Gypsy moth is a relatively new insect pest affecting the trees of Ontario. The first significant outbreak occurred in the Province in the early 1980s and, since then, it has spread throughout the range of its principle host, oak.

- Gypsy moth has been present in the City of Mississauga for more than 20 years, although major outbreaks have been rare. Low gypsy moth populations were detected in 2003 and surveys show that populations have increased dramatically in 2005.

- At high population densities, gypsy moth defoliation can be severe (up to 100%). Impacts will vary depending on tree vigour, but can include growth loss, branch mortality, attack by secondary insects and diseases and tree mortality.

- A number of naturally occurring predators, pathogens and parasites affect gypsy moth populations, keeping them in check at low densities and bringing about population collapses when gypsy moth populations are high.

- Gypsy moth outbreaks typically last two to four years in an area.

- Gypsy moth populations can be assessed at various stages in the life cycle, but egg mass surveys generally provide the most accurate assessment of populations and forecasts of defoliation. However, gypsy moth populations are subject to a wide variety of biotic and abiotic factors that may complicate the forecasting process.

- The City of Mississauga has conducted gypsy moth egg mass surveys since 2003. Egg mass densities have increased each year. Surveys in 2005 showed variable gypsy moth egg mass densities on trees in Wards 1, 2, 6, 7 and 8. The most serious outbreaks appear to be in Wards 2 and 7.

- Interpretation of the 2005 egg mass counts was complicated by the lack of survey methodologies available for gypsy moth in the urban environment. Consequently, City staff focused on delineating the boundaries of the outbreaks and collecting egg mass density estimates on individual trees. Data extrapolations were carried out to convert individual tree counts to estimates of egg masses per hectare, the standard area unit used in forested environments to forecast defoliation.

- BioForest conducted an independent assessment of gypsy moth egg mass density data under the same methodological constraints and applied a different procedure to determine defoliation forecasts.

- Both defoliation forecast procedures were based, in part, on established methodologies, but results differed. The BioForest analysis method showed a

higher proportion of moderate to severe forecasts (63%) than the City analysis (25%). The first is likely an overestimate while the latter is likely an underestimate of defoliation in 2006. Nevertheless, egg mass densities are high enough to cause light to severe defoliation in the outbreak areas. BioForest recommends using the City gypsy moth egg mass distribution and forecast map for management actions in 2006.

- Because of the biological evidence indicating high gypsy moth populations in 2006, the high value of the trees in the affected areas and the generally stressed condition of these trees, BioForest is recommending that the City conduct an aerial spraying program against the gypsy moth within the outbreak areas delineated by City surveys. The objective of the program is to reduce gypsy moth populations in the outbreak areas, reduce dispersal and expansion of the outbreaks into new areas and minimize tree defoliation to maintain tree vigour.

- BioForest recommends two to three applications of the bacterial insecticide *Bacillus thuringiensis* var. *kurstaki* at a rate of 50 BIU/hectare shortly after egg hatch in the spring using a twin engine helicopter.

- BioForest also recommends the implementation of an IPM program in the City that involves the active participation of residents to reduce gypsy moth populations and damage on private lands by using a variety of management options.

- BioForest recommends that the City approach the Ontario Ministry of Natural Resources and the Canadian Forest Service to develop a standardized gypsy moth egg mass survey method for urban environments to be used in future population assessments.

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## 1 Introduction

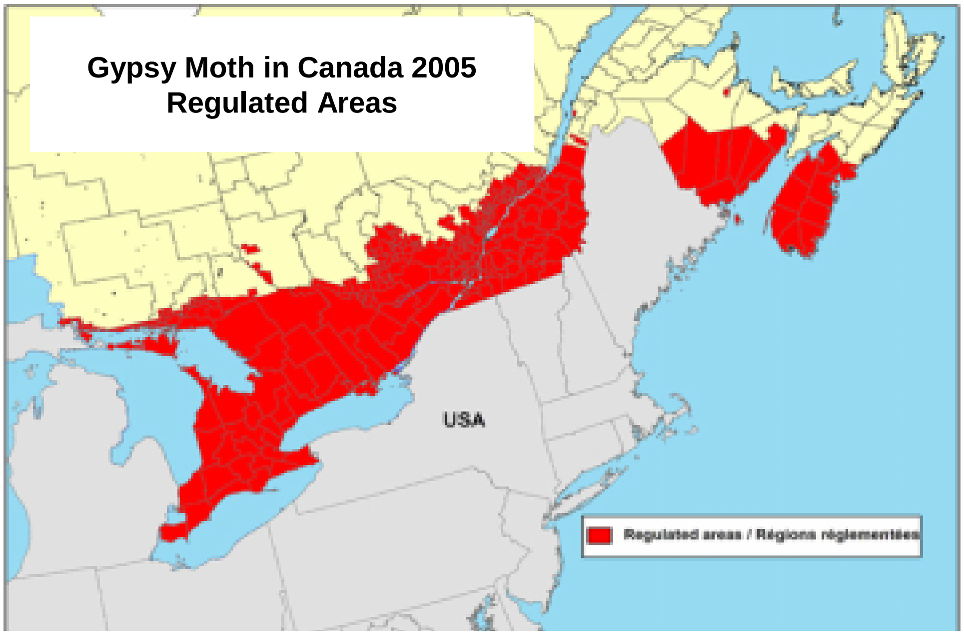
### 1.1 Background

#### *1.1.1 Gypsy Moth in North America*

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

Although the United States government has had a quarantine in place since the early 1900s, gypsy moth has been advancing slowly westward from the northeastern United States. In the United States, gypsy moth has spread from western Pennsylvania, through Ohio, Michigan, and Illinois and is now in central Wisconsin. It is estimated that gypsy moth is currently spreading at a rate of 21 km/year (USDA 2003). To address the gypsy moth invasion in the United States, the U.S. Forest Service has implemented the Slow the Spread (STS) project. The STS project is a large integrated pest management program that aims to eradicate or suppress colonies of gypsy moth detected along the expanding front of the population.

In Canada, the first gypsy moth was detected in British Columbia in 1912. The first gypsy moth infestation in Canada happened in southwestern Quebec in 1924 and the second in New Brunswick in 1936. Intensive egg mass removal programs were used to eradicate both infestations. Since 1955, when gypsy moth was detected again in Quebec, gypsy moth has become established in southern Ontario, 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 gypsy moth. Figure 1 shows the areas of Canada that CFIA regulates for gypsy moth.




Source: CFIA 2005.

**Figure 1. Areas in Canada regulated for gypsy moth by the CFIA.**

### *1.1.2 Gypsy Moth in Ontario*

Gypsy moth is a relatively new pest to Ontario. After its accidental release into Massachusetts in 1870, gypsy moth expanded its range over the next 100 years and was first detected in Ontario in 1969 on Wolfe Island, south of the city of Kingston. In 1981, the first major area of gypsy moth defoliation in the Province was detected near Kaladar in eastern Ontario. By 1985, gypsy moth was a serious problem throughout southeastern Ontario. As of 1996, the distribution of gypsy moth larvae includes the southern third of the Province and the northern boundary runs from North Bay to Sault Ste. Marie.

Figure 2 shows the outbreak history of gypsy moth defoliation mapped in Ontario between 1981 and 2005. Outbreaks peaked in the Province in 1985, 1991, and 2002. Although the overall gypsy moth populations in 2004 and 2005 were low, the Canadian Forest Service reported moderate to severe defoliation in Mississauga and Etobicoke in 2005 (Evans 2005).

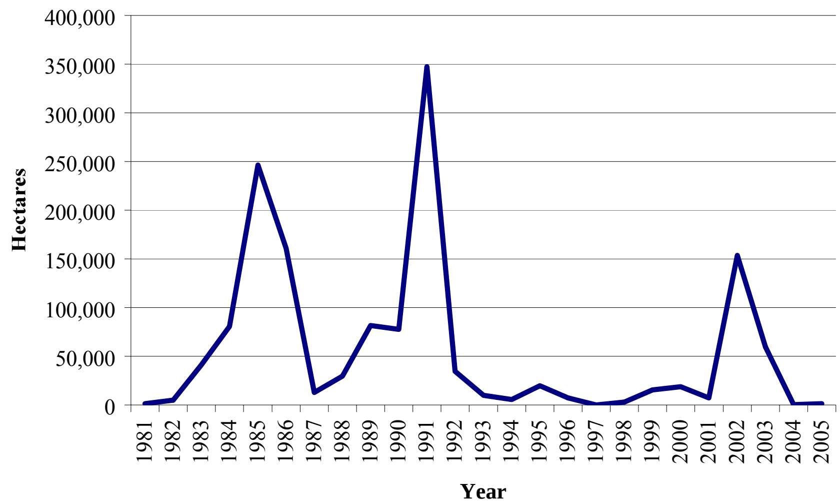



**Figure 2. Gypsy moth defoliation in Ontario between 1981 and 2005.**

### *1.1.3 Gypsy Moth Biology and Life Cycle*

Figure 3 presents the life cycle of the gypsy moth. Gypsy 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. Gypsy 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 be 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 gypsy 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 –32 $^{o}$C for an extended period, egg masses above the snow line may be susceptible to winter kill. 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.

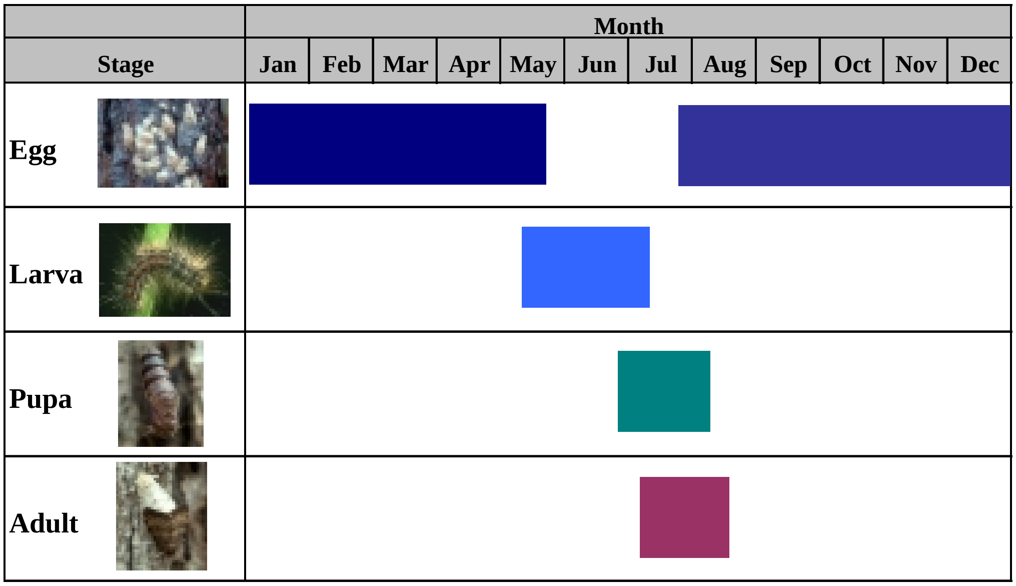



**Figure 3. Gypsy moth life cycle.**

Of the four life stages of the gypsy 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 gypsy 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 35-90 mm. They 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 gypsy moth larvae up to 1 km. Gypsy 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 gypsy moth life stages, most commonly they transport egg masses.
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 4a). The first three larval instars remain on the foliage and feed day and night. When populations are low (i.e. < 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. > 1250 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).

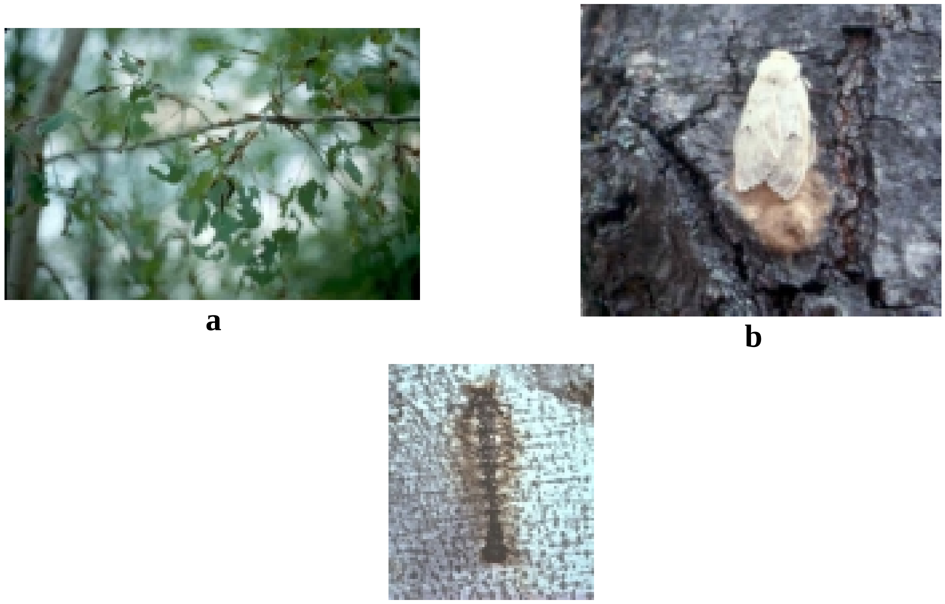


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**Figure 4. Gypsy moth photos: a) Gypsy moth defoliation; b) Female gypsy moth laying eggs; and c) Entomophaga maimaiga killed gypsy moth larva.**

Gypsy moth larvae are active from approximately early May to mid-July. During that time, one larva is able to consume an average of 1 $m^2$ of foliage, which is roughly the equivalent of 10-15 entire red oak leaves (Nealis and Erb 1993). Males generally eat slightly less than 1 $m^2$ 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 13-17 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 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 35-40 mm. The female is mostly white and has a wingspan between 60-70 mm. Dark wavy lines also cross the female moth's forewings but, because the female is lighter in colour, these lines are more prominent.

The female is too heavy bodied to fly, so gypsy moth relies on the larval stage for dispersal. 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 1.5 km away. Within about 24 hours of mating, the female lays eggs in a mass of 100-1000 on tree trunks, branches, houses, and fences and under rocks and forest floor debris (Figure 4b). 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).

### *1.1.4 Natural Controls*

Although in Europe and Asia there is evidence of cyclical outbreaks of gypsy moth, a clear pattern of outbreaks in North America has not yet been established. However, gypsy moth populations do appear to exist in one of two phases: low density or high density. Natural factors such as weather, predators, parasites, and pathogens significantly influence gypsy moth population densities.

Weather conditions can favour either low or high density populations. Extreme weather conditions characterized by prolonged periods of cold temperatures (<–32 $^{o}$C) can kill unprotected eggs, which can help to keep low density populations low or decrease high density populations. In contrast, warm, dry conditions tend to accompany increases in gypsy moth populations (Skaller 1985).

Low density populations are normally kept in check by natural enemies such as predators and parasites (Brooks and Hall 2005). Predators that feed on gypsy moth larvae include about 40 species of birds such as vireos, chickadees, tanagers, orioles, robins, blue jays, grackles, starlings, blackbirds, and cuckoos (OMNR, undated), other insects, and small mammals such as skunks, white-footed mice, squirrels, and raccoons. Insect parasitoids kill gypsy moth by laying their eggs in gypsy moth eggs, larvae, and pupae.

