Canadian Council of Forest Ministers
Conseil canadien des ministres des forêts

ASSESSING THE RISK POSED BY SPONGY MOTH TO CANADA'S FORESTS

Canadian Council of Forest Ministers | Conseil canadien des ministres des forêts

Assessing the Risk Posed by Spongy Moth to Canada's Forests

M. DiGasparro[1], J. St-Germain[2], J. Brandt[2], and R. Lalonde[2]

[1]Invasive Species Centre, Sault Ste. Marie, Ontario
[2]Natural Resources Canada – Canadian Forest Service, Ottawa, Ontario

Prepared for the Canadian Council of Forest Ministers' Forest Pest Working Group

Cat. no: Fo4-230/2024E-PDF
978-0-660-72165-1

Natural Resources Canada
Canadian Forest Service
580 Booth Street
Ottawa, ON K1A 0E4

A pdf version of this publication is available through the NRCan Open S&T Repository (OSTR): https://ostrnrcan-dostrncan.canada.ca.

Cet ouvrage est publié en français sous le titre : *Évaluation du risque posé par la spongieuse aux forêts canadiennes.*

Photo credit: Front page, page 6, 7, 22, 23, and 30, Natural Resources Canada.

TTY: 613-996-4397 (Teletype for the deaf)

Contents

List of Figures

Acknowledgement

Funding for this project was provided by the Canadian Council of Forest Ministers' Forest Pest Working Group, through Natural Resources Canada. The project was led by the Invasive Species Centre, run in collaboration with the Canadian Forest Service of Natural Resources Canada, and under the guidance of a task team including the following members from the federal and provincial governments:

- David Holden, Canadian Food Inspection Agency
- Jim Saunders, Ontario Ministry of Natural Resources and Forestry
- Pierre Therrien, Quebec Ministry of Natural Resources and Forests
- Brian van Hezewijk, Natural Resources Canada
- Caroline Whitehouse, Alberta Ministry of Forestry and Parks

Executive Summary

This assessment was triggered by recent increases in detection of spongy moth (*Lymantria dispar dispar*), an invasive species, in uninfested areas of Canada, as well as outbreaks in areas where this pest is considered established. The objective of this assessment was to characterize the risk posed by spongy moth's spread to currently uninfested forested areas across Canada, including the effect of climate change on the risk of spread and establishment of this insect. The assessment also identifies information needs that, once addressed, will help reduce existing uncertainties around spongy moth risk, and ultimately, will enhance prevention and management of spongy moth in Canada. This report has a primary focus on spongy moth, a subspecies of European origin that is currently present in eastern Canada. It also occasionally refers to the flighted spongy moth complex, which includes a group of subspecies and other closely related *Lymantria* species of Asian origin not currently established in Canada.

This report concludes that without control, spread of spongy moth to currently suitable but uninfested areas of Canada is highly likely and the negative consequences of the insect's establishment in these areas could be substantial, particularly from trade and ecological standpoints. Climate change is expected to exacerbate risk progressively during the next 30 years and to play a role in increasing the severity of outbreaks in areas where spongy moth is already established. Examples of successful eradication programs across Canada demonstrate the feasibility and efficacy of managing risk of spongy moth introductions. Existing prevention strategies to limit spongy moth spread to uninfested areas of Canada, although imperfect, should be maintained, and, where possible, reinforced through institutional partnerships to enhance their effectiveness.

This risk assessment was requested by the Forest Pest Working Group under the Canadian Council of Forest Ministers, a collaborative government forum supporting prevention and preparedness principles in addressing emerging forest pest issues. The report contributes to these principles by providing forest and pest management agencies across Canada with a resource to inform future response to the risk posed by this invasive pest at the local, regional, or national level.

Nature of the Threat

Spongy moth (*Lymantria dispar*) is considered one of the most destructive invasive species in North America. Moths from Europe were accidentally released in the eastern United States (U.S.) in 1868, and the insect has since spread and become established throughout the forests of northeastern North America. In Canada, spongy moth was first introduced into Québec in 1924 and was subsequently discovered in Ontario in the 1940s. By the 1990s, established populations of this pest could be found across much of eastern Canada in Ontario, Québec, New Brunswick, Nova Scotia, and Prince Edward Island. Spongy moth is currently established from the Atlantic coast west to the Great Lakes Basin and has been detected from coast to coast (Figure 1). This insect has more than 300 known host species in North America (Liebhold et al. 1995) and causes widespread forest defoliation during periodic outbreaks. Spongy moth caterpillars feed on developing leaves in the spring. Adult moths emerge during the summer and females lay eggs in masses that can contain up to a thousand eggs each. The insect overwinters in the egg stage. An important feature of the spongy moth of European origin is that females are flightless because of more significant abdominal muscles, smaller wings, and poorly developed flight muscles (Keena et al. 2014; Shi et al. 2015). Preferred hosts include oak, cherry, white birch, maple, alder, willow, elm, and trembling aspen (Liebhold et al. 1995) but suitable hosts also include conifer species such as fir and spruce (Hennigar et al. 2007). Outbreaks are known to occur in both native and invaded ranges. Mass defoliation events caused by the spongy moth have consequences on a region's urban and natural forests, its economy (including effects on tourism and forestry), as well as society and recreation as a nuisance species in communities.