At the start of a gypsy moth outbreak, natural enemies have little effect on the gypsy moth population (Brooks and Hall 2005). Populations increase when suitable conditions exist such as favourable weather and abundant foliage. Outbreaks typically last two to four years in a specific area. Pathogens, or disease organisms, generally cause infestations to naturally collapse. Population decreases tend to happen in cooler, wetter conditions that favour pathogens. Gypsy moth is susceptible to a variety of naturally occurring infectious diseases that are caused by bacteria, fungi, and the nucleopolyhedrosis virus (NPV) (Campbell and Podgwaite 1971). *Entomophaga maimaiga* and NPV, the most significant natural enemies of gypsy moth, are capable of killing large numbers of gypsy moth larvae. *E. maimaiga* is a fungus that is specific to gypsy moth and is prevalent throughout low-to-high density gypsy moth populations. Although it is not completely clear how *E. maimaiga* first became established in North America, it was first recovered from North American gypsy moth in the northeastern United States in 1989. It was recovered from gypsy moth in southern Ontario in 1990. A late larva killed by *E. maimaiga* hangs vertically with its head pointed downward and its body tight to the trunk of the tree (Figure 4c). An early larva killed by *E. maimaiga* generally remains on the foliage (Reardon and Hajek 1998). The NPV was inadvertently introduced to North America with the gypsy moth or its parasites. Like *E. maimaiga*, the NPV is specific to gypsy moth. The NPV is often referred to as "wilt" due to the soft, limp appearance of the diseased larvae (Nealis and Erb 1993). A larva killed by NPV hangs on the tree in the shape of an inverted "V".

No single natural enemy or combination of natural control agents can completely eliminate a gypsy moth population. Natural control agents can keep gypsy moth populations low, however, at times, outbreak conditions occur and the natural enemies are not able to control the growing gypsy moth populations (OMNR, undated).

### *1.1.5 Hosts and Impacts*

Gypsy moth has been found on approximately 500 different tree species (OMNR, undated) and is a major defoliator of forest, ornamental, and orchard trees. Gypsy moth defoliates mainly hardwoods and some conifers. Table 1 lists the most common host species for gypsy moth and categorizes them by 'most preferred', 'preferred', and 'least preferred'.

A gypsy moth infestation can impact an area in a number of ways. In the short term, high populations of larvae cause defoliation that affects the aesthetic and recreational value of an infested area. Generally, leaf loss becomes noticeable when a tree sustains 30 to 40% defoliation. Table 2 summarizes the number of egg masses/ha that cause light, moderate, and severe defoliation. Also in the short term, egg masses can be a nuisance because they can be laid on such a wide variety of surfaces including tree trunks, branches, rocks, logs, fences, picnic tables, and buildings. In the long term, a gypsy moth infestation can cause twig, branch and, in some cases, whole tree mortality, invasion from secondary pests such as rot, and thin tree canopies.

Several factors affect how a tree responds to gypsy moth defoliation including the amount of foliage removed, the weather, the number of years of repeated defoliation, the timing of defoliation in the growing season, the presence and number of other insects and diseases, and the health and vigour of the tree at the time of defoliation (OMNR, undated). For example, damage from gypsy moth may increase substantially if trees are growing on poor sites or if defoliation occurs during the same period as drought.
Most healthy trees can withstand a single year of moderate to severe defoliation, but two to three years of heavy defoliation (≥50%) can result in branch or whole tree mortality. A tree's crown condition plays an important part in its ability to survive gypsy moth defoliation. A tree with <25% dead branches in its crown is more likely to survive defoliation than a tree with >50% dead branches in its crown (Gottschalk 1993). Trees that are diseased, crowded, or stressed may die after one or two years of defoliation (OMNR, undated).

**Table 1. Most preferred, preferred, and least preferred gypsy moth tree hosts.**

| Most preferred | Preferred | Least preferred |
|---|---|---|
| Oak (all species) | Beech | Black ash |
| Largetooth aspen | Yellow birch | Green ash |
| Trembling aspen | Cherry (all species) | White ash |
| White birch | Butternut | Black locust |
| Grey birch | Chestnut | Mountain maple |
| Basswood | White elm | Red spruce |
| Tamarack | Eastern hemlock | White cedar |
| Alder | Ironwood | Eastern red cedar |
| Apple | Maple (most species) | Sumac |
| Hawthorn | White spruce | Red mulberry |
| Willow | Norway spruce | Tulip-tree |
| Manitoba maple | Pine (all species) | Balsam fir |
| Mountain ash | Hickory | Sycamore |
| Carolina poplar | Black walnut | |
| Larch | Sassafras | |
| | Serviceberry | |

Source: (GM-06-105)

**Table 2. Defoliation forecasts based on gypsy moth egg masses/ha (M. Francis, Ontario Ministry of Natural Resources. Pers. Comm.).**

| Egg masses/ha | Defoliation forecast |
|---|---|
| 0 | Nil |
| 1-1235 | Light (1-40%) |
| 1236-6175 | Moderate (40-75%) |
| 6176+ | Severe (>75%) |

The impact of an outbreak on an area can be influenced by when the defoliation occurs. Defoliation that happens in mid-season can be more damaging than that which occurs in the spring because in mid-season, trees do not have time to replenish food reserves and new buds do not have time to harden before colder temperatures start (Gottschalk 1993).

Tree location can also play a role in how susceptible a tree is to gypsy moth defoliation. Gypsy moth generally prefers ridge top sites and steep, south or west facing slopes. These sites tend to have the tree species that gypsy moth prefers and the trees are often crooked, are low in vigour, and have deep fissures in their bark, providing good gypsy moth habitat. In the winter, the temperature on these sites rarely drops below –32$^{o}$C, the threshold below which gypsy moth egg masses die. Therefore, more eggs survive to hatch in the spring. In the spring, these sites are not likely to be exposed to late spring frosts that would kill young gypsy moth larvae. In the summer, the sites tend to be hot and dry, which helps gypsy moth larvae to survive and thrive (Gottschalk 1993).

Healthy, vigorous trees on lower, north or east facing slopes are likely going to be less susceptible to gypsy moth defoliation. These sites tend to have deep, fertile soils and tend not to be stressed by drought. Trees on these sites are often straight and fast-growing with smooth bark and healthy crowns, making them more resistant to gypsy moth damage (Gottschalk 1993).

The composition of trees in an area can affect the amount of damage that gypsy moth causes. For example, areas with mostly oak, birch, or poplar are more susceptible than areas with predominately sugar maple, ash, spruce, or pine (OMNR, undated).
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### 1.2 Objectives

The objectives of this report are to provide the City of Mississauga with **1)** a comprehensive assessment of the gypsy moth situation in the City of Mississauga, **2)** forecasts of likely impacts, **3)** short and long term management options applying a philosophy of Integrated Pest Management (IPM) and **4)** specific recommendations for management in the affected areas in 2006. All options will be considered and evaluated.

## 2 Assessment of Gypsy Moth Populations

An essential component of any pest management action is a thorough assessment of the distribution and density of the pest population (i.e. where is it and how bad is it). A number of sampling methods have been developed for the gypsy moth and are discussed below. The results of these surveys are used to define the suite of actions best suited for management of the pest.

## 2.1 Gypsy Moth Population Assessment Methodologies

A variety of sampling methods have been developed for assessing gypsy moth populations and forecasting potential damage to host trees. Gypsy moth is a difficult insect to sample accurately because of its association with many host species, activity of the insect during the larval stage and the dramatic fluctuations between low endemic and high outbreak populations over relatively short periods of time (Nealis and Erb 1993). Another factor that can complicate gypsy moth population assessments and forecasts is the tendency of early instar larvae to disperse by ballooning over the landscape, often in large numbers. This can result in areas suffering high defoliation rates even though egg mass densities were low, or, in some cases, nonexistent.

Sampling methods have been developed for each stage of the gypsy moth life cycle.

**Caterpillars:** Burlap or tar paper bands placed around the main stem of the tree can be used to trap gypsy moth caterpillars and pupae. Gypsy moth caterpillars seek shelter under the bands during the later feeding stages and often pupate under these bands. Caterpillar densities can vary greatly from day-to-day and even during the day. Weather, tree species, caterpillar density and larval development can affect numbers, therefore, this method is not considered a reliable method for population assessment.

Caterpillars can also be sampled from foliage collected from the tree canopy. The accuracy of this method has not been assessed but can be used to determine the presence or absence of gypsy moth caterpillars, especially during the early instars.

A third method for assessing gypsy moth caterpillar populations is the collection of frass (droppings) in containers placed on the ground (Liebhold and Elkinton 1988a and Liebhold and Elkinton 1988b). This is the most accurate method but is a time-consuming process that requires some expertise and is usually restricted to research.

**Adults:** Female gypsy moth adults do not fly but attract the male moths by releasing a powerful airborne scent called a pheromone. This pheromone has been synthetically reproduced and is used to lure male moths to a variety of sticky or bucket-like traps. This is an effective method for detecting the presence of low level gypsy moth populations and is widely used in the United States and Canada (Gage *et al*. 1990). Because this pheromone is so efficient, gypsy moth pheromone traps are less effective during periods of high populations when they tend to become saturated with moths, making it is difficult to develop relationships between trap catches and subsequent populations and damage.

**Egg Masses:** Gypsy moths lay their eggs in masses of up to 1000 eggs on the stems and branches of trees as well as on the forest floor and man-made objects in July and August each year. They will remain in the egg mass until hatch begins sometime in April or May the following year. This provides the longest period for assessing gypsy moth populations and is considered the most reliable method. Egg masses are easily counted, especially following leaf fall in the autumn, and old egg masses are generally easily distinguishable from new egg masses so accurate counts of the current year population are possible. Egg mass size can also be measured and is a good indicator of outbreak status – large egg masses indicate a healthy, increasing population and small egg masses indicate a decreasing population. Moore and Jones (1987) provide a simple equation for estimating the numbers of eggs per mass based on a measure of egg-mass length.

A number of sampling methods have been developed for estimating egg mass densities and forecasting host defoliation:

- ***Timed Walks:*** Observers count all the egg masses visible during a five-minute walk through an area. This method can be used as a quick survey tool but is imprecise and is usually followed up with a more detailed survey.

- ***Fixed-area plots:*** Observers count egg masses within a standardized area. Results can be extrapolated into numbers per hectare, which allows comparisons between areas and years. In the United States, the fixed radius plot (5.4 m radius) of 1/40 acres (0.01 ha) is the most commonly used. In Ontario, the 10m x 10m Modified Kaladar Plot (MKP) has been used since the gypsy moth was detected in the Kaladar area of eastern Ontario in the early 1980s.

**Egg Mass Surveys in Forest and Urban Environments:** Definitions of urban and suburban environments may vary but Fleischer *et al*. (1992) defined these areas as having a minimum of one house per ten acres (4.04 ha). With the exclusion of some parks, this would apply to most of the areas surveyed within the City of Mississauga. Use of fixed-area plots is the most accurate method for assessing gypsy moth egg mass densities and is the most frequently used method in forest environments. Generally, groups or clusters of three to five MKPs were used in Ontario to estimate average egg mass densities and forecast defoliation in specific areas. In urban or suburban environments, however, the 10m x 10m fixed-area plot may not be practicable when egg mass surveys are limited to street trees and when access to private property and backyards is a constraint.

The urban environment is influenced by man-made objects and the distribution of gypsy moth egg masses is more clumped than in the forest (Fleischer *et al.* 1992). This probably reflects the clumped distribution of preferred host and the discontinuous nature of treed areas in urban environments. Sample methods for urban and suburban environments need to reflect this difference in egg mass distribution.

## 2.2 Gypsy Moth Egg Mass Surveys in Mississauga

Crews from the City of Mississauga began assessing gypsy moth populations in 2003 when caterpillars were observed feeding in several areas of the City. In 2004 and 2005, staff visited previously known hotspot areas and probable gypsy moth locations based on the presence of its preferred host species, oak. The surveys were conducted in residential areas and park woodlots. In August 2005, pheromone traps were used to attract male gypsy moths in an effort to detect new infestations.

**2005 Gypsy Moth Egg Mass Survey:** The first egg mass surveys were conducted in the White Oaks Park area and the surrounding residential properties. This area was known as a previous hotspot. To inventory gypsy moth egg masses along residential streets, all trees located within 10 m of the road were inspected. When egg masses were observed on a tree, the following data was collected: street address, ownership of tree, species of tree, tree diameter at breast height, tree condition, percent defoliation, percent shot holing, percent die-back, number of egg masses, size of egg masses, and general comments. This procedure was followed for the entire street. Egg masses were detected and counted on some 1800 trees during the course of the 2005 survey, and crews were still in the field examining more trees as this report was being prepared.

In City parks, egg mass surveys were conducted around the periphery of the park and then along 5 m swaths transecting the forested areas. Canopy characteristics were not rated once leaves had fallen in the autumn. Also, the more detailed surveys were simplified when it became apparent that time and resources were limited and needed to be focused on delineating the extent of the gypsy moth populations in the City. Throughout the winter, city staff continued to inspect all areas of the city where there were known locations of un-inspected oak trees and where residents had reported egg masses. Recently, the City created a street-tree inventory that has been useful in directing surveyors to probable locations of gypsy moth habitat.

All gypsy moth egg mass data was entered and maintained in a Microsoft Excel database. In addition, a point shapefile of city properties and egg mass data was entered into a Geographic Information System (GIS) using ArcView v3.2. One hectare grids were created in ArcView that were aligned with the direction of city streets. This facilitated the extrapolation of collected egg mass counts to egg mass counts per hectare, the standard area used to forecast future defoliation. Both egg mass density maps and 2006 defoliation prediction maps were then constructed. The predicted defoliation values were obtained using a USDA defoliation prediction model (Gansner *et al.* 1985) based on egg mass counts.

The methodology used for the egg mass surveys in Mississauga was based on the fixed-area plot method described earlier. No standardized method for conducting an egg mass survey in the urban environment was available so crews had to adapt to a variety of situations encountered during the course of the survey. This resulted in some problems when the individual tree data was extrapolated to counts per hectare.

Boundaries for outbreak areas were determined by using various parameters including the density of gypsy moth eggs masses and the known location of vulnerable tree species. These boundaries were digitized and layered over aerial photographs of the city.

**Gypsy Moth Egg Mass Size:** City survey crews assessed gypsy moth egg mass sizes in 2004 and 2005. They used a quick and commonly used technique of comparing egg mass size to pocket change: dime (17mm), nickel (20 mm), quarter (23 mm) or looney (25 mm). Results show an overall increase in gypsy moth egg mass size between 2004 and

2005, suggesting a relatively healthy, building population (Figure 5). The percentage of large egg masses (i.e. ≥ 23 mm) increased from 42% to 61% between 2004 and 2005.

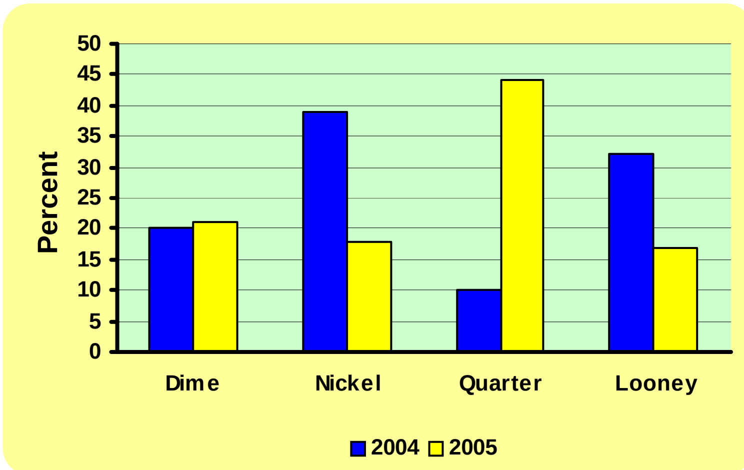


**Figure 5. Gypsy moth egg mass sizes in 2004 and 2005 in the City of Mississauga.**

**Gypsy Moth Egg Mass Distribution:** City survey crews assessed the vertical distribution of egg masses along the main stem of infested trees. The proportion of egg masses in each height class (0-1 m, 1-3 m, 3-10 m, and >10 m) provides an indication of the potential impact of homeowner actions such as egg mass scraping. In 2005, more than 70% of the egg masses counted were above 10 m on the main stem where it is difficult for homeowners to implement management options from the ground.

**Gypsy Moth Egg Masses -New/Old Ratio:** The proportion of new and old egg masses is an indicator of population vigour. A high proportion of new egg masses indicates a healthy, growing population while a high proportion of old egg masses suggests a population in decline. Estimates of the new/old egg mass ratio were not available for 2005.

**Natural controls:** BioForest consulted with Mr. Hugh Evans, Forest Health Technician with the Canadian Forest Service, who is responsible for conducting forest health surveys in the Mississauga area. Mr. Evans viewed the damage from the ground and from the air in 2005. He did not observe evidence of a build-up of the NPV or E. *maimaiga* during his surveys. This is further evidence that the population is unlikely to collapse in 2006 and that defoliation will be severe in areas with high egg mass densities.

## 2.3 2006 Defoliation Forecasts in Mississauga

Gypsy moth forecast surveys using egg mass densities to predict defoliation are difficult to conduct in the urban environment. Most of the methodologies developed to date are suitable for forested environments, but are not easily adapted to the city where tree species and tree densities can vary considerably and where access is often limited. City crews conducted surveys in parks and along residential streets to assess 2005 egg mass densities, egg mass size and egg mass distribution. A forecast map was then developed based on a calculation of the density of gypsy moth egg masses per hectare, the standard measure for temporal and spatial comparisons of populations and defoliation forecasts. The method developed and applied by the City survey crews to assess gypsy moth egg mass densities and the subsequent extrapolations to calculate densities per hectare is untested but appears essentially sound.

Overall, an average of 37 (SD = 142) egg masses were observed on the trees examined. There was considerable variability in the data as demonstrated by the high standard deviation. The minimum count on individual trees was 0 and the maximum was 3250. Results of the City's egg mass survey and calculations of gypsy egg mass densities show high densities, or moderate to severe defoliation forecasts, occur in about 25% of the 184 one hectare quadrants (Figure 6). Wards 1 and 7 appear to have the highest gypsy moth populations, with the lowest populations in Ward 6.

The results were reviewed by BioForest staff who developed and used an alternate forecast method in an attempt to validate the City forecast for 2006. The method used by BioForest was also untested but was based on the sequential survey methodology developed by Fleischer *et al*. (1992) for urban environments. As with the City survey, BioForest staff made several assumptions and extrapolations to generate the forecasts for 2006 defoliation.

Results of the BioForest analysis showed that 63% of the one hectare quadrants had moderate to severe defoliation forecasts for 2006 (Figure 7). All Wards had at least one quadrant with a moderate to severe defoliation forecast, but the highest populations appear to be in Wards 1, 2, and 7.

When the analytical methods were compared, a clear shift towards more severe defoliation forecasts was evident in the BioForest predictions for each Ward (Figure 8). More detailed gypsy moth defoliation forecast maps comparing the two analyses are provided in Appendix A.

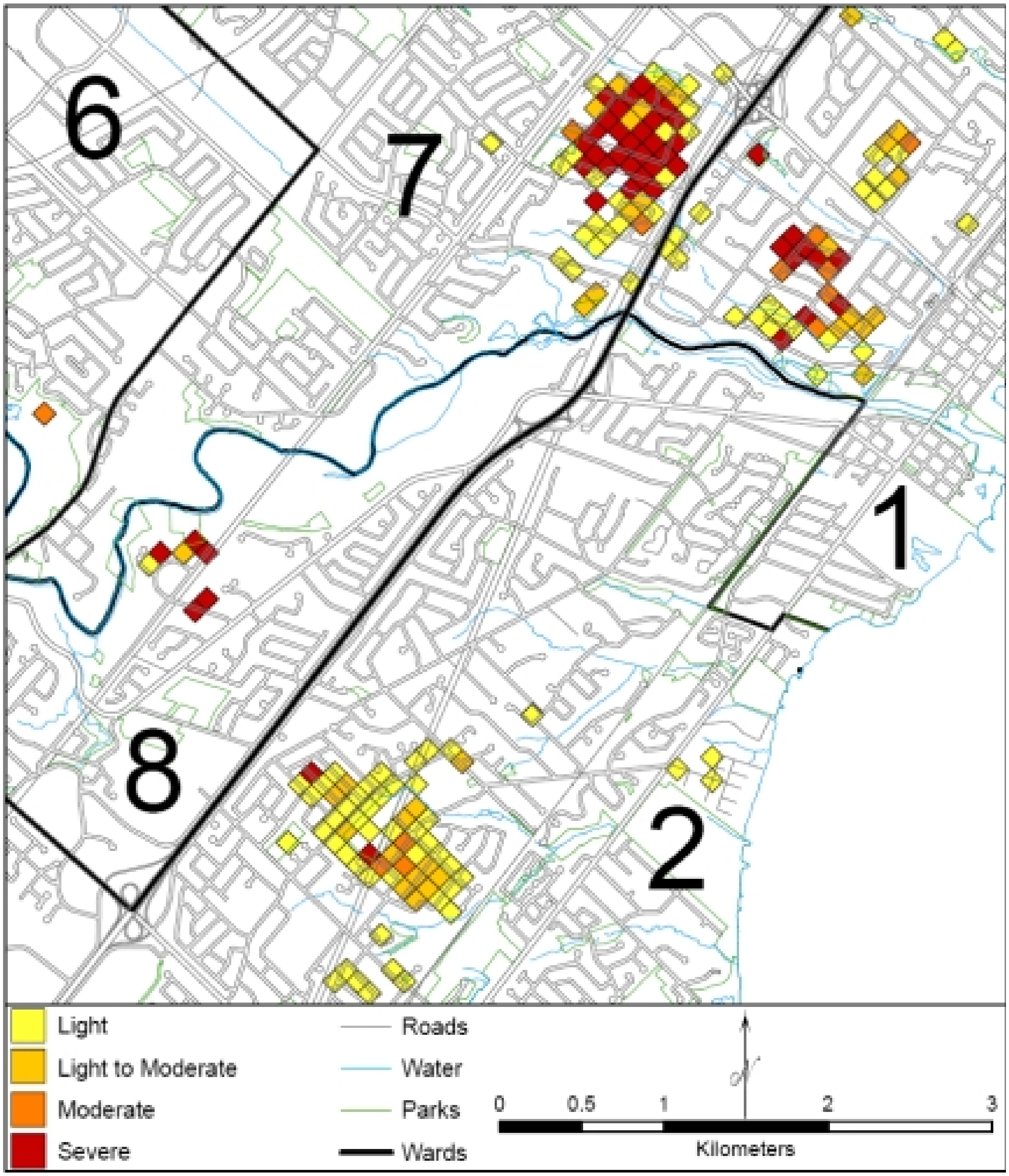


**Figure 6. Gypsy moth defoliation forecasts for 2006 based on the results of the City gypsy moth egg mass surveys conducted in 2005.**

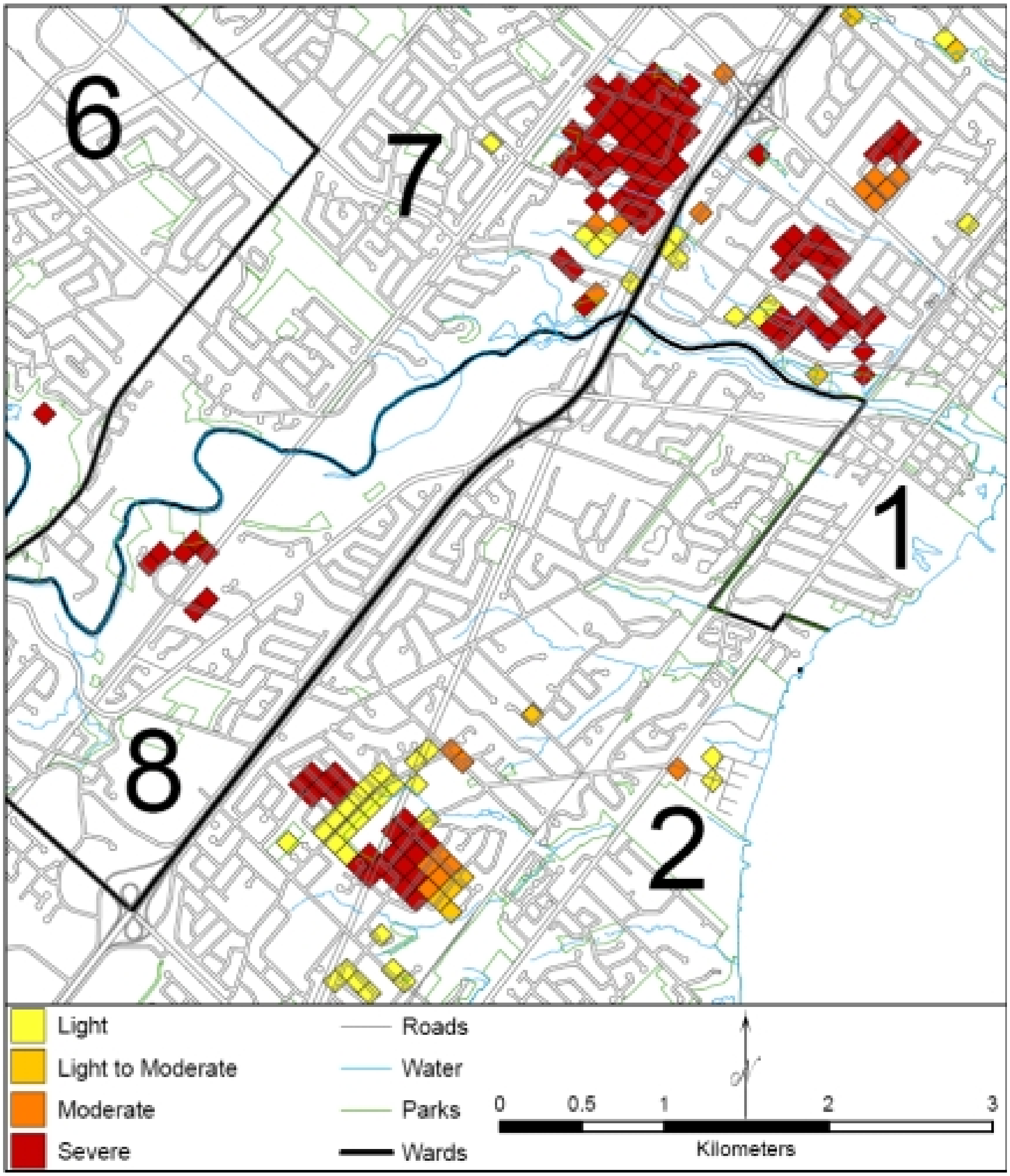


**Figure 7. Gypsy moth defoliation forecasts for 2006 calculated by BioForest Technologies based on the results of the City gypsy moth egg mass surveys conducted in 2005.**

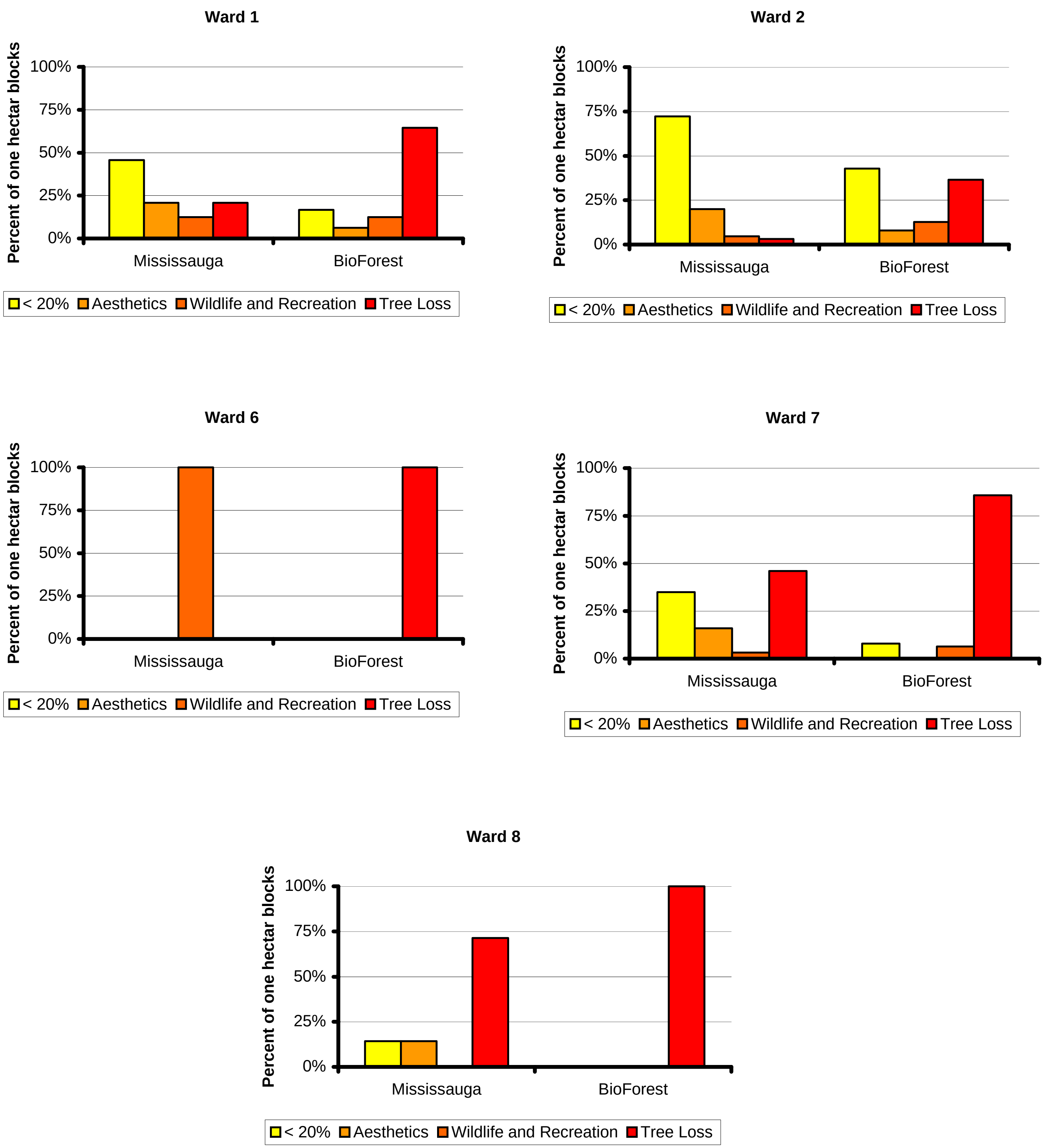


**Figure 8. A comparison of gypsy moth defoliation categories using two analytical methods for egg mass data collected in Wards 1, 2, 6, 7, and 8 of the City of Mississauga in 2005.**

The true levels of gypsy moth defoliation will likely be somewhere in between the forecasts generated by the two methods. Even when standard forecast methods are used in the natural forest, gypsy moth defoliation is difficult to predict with a high degree of probability. As noted earlier in this report, gypsy moth populations are subject to a wide variety of biotic and abiotic factors that complicate the forecasting process. The data collected by City staff does delineate quite well the areas likely to be affected in 2006. The data also shows very high egg mass densities in some areas of the City and much more variable densities in other areas. It should be noted that the forecasts are based on observed egg masses on trees in residential areas and parks. Depending on site conditions, there may be as many egg masses hidden on the ground, on debris and on backyard structures as observed on the trees. Defoliation is likely in all areas where egg masses have been observed.

Overall, the City gypsy moth egg mass survey was very thorough and the extensive data set provided by the assessment of some 1800 trees provides a very good base for predicting defoliation levels in 2006 and for making intervention decisions.

## 2.4 Potential Impacts of No Intervention

Despite its arrival in North America in 1869, gypsy moth is a relatively new pest in the forests of Canada. It joins a number of other native insect pests, such as the forest tent caterpillar (*Malacosoma distria*), as a potential defoliator of many different tree species and is, therefore, another potential stress on our forests. The impacts of concurrent or sequential outbreaks of these defoliators are not completely understood, but evidence suggests that tree condition is more severely affected and tree mortality is more likely to occur. The analysis is made even more complex when abiotic factors such as drought, increased SMOG and increased ozone levels are a reality in the urban environment.

The urban environment, while in many ways similar to forested environments, generally involves several unique features that influence pest problems (Coulson and Witter 1984) and consequently management strategies. For example, in urban environments:

- the diversity of valued host species is generally greater;
- host trees consist of both native and exotic species;
- there is usually a greater range of age-classes of host trees;
- mature, and often senescent trees, are especially valued.

Urban trees are under considerable stress. The urban forest is subject to a wide variety of disturbance factors that generally reduce tree vigour and increase susceptibility to pests. These disturbances include: road construction, transmission line clearing, building construction, sidewalks, driveways and photochemical oxidation. Therefore, predicting the impacts of a gypsy moth outbreak in the natural forest is different than in the urban setting.

### 2.4.1 Environmental Impacts

Environmental impacts of a gypsy moth outbreak will be greatly influenced by a number of factors including forest composition, forest age, stand vigour, soils and climate. Some general observations from previous outbreaks are:

- Generally, areas of mature to overmature forests with a high composition of host tree species will be the most heavily impacted by gypsy moth defoliation;
- Vigourous trees can usually withstand severe defoliation for a few years. Eventually these trees will become more susceptible to attack by secondary pests such as two-lined chestnut borer and Armillaria root rot;
- Heavy defoliation over large areas of forest reduces water use by the trees and can result in increased fluctuations in run-off (Benoit and Lachance 1990);
- In heavily defoliated areas, sunlight falls directly onto ground vegetation and soils, raising temperatures. This may drive away predators such as snakes, lizards and frogs and may cause root damage and increase the effects of drought;
- Some thin-barked tree species may be damaged by the sudden increase in sunlight penetration;
- The aesthetic value of treed areas within the city is lessened and their utility as windbreaks and privacy barriers is reduced;
- Several years of heavy defoliation may kill host trees and, therefore, reduce the proportion of susceptible host trees in an area. This is a slow process, but may ultimately reduce the susceptibility of the stand by increasing the proportion of less susceptible tree species;
- Less favoured food species and understory vegetation may benefit indirectly from gypsy moth defoliation through increases in light, moisture and nutrients (Campbell 1979);
- Gypsy moth infestations can have positive and negative effects on wildlife. Defoliation of the overstory can result in more growth of shrubs, grasses, and herbs, which provides additional habitat for some wildlife species. In some cases, however, defoliation may reduce or compromise habitat for some wildlife species. For example, defoliation may make bird eggs vulnerable to predation due to the reduction in protection from a tree's foliage (Gottschalk 1993);
- Gypsy moth outbreaks can also impact waterways. For example, increases in frass, or droppings, and leaves into streams can reduce the quality of the water. Loss of canopy cover due to gypsy moth defoliation can cause the temperature of streams to increase, which can have harmful effects on organisms in the streams (Gottschalk 1993).

### 2.4.2 Human Health

During low population periods there is little human exposure to the gypsy moth life stages. However, as populations increase, children and others who spend a lot of time outdoors can be affected in a number of ways (USDA 1995b):

- Allergic reactions in some people to the gypsy moth larval hairs, the hairs that coat egg masses, and wing scales have been reported;
- Rashes or other skin irritations from contact with caterpillars;
- Eye irritation;
- Respiratory tract irritations;
- Some individuals may be psychologically affected by high numbers of caterpillars or adverse effects of the outbreak on local aesthetics;
- Safety hazards may be created when caterpillars and their droppings make walkways and roads slippery;
- Dead or dying trees caused by gypsy moth defoliation can pose a hazard as tree crowns deteriorate and dead limbs break and fall to the ground.

Indirect human health effects can result from damage caused by the gypsy moth to the urban environment. These include:

- Increased air pollution;
- Local climate extremes;
- Increased noise pollution.

### *2.4.3 Economic Impacts*

Gypsy moth outbreaks can impact local or regional economies. Outdoor activities can be reduced significantly when gypsy moth populations are high, thus impacting recreation and tourism businesses. Repeated defoliations can affect the aesthetics of an area, reducing the numbers of visitors for periods of several years beyond the duration of the outbreak. Property owners may incur costs for:

- treating the gypsy moth with a pesticide;
- removing caterpillars or their droppings;
- removing egg masses;
- repainting buildings;
- pruning or removing trees;
- replacing damaged or dead trees and shrubs;
- increased liability for damage or injuries sustained from falling trees and branches.

Studies have also shown the contribution of trees to the overall property value of a residence. In an early study, Payne (1971) evaluated the contribution of trees to the property values in Massachusetts and found that they contributed an average of 7% and as much as 15% to the value of a residence. More recent valuations can be found in Miller (1996).

Economic impacts to the City of Mississauga could include:

- increased tree removal and replacement costs;
- loss of aesthetics in parks and woodlands resulting in reduced use;

- increased tree inspection costs;
- increased tree pruning and maintenance costs;
- potential liability costs for damage to property and personal injury.

# 3 Management Options: An Integrated Pest Management Approach

While definitions of Integrated Pest Management (IPM) vary, it is essentially a philosophy, concept and methodology for dealing with destructive insects and diseases affecting trees either in an urban environment or in the natural forest (Coulson and Witter 1984). Waters (1974) provides a good definition:

*"IPM is the maintenance of destructive agents, including insects, at tolerable levels by the planned use of preventive, suppressive, or regulatory tactics and strategies that are ecologically and economically efficient and socially acceptable."*

Components of an IPM strategy include: pest surveys and monitoring, and a decision-making process based on surveys and other supportive data (Reardon *et al*. 1987). In the case of gypsy moth this could include:

- egg mass densities and quality;
- larval and pupal counts;
- male moth captures;
- defoliation estimates;
- area affected;
- stand susceptibility;
- environmental sensitivity;
- parasite and disease incidence.

The decision-making process in an IPM strategy results from an evaluation of treatment options available and an analysis of impacts. Information requirements include knowledge of pest biology and population dynamics, tree impacts and stand dynamics. The final component of the IPM strategy is a benefit-cost analysis. In the urban forest everyone is a potential participant in the implementation process.

The options described in this report reflect the philosophy of an IPM system for gypsy moth control. The overall strategy is to maintain gypsy moth populations at tolerable levels in terms of tree impacts and effects on human health and safety. The tactics employed will be influenced by the status of the gypsy moth population at any point in time but, to be effective, strategies and tactics must be communicated and implemented.

The application of an IPM system will not eradicate the gypsy moth from the forests and streets of the City of Mississauga. That is not the goal of an IPM system and it would imply a degree of knowledge about this pest that scientists and pest management practitioners do not have. Therefore, outbreaks of the gypsy moth will most certainly occur again in the future. The objective of an IPM system is to reduce the frequency and severity of future outbreaks.

## 3.1 Do Nothing

The "do nothing" option is the one most often chosen for most pest outbreaks in Canada. A review of major pest outbreaks and control efforts in North America between 1985 and 1997 showed that of the 156,549,000 hectares infested by pests such as the gypsy moth, spruce budworm and hemlock looper, only 13,841,000 hectares, or 9%, were actually treated with an aerial application of an insecticide (Hayes *et al*. 1998). Doing nothing is always an option to be considered and may be the most practical option in specific areas of the current gypsy moth outbreak.

Pest outbreaks come and go. Based on the historical record of gypsy moth in North America and Ontario, it is likely that the current outbreak in the City of Mississauga will collapse naturally over the next several years. As described in section 1.1.4 of this report, predators, parasites and pathogens will bring about a significant decrease in gypsy moth populations to low endemic levels. The pest will exist at these low population levels until conditions allow for another rapid rise to outbreak levels.

Potential consequences of the "do nothing" option are described in section 2.4 of this report. It should be noted, however, that the nuisance factor resulting from gypsy moth/human contacts and experiences in the outbreak will be variable but frequent in some areas, forcing residents to respond with their own management efforts. This is a concern because in some cases residents will choose to mitigate impacts to their properties by applying pesticides on their own or through a commercial tree care company. **The end result of potentially hundreds of property owners taking their own control measures is a significant increase in the overall use of pesticides in the area and the consequent increased risk of exposure for users, bystanders and the environment. Thus, in urban and suburban areas, the "do nothing" option may actually result in an increase in pesticide use.** Other innovative control measures employed by homeowners may not be very effective and some may actually cause more harm than good to trees.

## 3.2 Gypsy Moth Management Options

### *3.2.1 Maintain or Enhance Tree Health*

Trees stressed by other factors such as drought or disease are more vulnerable to defoliation caused by insect pests such as the gypsy moth or to attack by secondary pests such as the two-lined chestnut borer and Armillaria root rot. Therefore, efforts should be made to maintain or improve tree vigour and property owners should be encouraged consider the following (McManus *et al*. 1979):

- Maintain good soil conditions to encourage the development of the tree's fine feeder roots. Many activities such as construction, cutting and filling, paving, changing grades and tree removal can have harmful effects on soil/moisture relations;
- In wooded areas or in transition zones between lawns and forested areas, keep the forest floor as natural as possible. Oaks thrive under acidic soil conditions, so removal of the organic acid-rich leaf litter can be harmful;
- Maintain the natural layers of leaf litter to reduce drying in the surface soils where most of the tree's feeder roots occur. This will also provide natural habitat for mice and shrews, predators of gypsy moth larvae and pupae;
- Mulching isolated trees growing on lawns will also improve growing conditions. Mulch out to the edge of the canopy drip line to reduce competition from grasses which compete for soil moisture and nutrients;
- Water trees during periods of drought. A light pruning will thin the crown and reduce moisture demands.

### *3.2.2 Low Population Strategies*

During periods when gypsy moth populations are low, homeowners can mitigate future outbreaks by:

- cleaning yards of objects that may provide shelter for gypsy moth larvae, pupae and egg masses (e.g. dead branches and trees, stumps, and debris such as boxes, tires, containers etc.);
- diversifying the tree species in an area to reduce the proportion of preferred gypsy moth species. Select tree species most compatible with the local climate and soil conditions to encourage tree vigour.

### *3.2.3 Destroy Egg Masses*

Finding and destroying egg masses is a management technique that homeowners can use to reduce gypsy moth damage on their properties. Finding egg masses on trees is easiest from fall until early spring when the leaves are off the trees. Egg masses can be found on tree trunks, under branches, on rocks, woodpiles, fences, or almost any other surface. Egg masses can be scraped into a container of soapy water (e.g. one teaspoon of detergent in 1 L of water) and soaked for one week or scraped into containers of household bleach or ammonia. Egg masses should not be simply scraped onto the ground because this will not prevent them from hatching. It is important to wear gloves when removing and destroying egg masses because many people are sensitive to the hairs that cover egg masses.

When searching for egg masses, old ones can be distinguished from new ones because they are softer than new ones and have a bleached appearance (Figure 9a). While it is not necessary to destroy old egg masses, in many cases it easier to simply destroy both types.


a

b

**Figure 9. Gypsy moth management photos: a) New and old gypsy moth egg masses; and b) Burlap band wrapped around tree to capture gypsy moth larvae.**

### *3.2.4 Barrier Bands*

Barrier bands intercept larvae crawling up and down trees. Barriers can be created using sticky material applied to bands wrapped around tree trunks. To make barrier bands, wrap duct tape (sticky side towards bark) or tar paper around the trunk of a tree in overlapping bands about 1.5 m from the ground. The total width of the band should be at least 12.5 cm. Press the band into the bark crevices so that the larvae cannot crawl underneath the band. Tuck the edges of the tape or paper into the bark and apply a vegetable-based sticky material to the band. **Do not apply sticky substances directly to the tree trunk.** Sticky substances can kill thin-barked trees and will leave permanent dark stains on all trees. Avoid petroleum-based products because they may cause swelling and cankering on thin-barked trees. The small insects will get caught in the sticky material as they crawl on the trees. Replace the sticky bands as they get covered with larvae and dirt. Larvae can be destroyed by dropping them in buckets of soapy water (e.g. one teaspoon of detergent in 1 L of water) and letting them soak for one week. It is important to wear gloves when removing and destroying larvae because many people are sensitive to the larval hairs. Barrier bands can be removed when they are no longer catching gypsy moth larvae or when the larvae have pupated.

### *3.2.5 Burlap Bands*

Burlap bands wrapped around trees is a control method that takes advantage of the movement of larvae during the day. Fourth, fifth and sixth instar larvae do most of their feeding at night and seek protection from the sun and predators during the day by, in some cases, crawling to the ground for shelter in dead leaves and underbrush. Burlap bands wrapped around trees will intercept larval movement and the larvae will seek shelter in the bands (Figure 9b). The larvae can then be removed from the bands and destroyed.

Hiding bands can be made using cloth or burlap. Bands should be 30-45 cm wide and fastened to trees at chest height. Use twine to loosely tie the middle of the bands to the trees and fold the tops of bands over the bottoms. Bands must be checked and larvae removed daily because the bands will neither kill the larvae nor keep them from crawling back up the tree. Late afternoon is the best time to remove larvae. Larvae can be destroyed by dropping them into buckets of soapy water (e.g. one teaspoon of detergent in 1 L of water) and letting them soak for one week. It is important to wear gloves when removing and destroying larvae because many people are sensitive to the larval hairs. Burlap banding is a popular method of control but, if done improperly, can cause more damage to trees than gypsy moth. For example, foil and plastic wrap should never be wrapped around a tree in place of burlap or cloth because they can scar or kill the tree.

### *3.2.6 Homeowner Sprays*

Homeowners can use insecticides for small scale treatment of shrubs and small trees on their properties. Insecticides registered in Canada for control of gypsy moth include *Bacillus thuringiensis* (Btk), carbaryl, pyrethrin, phosmet, and permethrin. Homeowners should follow all pesticide label instructions.

### *3.2.7 Aerial Spraying of Btk*

**Forest Pest Management and Intervention Thresholds:** Before any gypsy moth management decisions can be made, it is critical to determine the population levels and to clearly define the forest management objectives of the intervention. Typically, the treatment objectives or goals within an infested area include population suppression, prevention of defoliation or a combination of both. Counts of overwintering egg mass populations are generally used to make these decisions for gypsy moth infestations.

Gypsy moth egg mass densities expressed as a number **per unit ground area** are used to predict defoliation levels. It should be noted, however, that there is no magic formula for interpreting the results of an egg mass survey (Liebhold *et al*. 1994). Research has shown that there is a great deal of “scatter” about density/defoliation forecast relationships and therefore considerable uncertainty. This uncertainty is important to consider when management decisions are made. For example, for densities between 250 and 2500 egg masses per hectare, defoliation may vary between 0 and 100% regardless of the estimated density (Liebhold *et al.* 1994).

The following factors can be assessed to more clearly forecast expected outcomes:

**Egg mass size** is an important indicator of the condition of the gypsy moth population. Small egg masses (<20 mm in length) suggest a declining population while large egg masses (>30 mm in length) suggest an increasing population.

The **proportion of new and old egg masses** is also an important characteristic. Large numbers of old egg masses (> 50% old) indicate a declining population whereas a low proportion of old egg masses (< 25%) suggests that the population is building.

**Distribution of gypsy moth egg masses** may be influenced by tree species composition and ground cover. When a disproportionate number of egg masses are laid high along the main stem of trees, it is more difficult for homeowners to significantly reduce gypsy moth populations by removing egg masses.

**Intervention thresholds** are defined by the management objectives and could include **nuisance abatement**, **foliage protection**, and **prevention of tree mortality** or a combination of these objectives. The relationships between egg mass density and subsequent damage (defoliation) will guide the manager in establishing these thresholds, which in turn will determine when and where treatments are needed (Table 3). For example, in hardwood forests:

- Damage is not noticeable from the air until defoliation levels reach about 30%;
- Growth loss in trees begins when defoliation reaches about 40%;
- Refoliation occurs when about 60% of the foliage is lost. This can cause a reduction in the tree's overall health and survival.

**Table 3. Intervention thresholds based on gypsy moth egg mass densities and expected defoliation rates.**

| Management objective | Egg masses per hectare |
|---|---|
| Prevent noticeable defoliation | 1250 |
| Prevent growth loss | 1750 |
| Prevent tree mortality | 2500 |
| Widely used threshold* | 600 |

* This threshold has been used in forest and residential areas and, while it may be justified for reducing nuisance impacts, it may not be justified for other management objectives (Liebhold *et al.* 1994).

Of course, managers may lower treatment thresholds if stands have experienced other stress factors, such as drought, that may predispose trees to mortality. General stand condition/vigour must also be considered. This can be influenced by tree age and human related disturbances to the environment that negatively affect tree health.

The density at which gypsy moths become a nuisance in residential or recreational areas is not well established. The sight of one or two larvae may be intolerable for some individuals, while others may be comfortable with much higher populations.

It must be noted and understood that it is impossible for managers to predict defoliation levels without a certain amount of error.

# 4 Conclusions and Recommendations for 2006

## 4.1 Conclusions

The forest cannot be preserved unchanged. In the absence of any defoliators, forest stands evolve over time, trees die and species compositions change. Since 1981, gypsy moth outbreaks have become another natural agent affecting the oak forests of Ontario. Data from the United States shows that outbreaks of gypsy moth tended to be most prolonged and damaging within the first few decades after the insect had invaded a new area (Campbell 1979). Campbell (1979) noted that defoliation and subsequent tree mortality in the United States has had more economic impact among roadside, park and ornamental trees than among trees within the forest. The gypsy moth outbreak history in Ontario appears to support Campbell's (1979) observations. Extent and severity of outbreaks after the initial events in the 1980s and early 1990s suggest that recent outbreaks are less severe and short lived (Figure 2). Nevertheless, the current outbreak in the City of Mississauga appears to be building and egg mass data indicate there will be areas of moderate to severe defoliation in infested areas of the City in 2006.

Historical datasets from the United States have been used to develop a general defoliation /egg mass density relationship used to forecast expected defoliation rates (Figure 10). As noted earlier in this report, there is considerable scatter about the curve generated by this data. Therefore, there is considerable uncertainty about the level of defoliation resulting from any specific egg mass density. The relationship presented in Figure 10 is generally used to predict defoliation based on egg mass densities extrapolated from field surveys (e.g. fixed-area plots).

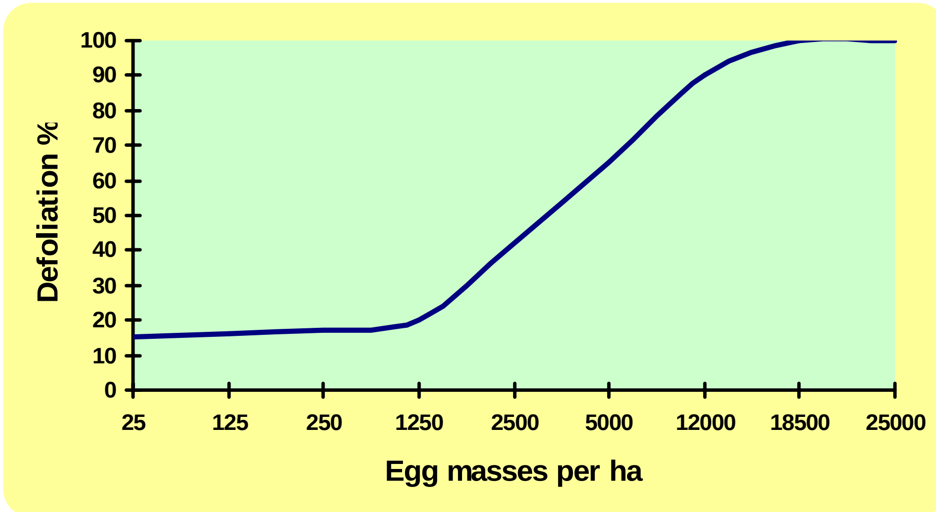


**Figure 10. Relationship between egg mass density and defoliation (Liebhold et al. 1994).**

Decision thresholds are likely to be different for natural forests and urban forests. Trees affected by gypsy moth in the City of Mississauga are often old, majestic oaks that add significant aesthetic value and considerable economic value to residential properties and city parklands. Research has demonstrated the value of trees in the urban environment goes beyond the aesthetic and economic. For example, trees:

- reduce air pollution;
- fight atmospheric greenhouse effect;
- conserve water and reduce soil erosion;
- save energy;
- modify local climate;
- increase economic stability;
- reduce noise pollution;
- create wildlife and plant diversity.

Environment Canada statistics show that nationally, after 2001 and 1999, 2005 was the third warmest year since records began in 1948. Temperatures have generally been increasing with temperatures above normal for the last nine years (www.msc-smc.ec.gc.ca/ccrm/bulletin/national-e.cfm). In the Toronto area, the number of SMOG Alert days has been increasing steadily since 1993 (Figure 11). If this trend continues, the value of trees in the urban environment can only increase. Therefore significant tree loss due to pest outbreaks must be considered and evaluated in a broader context than just the costs of tree removal and replacement.

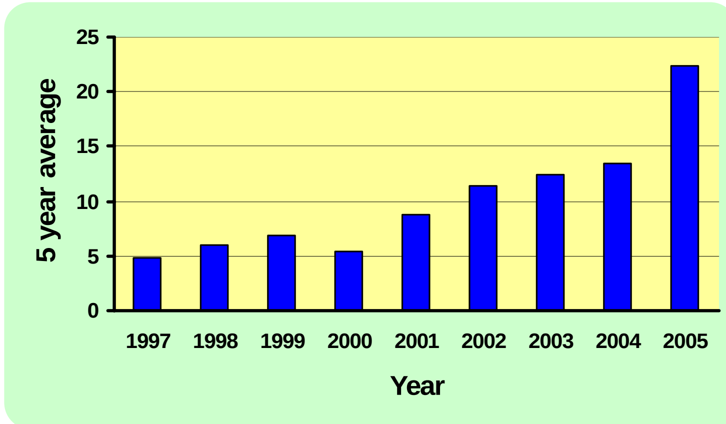


**Figure 11. Five year averages for SMOG Alert days in Toronto area (www.torotno.ca/health/smog/smog-new-htm).**

Tree mortality is normal in any environment and typically averages 1- 2 % per year in natural forests and 5% or more in the urban environment (Nowak *et al*. 2004). Insect and disease outbreaks can accelerate tree mortality, thus reducing the benefits to residents and the urban environment. Damage to forests can be increased when insect outbreaks occur during periods of environmental stress. Short and long term climate changes can increase stress levels on trees making them more susceptible to pests such as the gypsy moth.

## 4.2 Recommendations

1. The City staff have conducted extensive surveys that have effectively delineated the area of the infestation based on detection of new egg masses and has provided forecasts of expected defoliation in 2006 based on estimates of egg mass density. Consequently, we recommend that the forecast maps generated by City staff be used as the basis for delineation of the management actions and implementation of an IPM program to reduce the negative effects of the current gypsy moth outbreak.

2. Gypsy moth egg mass survey data collected by City staff in 2005 show that the gypsy moth populations are likely to be at moderate to high levels throughout most of the delineated infestation in 2006. The analysis conducted by BioForest suggests that the levels of defoliation may be greater than predicted by the City. Egg mass size data suggests a vigorous or building population and past observations indicate that 2006 could be the first year of severe defoliation over large areas. There was no evidence of a build-up of the NPV or *E. maimaiga* in 2005, so a dramatic collapse of populations is unlikely in 2006. Also, the mature nature of many trees and the observed distribution of egg masses along the main stem limit management options from the ground for homeowners and City staff. An additional consideration is the maturity of many trees in the affected areas and the evidence of declining vigor due to age and environmental stresses. Therefore, we

recommend that aerial applications of the bacterial insecticide *Bacillus thuringiensis* var. *kurstaki* (Btk) be conducted in 2006 to reduce impacts on affected trees.

3. Intervention thresholds normally used to protect trees in forested environments (Table 3) may be too high for trees in an urban environment. Many factors associated with the urban environment can reduce tree vigor and increase their susceptibility to insects and diseases. Also, because of the high value of the trees affected and the aesthetic and environmental benefits associated with the affected trees, the City should consider a lower intervention threshold to minimize impact on tree health. This approach may also reduce the potential for expansion of the gypsy moth populations into other areas of the City. We recommend that aerial spraying be conducted over the entire infested area, as delineated by City surveys, to optimize spray efficacy, reduce gypsy moth populations, minimize host tree defoliation and reduce expansion of the outbreak to other areas in the City.

4. Implementation of IPM techniques will help to reduce the susceptibility of City trees to gypsy moth defoliation. Implementation of an IPM program is an ongoing process and must begin before an outbreak occurs and continue during and after an outbreak. Homeowner involvement in these programs is essential. We recommend that the City develop a communications package for informing the public about the benefits of an IPM program for gypsy moth control and provide educational materials detailing alternate control methods such as egg mass scraping and larval trapping.

5. The difficulties of assessing gypsy moth populations in the urban environment have been noted in this report. City staff has done an excellent job of delineating the outbreak and of providing estimates of gypsy moth egg mass densities on individual trees. However, it has been difficult to extrapolate egg mass densities to a standard area unit (e.g. egg masses per hectare) for use in defoliation forecast models developed for forested areas. We recommend that the City initiate discussions with the Ontario Ministry of Natural Resources and the Canadian Forest Service to develop a standardized egg mass survey methodology for use in urban environments in future years.

# 5 Conducting an Aerial Spraying Program

## 5.1 Contracting an Aerial Applicator

The following are recommended elements of an aerial application agreement between the City and an Applicator.

The City of Mississauga intends to conduct aerial applications of the insecticide Btk on wooded areas within the city that are infested with gypsy moth. It is expected that two or three applications, each on approximately 500 hectares will be required.

This is a **full service contract**. The contractor will supply insecticide (Foray 48B), suitably equipped rotary winged aircraft, mixing, loading and refuelling equipment, storage and security for all equipment, meals and accommodations for all contractor staff and all other equipment, supplies, labour and services required to provide the aerial spraying services.

**Aircraft Specifications:** A rotary winged aircraft, duly licensed for application of pesticide in Ontario, must be used. The contractor will supply a rotary winged aircraft equipped for gypsy moth spraying using Foray 48B. The aircraft must be equipped with rotary atomizers.

**Navigation equipment**: The application aircraft must be equipped with a functional Geographical Positioning System (GPS). The GPS system must include:

- An in-cockpit map display device showing spray block boundaries, flight lines, exclusion areas, aircraft position, area sprayed, and swath number.
- A light bar or other visual track guidance indicator, located so the pilot can see the guidance information while looking through the windshield.
- The ability to load and download data to or from a standard 3.5" high-density disk. ARC/INFO data will be supplied to the contractor either on a 3.5" high-density disk or via electronic mail.
- All equipment, materials, personnel, and services required for the system to be used.
- All loading and downloading of data on the GPS unit, and operating the post-processing software as directed by Mississauga officials.
- Positional accuracy of 1-5 m, with 5 Hz or faster update for aircraft positioning. One-second updates shall be used when in flight over the spray block, and no greater than five second updates shall be used when in flight to and from spray blocks.
- A fully logged record for each mission indicating position, time, ground speed, track, booms on/off, and aircraft identification. All flights shall be logged from takeoff to landing.
- Capability to mark a position during flight and return to the precise point where the previous application flight ended.
- Capability to choose and switch flight line directions.
- Capability to select the number(s) of any flight line(s) for re-spray.

The Proponent should include the following information: i) GPS type and model, ii) list of 5 projects, dates, and hectares sprayed using the system specified in the proposal, with reference names and contact telephone numbers.

**Note: Application blocks will be provided to the contractor in shape files and, if requested, hard copy maps.**

**Permits:** The contractor must secure "low flight authority over a built up area" from Transport Canada. The contractor will ensure all equipment and personnel are suitably licensed under the Pesticides Act of Ontario.

**Note: There are aerial insecticide programs elsewhere in Canada that operate under a low flight authority. The City of Winnipeg conducts annual insecticide applications for the control of mosquitoes using helicopters. This is done as a matter of nuisance control and for public health emergencies (e.g. West Nile virus). Aerial application of Btk to control Asian and European gypsy moth has been conducted over built up areas in Delta, B.C. (1998, 1999, 2000, 2001,2003), and Burnaby, B.C. (1999), among other locations.**

**Insecticide:** The contractor will be required to supply sufficient insecticide to complete up to 1500 hectares. The contractor will use Foray 48B, (Registration number 24977), a biological insecticide containing a naturally occurring strain of *Bacillus thuringiensis* var. *kurstaki*.

**Insecticide application rate**: The insecticide will be applied undiluted at a rate of 50 BIU/4.0 l/ha.

**Loading sites:** The contractor will provide the City of Mississauga with the locations of loading sites 48 hours before the anticipated start of the program.

**Flight areas:** The contractor will minimize flight time over built up areas. Wherever possible, transport to the spray sites and return from the spray sites will be over rail lines, parks or other areas without buildings.

**Seasonal spray window:** It is expected the application treatment will occur between April 15 and May 15. However, the seasonal spray window will be defined by insect and foliage development. The City of Mississauga will provide the contractor with 4 days advance of the seasonal spray window.

**Daily spray window:** All spray applications must be completed by 0730 on a daily basis.

**Spray weather:** Applications will occur when winds are between 1-16 kph; temperatures are above 2 degrees Celsius and not more than 25 degrees Celsius; relative humidity not less than 40%.

**Insurance Requirements:** $5,000,000 per occurrence and annual aggregate per policy term; each aircraft; combined limit on bodily injury, property damage, products and completed operations; subject to the following sub limits:

$250,000 per occurrence and annual aggregate per policy term; each aircraft; on bodily injury and property damage; Pesticide Chemical Drift Liability for Off Target Deposition.

It is understood and agreed that for the purposes of this policy, pesticides are not pollutants, contaminants or irritants to the environment.

**Comprehensive General Liability Insurance:** $2,000,000 per occurrence (no aggregates); combined limit on bodily injury, property damage, products and completed operations.

To cover all premises and operations of the insured including storage, mixing, loading and transporting of pesticides. For the purposes of this policy, pesticides are not pollutants, contaminants or irritants to the environment.

**Note: Certificates of Insurance for the above policies including the following endorsements: The City of Mississauga as additional insured; cross liability; contractual liability; thirty (30) days notice of cancellation; must be submitted prior to commencement of work.**

## 5.2 Aerial Spray Operations

### *5.2.1 Number of Applications*

Historical records show that gypsy moth egg hatch generally occurs over several weeks in Ontario. Differential degree day accumulations between egg masses on and above ground are responsible. In order to minimize defoliation under such circumstances, two or more applications may be necessary. Multiple applications should also be considered in areas with building populations.

### *5.2.2 Spray Timing*

Both insect and host development will be monitored and used to determine the timing of Btk applications. There are several phenological models available for predicting gypsy moth egg hatch and subsequent larval development. They are dependent on historical temperature norms and are updated using current year temperatures. These models will be evaluated and, if applicable, used to provide timing information. On site observations will be recorded to validate model predictions.

The following guideline is suggested for timing applications of Btk against the gypsy moth:

- 1st Application – Spray when egg hatch is essentially complete and 50% of the larvae are in the 1st instar and 50% are in the 2nd instar (approximately 10-14 days after peak hatch). Host leaf expansion should be a minimum of 25-50%, to ensure sufficient leaf surface upon which to deposit the spray material;
- 2nd Application – Spray within 5 to 7 days of the 1st application when no more than 25% of the larvae are in the 3rd instar.

### *5.2.3 Spray Weather Parameters*

It is recommended that the Applicator will err on the conservative side when making the decision to halt spraying due to weather. The following weather parameters should be used as a guide for making spraying decisions (OMNR 2001):

- Wind speed in the tree canopy is 1 to 16 kph and steady;
- Avoid temperature inversions;
- Avoid thermal updrafts;
- Avoid applications during periods of fog;
- There should be a <50% chance of precipitation within six hours of the application;
- If rainfall in excess of 25 mm occurs within three hours of a treatment with Btk, re-treatment may be necessary;
- Do not spray if foliage is wet to the point of dripping. Damp foliage is acceptable. A walk through the area to be sprayed should be conducted prior to spraying;
- Relative humidity and temperature should be monitored before and during spray operations and Btk label guidelines followed.

### *5.2.4 Spray Efficacy Assessment*

Gypsy moth aerial spray programs are normally assessed for efficacy by measuring population reduction and defoliation in sprayed and unsprayed plots. The comparative data is used to determine program efficacy. There will likely be few untreated areas in the City's 2006 program so comparisons between treated and untreated areas will be difficult if not impossible. Therefore, program efficacy must be measured against some predetermined objective (e.g. keeping defoliation below 50% in treated areas).

Branch samples will be collected from trees within spray blocks just prior to treatment to assess pre-treatment defoliation levels (typically < 10%). A second foliage sample will be collected at the completion of larval feeding to determine final defoliation levels. Pole pruners will be used to remove a branch from the mid-crown area of the tree and a detailed assessment of defoliation will be conducted (e.g. modified Fettes Method). As well, binoculars will be used to estimate defoliation on two additional branches within the tree crown. Approximately 10-25 trees will be assessed in each spray block.

Egg mass surveys conducted in the fall 2006 should provide some indication of overall population reduction.

### *5.2.5 Spray Deposit Assessment*

Valent BioSciences provides clients with field evaluation kits, called ADAM Kits, for assessment of Btk deposit on foliage. The ADAM Kit will be used to assess spray deposit during each treatment of each spray block. A single branch will be removed from the crown area of several trees within each block within 24 hours of each treatment. Leaf material will be removed as per ADAM Kit instructions and processed to assess Btk deposition. Additional foliage samples will be collected from trees outside and downwind of the spray blocks to assess off-block drift (e.g. at 100, 200, 500, 1000 metres).

## 5.3 The Pesticide: Bacillus thuringiensis var. kurstaki

The recommended Btk formulation for the gypsy moth aerial spray program within the City of Mississauga is Foray 48B, manufactured by Valent BioSciences. This formulation is registered in Canada and has been used extensively in previous aerial control programs against gypsy moth. This formulation has been the subject of numerous human health and environmental impact studies.

### *5.3.1 A Brief History*

The common bacterium, *Bacillus thuringiensis* (Bt) was first isolated about 100 years ago in Japan from silkworm larvae suffering from a disease (Nester et al. 2002). The organism causing the disease was named *Bacillus thuringiensis* by Berliner in 1911 after he isolated it from a diseased flour moth. The first commercial products containing Bt were marketed in France in 1934 and in 1954, T. Angus, from Sault Ste. Marie, demonstrated that the crystalline protein inclusions formed during sporulation were responsible for the insecticidal action. Bt has been sprayed over crops for more than 40 years and by 1995 some 182 Bt products were registered in the United States by the Environmental Protection Agency. Bt formulations are currently used in agriculture, organic farming, public health and forestry.

*Bacillus thuringiensis* is a member of the genus Bacillus, a wide group of gram- positive, aerobic, spore forming bacteria consisting of more than 20 species. Members of the genus Bacillus generally are considered soil bacteria and Bt is common in terrestrial habitats. The two most widely used commercial insecticides are *B. thuringiensis* subsp. k*urstaki* (Btk), which controls lepidopteran species (butterflies and moths), and *B. thuringiensis* subsp. *israelensis* (Bti), which is used to control mosquito and black fly larvae. Bt sprays comprise 1-2% of the global insecticide market with half the current sales used in Canadian forests to control gypsy moth, spruce budworm and other lepidopteran pests.

### *5.3.2 Btk and Human Health*

In Canada, the Pest Management Regulatory Agency (PMRA), a federal agency with Health Canada, is responsible for assessing and registering pesticides under the Pest Control Products Act. Human health and safety assessments are conducted on all formulations submitted for registration. The pesticide manufacturer must provide data on its toxicity, effectiveness and on any residue products. Products must be shown to be non-toxic and non-infective before registration is granted. Canada's regulatory requirements are considered among the strictest in the world.

Registered pesticides are classified into one of three categories: **restricted, commercial** or **domestic**. Information about a registered pesticide is referenced by its Pest Control Product Number (PCP No.) and technical information can be found on the product label. All insecticides registered for aerial application in forested areas are classified as restricted irrespective of their toxicity. The use of either a restricted or commercial pesticide requires an applicator's licence.

Btk is not considered to be a human health hazard by Canada (Health Canada 2000), the United States (U.S. Environmental Protection Agency 1998) or the World Health Organization (World Health Organization 1999). Btk is only toxic to a small group of lepidopteran insects and there have been no documented cases of potential toxicity to humans or other mammals. A number of detailed health studies have been conducted in conjunction with operational aerial spraying programs in recent years: Noble *et al*. (1992), Capital Health Region (1999), and Aer'aqua Medicine (2001). Results consistently showed no health effects in the general population from exposure to Btk during the spray program. There was no relationship found between aggravation of asthma in children and aerial spraying of Btk. Symptoms were reported by individuals, however, follow-up studies showed no increase in emergency room visits during the spray programs, no change in health status that could be attributed to the spray programs and no adverse health patterns in the populations.

Complaints from people living within the spray area generally involved respiratory, eye, skin, nose or throat irritations and headaches. In the Auckland study, the most frequently reported concern was "fear of unspecified future disease."

A more complete review of human health issues and effects of Btk spray programs can be found in a report prepared by AXYS Environmental Consulting Ltd. (2003) for Parks Canada (http://www.axys.net/news/publications.htm).

## 5.4 Regulatory Compliance

There are several acts, regulations, policies and procedures that govern and influence aerial spraying in Ontario. Several key acts are described and others referenced.

### *5.4.1 The Pest Control Products Act*

The Pest Control Products Act is federal legislation governing the registration and sale of pesticides. The process of federally registering a pesticide includes a review of the potential health and environmental effects and the efficacy of the product.

Any pesticide used operationally in forestry must be federally registered. Pesticides must have a Pest Control Products Act number (PCP number) to be legal for operational use. The pesticide label will, in most cases, specifically state that the product is registered and available for the specific use that is being proposed. For example, a product will be registered for aerial application to protect foliage from damage caused by gypsy moth. Occasionally, and this is the case more often with less recently registered products, the label will be less specific. For example, the label may indicate that the product is approved for aerial application against defoliating insects. In this case, it is important to confirm the status of the product with the Ministry of the Environment (MOE) and the Pest Management Regulatory Agency (PMRA) early in the planning process.

Pesticides federally approved for aerial application in forests or woodlands in Canada are sold as “restricted” products. This means that a provincial permit authorizing the specific use of the pesticide is required (MOE Form 5, *Permit to Conduct an Extermination from an Airborne Machine*).

The label contains a substantial amount of information that is useful to the applicator and the project manager. It is a legally binding document. It will provide instruction and precaution on first aid, on potential environmental effects, on human health concerns, if any, and specific recommendations on use patterns.

### *5.4.2 Ontario Pesticides Act and Regulation 914*

The Ontario Pesticides Act (Pesticides Act) governs the use of all pesticides in Ontario. Following federal registration, pesticides are provincially reviewed, and scheduled for use. The pesticide must be provincially scheduled prior to use in the Province.

The Pesticides Act contains directions pertaining to aerial spraying. Project supervisors and contractors should be very familiar with the Act. Permits are not required to conduct aerial spraying on municipal land, however, all aspects of the legislation must be followed. Specific directions from the Act include:

**Operator's licence:**

The contractor applying pesticide must have a valid MOE operator's licence.

**Applicator's licence:**

The applicator must have a valid MOE extermination licence (aerial). Note that the applicator is directly accountable for the application and will be charged for any infractions under the Pesticide Act.

**Posting:**

All spray blocks need to be "posted" at all known points of public access to the block. These include roads, canoe routes, hiking trails, etc. The posting must be done with signs approved by MOE.

**Pesticide type:**

The pesticide being used must be federally registered, provincially approved and scheduled, and specifically endorsed on its label for aerial application in forest or woodlands. There are a number of situations in which manufacturers have packaged identical or near-identical products under different name brands, with one name brand listing forestry applications as an approved use and the other listing agriculture or horticultural uses. Although the products may be identical except for the name and approvals, only the products specifying forestry applications on the label are legal for use in aerial applications.

**Pesticide storage:**

Pesticides must be stored in a safe and secure manner. Acceptable field storage typically involves security such as a lockable snow fence, staffed security (a crew trailer on site) and posting of the area with pesticide warning signs.

Sections of the Pesticides Act and regulations that are pertinent to aerial spraying are listed below:

**Sec. 4** A pesticide may be discharged or applied if carried out in a proper manner so that it does not:

a. Impair the quality of the environment
b. Damage plant or animal life
c. Cause material discomfort to persons
d. Affect or endanger health
e. Impair safety
f. Render property, plants or animals unfit

| | |
|---|---|
| **Sec. 5(1)** | An exterminator's licence is required. |
| **Sec. 5(2)** | An operator's licence is required. |
| **Sec. 7(1)** | A permit is required. |
| **Sec. 9** | The operator carries the insurance. |
| **Sec. 11(3)** | The director may impose conditions on a permit. |
| **Sec. 229** | The director must be notified of damage or impairment. |

The following general regulations under the Pesticides Act apply to aerial spray operations:

| | |
|---|---|
| **Sec. 20** | Insurance requirements are set. |
| **Sec. 22(1)** | Pesticides must be registered under the Pest Control Products Act, Canada. |
| **Sec. 22(3)** | Federal research permits are needed. |
| **Sec. 25 (1)** | A backflow device is required when sprayers are being filled from surface sources of water. |
| **Sec. 25(2)** | Do not wash equipment in surface water. |
| **Sec. 246(2)** | Where a pesticide is transferred to a secondary container, a label with the common name and concentration of the active ingredient is required. |
| **Sec. 27** | Disposal of empty containers for schedules 1, 2 and 5. |
| **Sec. 28** | Broken container: replace with a similar container. Approval for disposal of contents. |
| **Sec. 29** | Fires, accidents and theft. The person responsible for the pesticide must notify the director. |
| **Sec. 89** | Aerial licences are required for aerial application. |
| **Sec. 88** | Airborne machine application requires a permit for schedule 1 and 5 pesticides or schedule 2 pesticides containing a "hormonal type herbicide" only. |
| **Sec. 88(3)** | A permit is required for spraying of Crown timber with any pesticide. |
| **Sec. 90(b)** | The pilot must not assist in the loading or otherwise expose himself to a pesticide. |
| **Sec. 91(1)** | The exterminator or pilot keeps records on Form 6. |
| **Sec. 91(2)** | The pilot or operator must provide the required record to the provincial officer. |
| **Sec. 119/122** | The storage area must be separate from food-storage areas, ventilated, and locked. It must be posted with a warning sign, it must have no flood drain, and adequate respiratory protection must be available. |

### *5.4.3 Environmental Protection Act*

The Environmental Protection Act regulates discharges of potential pollutants to air and water. Part 9 of the Act, the "Spills Bill", provides the following direction in the event of a spill of any material that might be deleterious to the environment (i.e. pesticides or fuel):

- A spill is defined as a discharge of a pollutant "into the natural environment… that is abnormal in quality or quantity…"
- If a spill occurs, the discharger is to notify MOE immediately (Spills Action Centre, 1-800-268-6060) and to advise the municipality where the spill occurred.
- A duty to clean up is imposed on the owner and the person in charge.
- The discharger has right of entry to property for cleanup.
- Approval is required for disposal of spill material.

### *5.4.4 Other Relevant Acts, Regulations and Policies*

Other relevant acts, regulations and policies include:

- Transportation of Dangerous Good Act;
- Environmental Assessment Act;
- Aeronautics Act of Canada – Canadian Aircraft Regulations;
- Occupational Health and Safety Act;
- Worker's Compensation Act
- Workplace Safety and Insurance Board (WSIB).

## 5.5 Communications Plan

The City of Mississauga has developed a comprehensive Communications Plan for the 2005-2006 Gypsy Moth Program.

### *5.5.1 Community Outreach and Education*

Implementation of an IPM program for managing the gypsy moth and reducing damage will require an effective education program. A thorough understanding of the pest and its environment is an important first step towards proper pest management. A first step towards the development of a community outreach and education program is to identify the target audience (e.g. homeowners, schools and educators, nursery operators, and arborists).

Educational resources are available from a variety of sources including:

- Canadian Forest Service, Great Lakes Forestry Centre;
- Canadian Food Inspection Agency;
- Pest Management Regulatory Agency, Health Canada;
- International Society of Arboriculture;
- Ontario Ministry of Natural Resources;
- Ontario Ministry of Agriculture, Food and Rural Affairs;

- U.S. Department of Agriculture, Forest Service;
- University departments of entomology, forestry and natural resources.

## 5.6 Safety Plan

The key elements of a safety plan for aerial applications of pesticides over residential areas should include consideration for the safety of:

- the public;
- City staff involved in the program;
- applicator staff.

A safety officer from the City should be designated for the project to work with the applicator and be responsible for:

a. locating "no smoking" areas;
b. instructing all personnel in aircraft safety procedures;
c. instructing all staff in WHMIS;
d. operating the mobile first-aid station and provide training in first-aid procedures;
e. advising MOL of the work location;
f. inspecting the mixing site, chemical storage site, etc., to identify safety and fire hazards;
g. promptly completing all forms;
h. ensuring that air operations are safe;
i. having Pesticide Handling and Safety Handbook (Health and Welfare Canada 1988), Ontario Health and Safety Act and Regulations handbook, and Pesticides Safety Handbook (MOE 1986) available;
j. being fully familiar with emergency procedures;
k. having a list of all emergency inventory;
l. maintaining a daily diary;
m. watching for fatigue among the program staff.

### *5.6.1 Example - Safety Plan*

**Personnel training:** All personnel in the spray program will be trained to avoid the known hazards involved in aerial spraying operations. Training will take place in the following areas:

> **First aid:** The project supervisor and the safety officer designated by the contractor will have current St. John's Ambulance standard first aid certificates or equivalent and CPR.

**Aircraft Awareness:** The safety officer will ensure that all personnel working in or around aircraft have been properly briefed on the hazards associated with aircraft, including:

- Fuel management/smoking
- Propeller wash
- Hazards around moving propellers
- Hazards around aircraft flaps
- Communications with pilots in aircraft
- Approaching aircraft
- Exhaust stack hazard
- Ear and eye protection.

**Fire prevention:** "No-smoking" zones around the fuel and aircraft will be observed and enforced. The MSDS will be reviewed in advance to determine the hazards associated with pesticide and fuel fires.

**Pesticide handling:** Personnel will be trained in the proper use of personal safety equipment. All personnel likely to be exposed to pesticides will review Health Canada's "*Pesticide Handling - A Safety Handbook*". The safety officer will ensure that all personnel have reviewed the MSDS for aviation fuel and Btk.

**Emergency response:** The safety officer will conduct training sessions with all staff to rehearse roles and activities in the event of a fire, pesticide spill, vehicle accident or aircraft accident. Specific procedures are outlined under Emergency plans.

### *5.6.2 Emergency plans*

**Emergency phone numbers:**

Police:
Hospitals:
Air Ambulance:
Poison Control:
Marine & Air Search and Rescue (Trenton):
Ministry of Environment
    24-hour Spills Action Centre:
    Regional Office:
Ministry of Labor:

**Emergency plan for personal injuries or medical emergencies:**

The procedures for reporting personal injuries or vehicle accidents are the same for aerial spray programs as they are for other municipal operations.

1. Anyone who witnesses an injury or discovers a casualty is to notify the project supervisor and safety officer.
2. The safety officer will treat the injuries following standard first-aid procedures and transport the casualty to hospital if necessary.

**Critical injury - defined (R.R.0. 1990, Regulation 834):**

Critically injured refers to an injury of a serious nature that:

- places life in jeopardy;
- produces unconsciousness;
- results in substantial loss of blood;
- involves the fracture of a leg or arm but not a finger or toe;
- involves the amputation of a leg, arm, hand, or foot, but not a finger or toe;
- consists of burns to a major portion of the body;
- causes the loss of sight in an eye.

**Procedure - critical injury:**

When a fatality or critical injury occurs:

1. Ensure that first aid is given immediately to the injured worker and treatment is recorded.
2. Provide immediate transportation to a physician or medical facility if required.
3. Report the injury to the project supervisor.
4. The supervisor must notify the following immediately and directly:
   a. Ministry of Labor (MOL). A MOL inspector may be dispatched to the scene. Within 48 hours of the occurrence, the municipality sends written reports(s) of the circumstances to the MOL area director.
   b. Joint Health and Safety Committee (JHSC)
   c. Local union steward
   d. Local police/OPP (if applicable)
   e. Air Ambulance (800) 461-4850 (if applicable)
5. On-site first-aid treatment is recorded on the Supervisor's Accident Investigation Summary (form 905), Sections 1 and 2.

**Emergency plan for pesticide fires:**

The MOE Spills Action Centre should be notified in the event of a pesticide fire (800-268-6060).

**Emergency plan for fuel and pesticide spills:**

1. Whoever discovers a spill should notify the application boss.
2. The Application Boss will initiate containment and clean-up procedures and

will notify the Project Supervisor.

3. The Project Supervisor must report fuel and pesticide spills to the MOE Spills Action Centre (800-268-6060). If personnel have been exposed to pesticides the pesticide incident form must be filled out.

**Emergency plan for aircraft incidents or accidents:**

All accidents, occurrences or incidents are to be reported to OMNR's Aviation, Flood and Fire Management Branch (AFFM), Provincial Coordination Centre (705-945-6666)

### 5.7 Security Plan

Security of the application equipment, fuel and pesticide are the responsibility of the aerial applicator. Specific plans will be developed when municipal lands are used as staging sites for the operation.

## 6 Likely Outcomes of an Aerial Spray Program against the Gypsy Moth

Gypsy moth populations should be reduced within the treatment areas and consequently dispersal into surrounding areas should be minimized. **The spray will not kill all gypsy moth larvae** and results will be variable within and between spray blocks. Some defoliation will likely occur and residents will observe gypsy moth life stages in treated areas following treatment.

Trees within the spray areas vary in overall condition and vigour. Some trees already show signs of decline with dead branches in the crowns and evidence of attack by secondary pests such as the two-lined chestnut borer and Armillaria root rot. Many trees are mature to over mature or essentially senescent and will likely continue to decline over the next few years despite any benefits realized from the spray program. Some trees will die. However, if gypsy moth defoliation rates can be minimized, then many trees should show signs of improvement over the next few years if other stress causing factors can be reduced.

High gypsy moth populations are possible again in 2007. Small pockets of infestation not detected during the current surveys may develop and cause defoliation in 2006. Surveys should be continued to monitor gypsy moth population distribution and density within the city.

# 7 Potential Constraints

**Technical:** Availability of Transport Canada approved aircraft for aerial spraying over residential areas.

**Financial:**

**Operational:** Proximity of major provincial and municipal highways and Pearson International Airport to proposed treatments over residential areas.

**Geographic:** N/A

**Time:** Delays in acquiring program permits from federal and provincial authorities and accelerated pest and host development resulting from a mild winter and warm spring.

**Resources:**

**Legal:** Potential legal actions initiated by opponents to the program.

**Political:** High degree of public opposition to the program resulting in a change in political priorities.

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# Appendix A: Gypsy Moth Defoliation Forecast by Ward

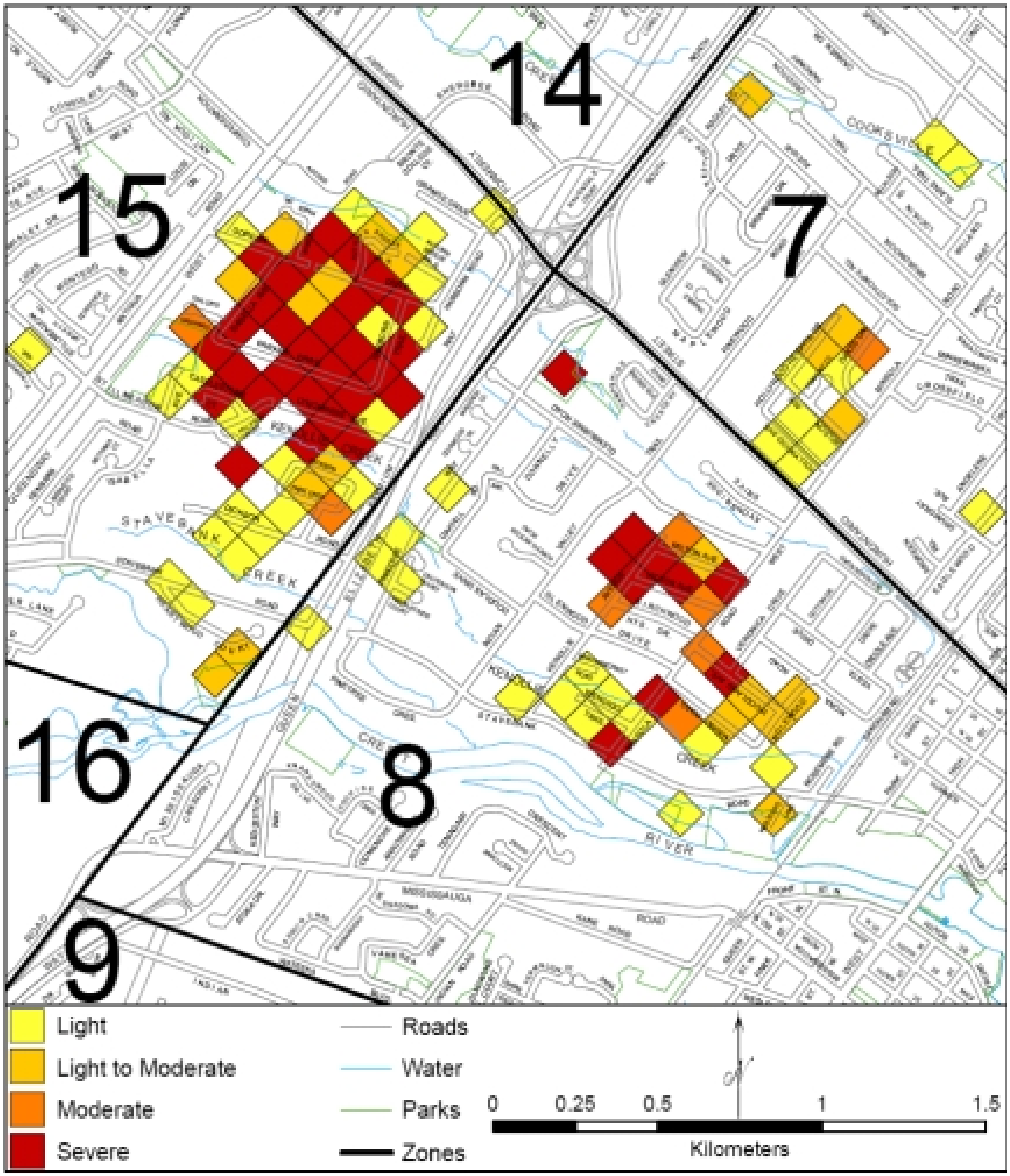


**Figure A-1. Gypsy moth defoliation forecasts for 2006 for Wards 1 and 7 based on the results of the City gypsy moth egg mass surveys conducted in 2005.**

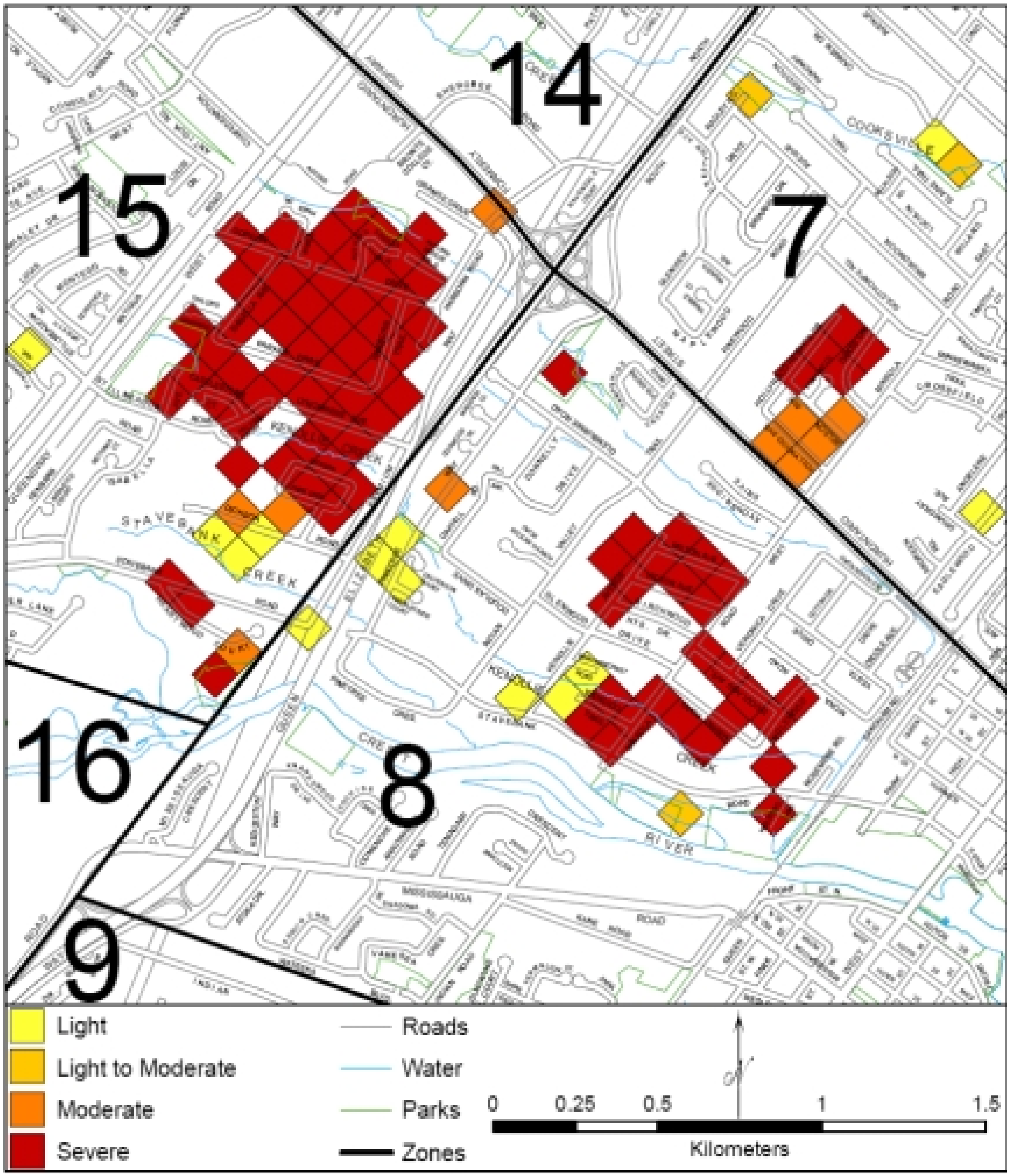


**Figure A-2. Gypsy moth defoliation forecasts for 2006 for Wards 1 and 7 calculated by BioForest Technologies based on the results of the City gypsy moth egg mass surveys conducted in 2005.**

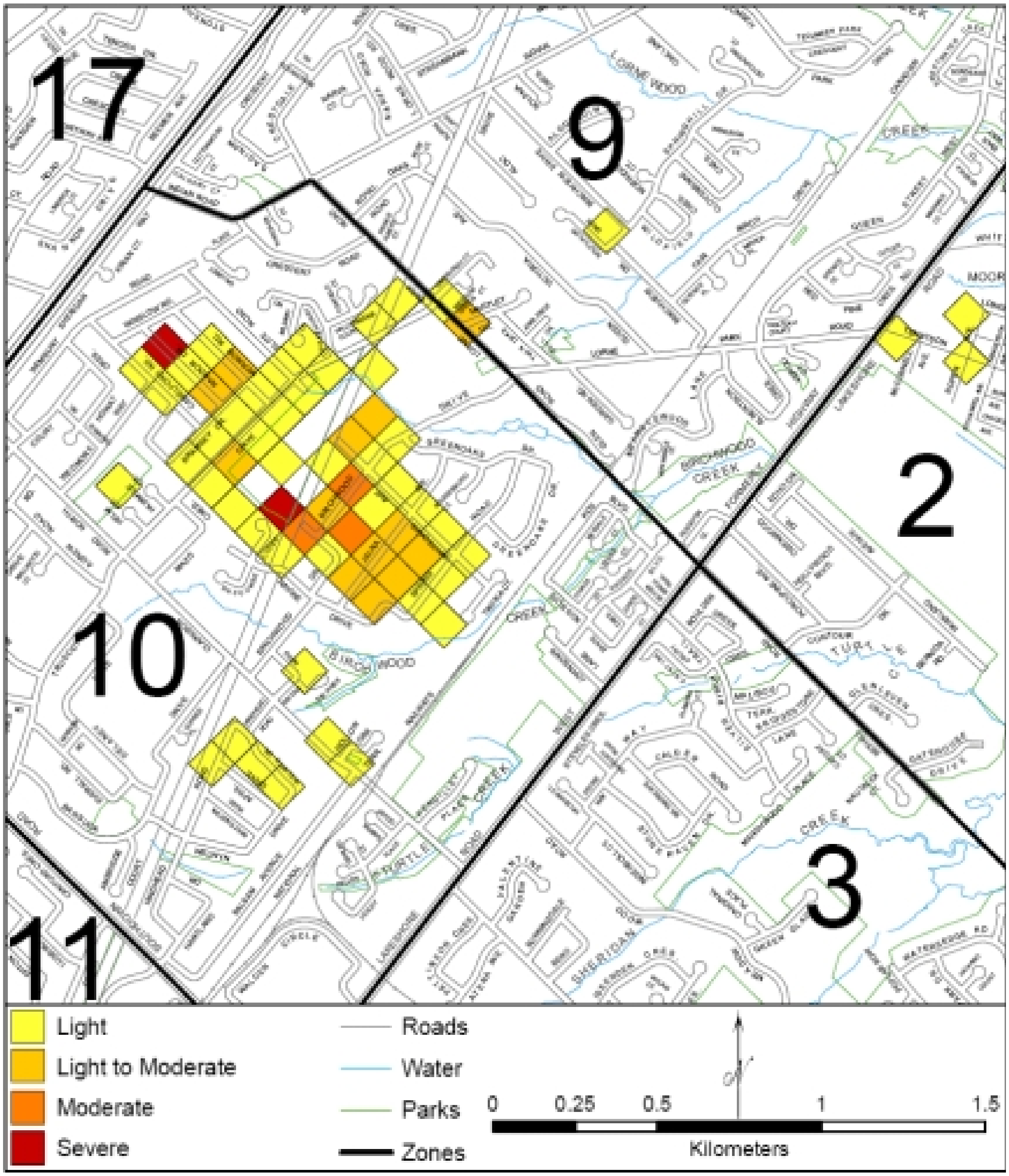


**Figure A-3. Gypsy moth defoliation forecasts for 2006 for Ward 2 based on the results of the City gypsy moth egg mass surveys conducted in 2005.**

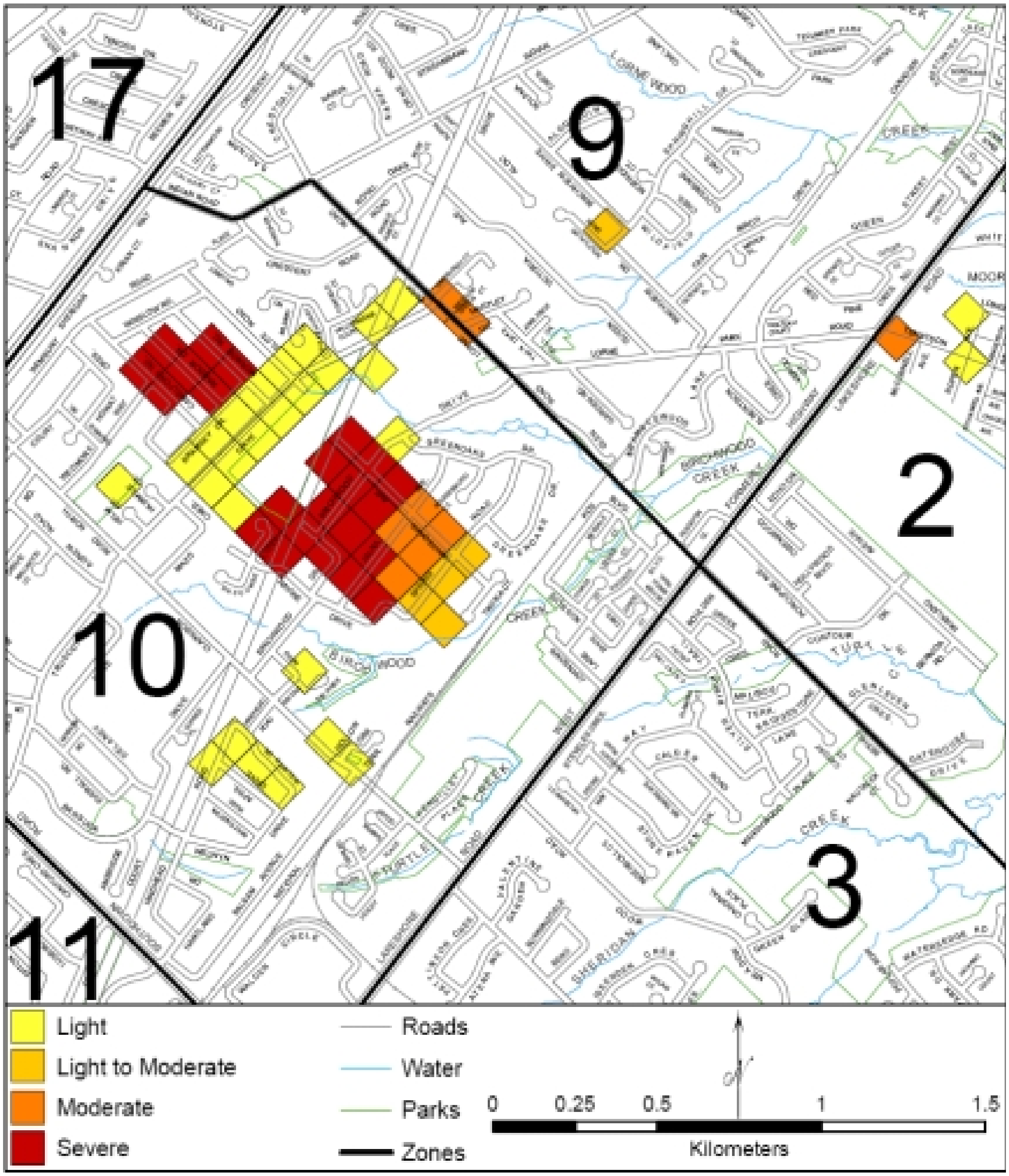


**Figure A-4. Gypsy moth defoliation forecasts for 2006 for Ward 2 calculated by BioForest Technologies based on the results of the City gypsy moth egg mass surveys conducted in 2005.**

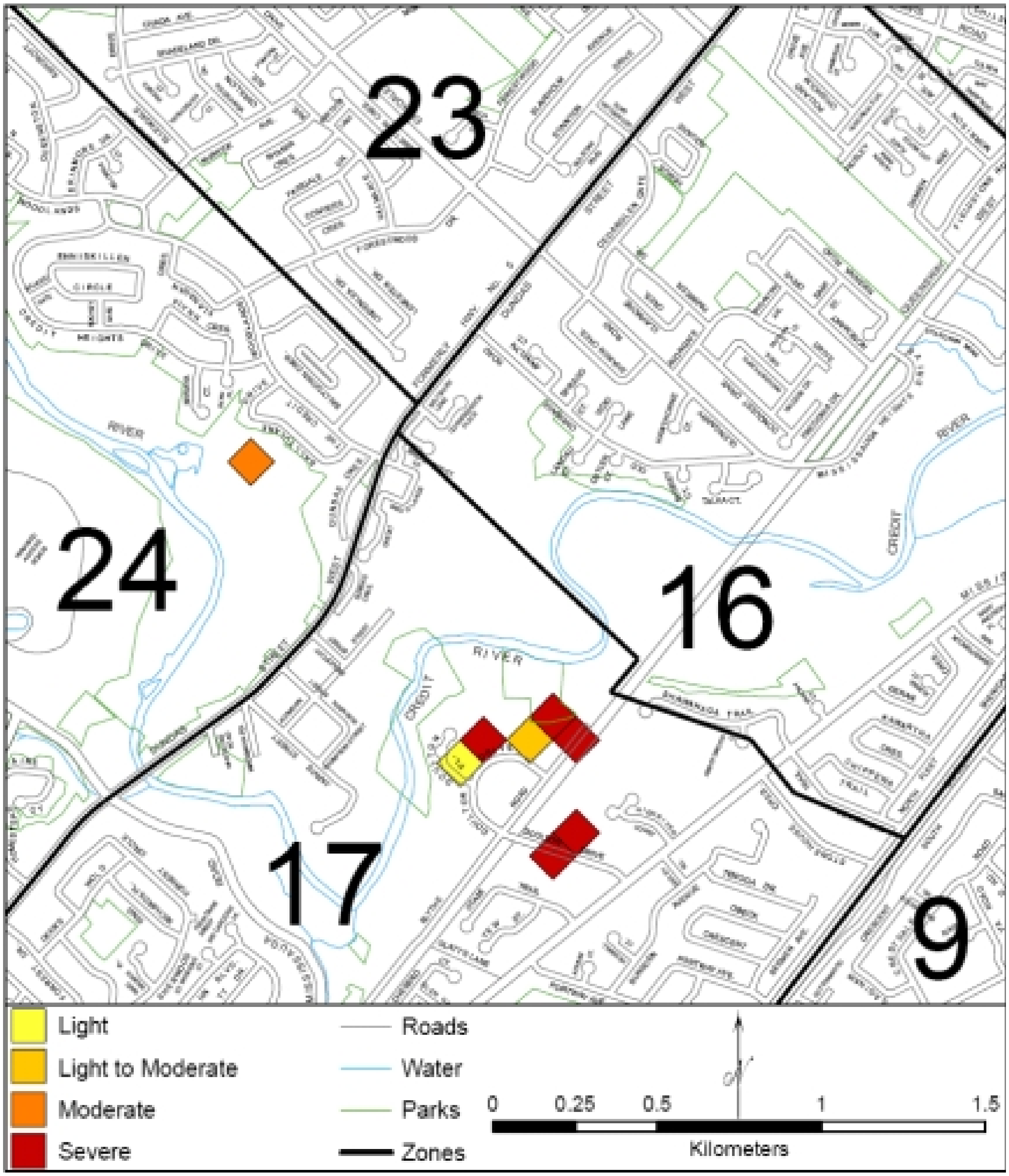


**Figure A-5. Gypsy moth defoliation forecasts for 2006 for Wards 6 and 8 based on the results of the City gypsy moth egg mass surveys conducted in 2005.**

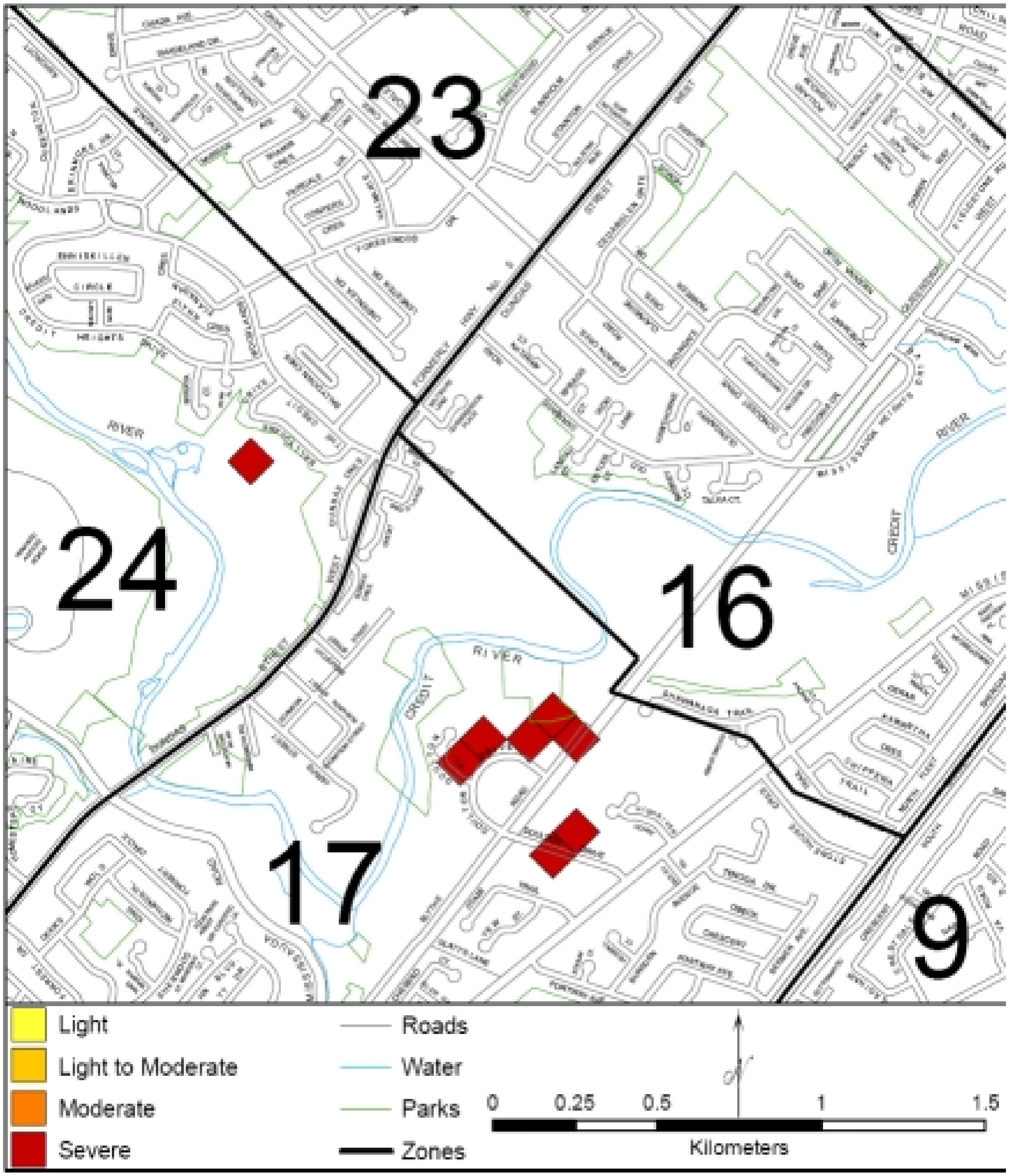


**Figure A-6. Gypsy moth defoliation forecasts for 2006 for Wards 6 and 8 calculated by BioForest Technologies based on the results of the City gypsy moth egg mass surveys conducted in 2005.**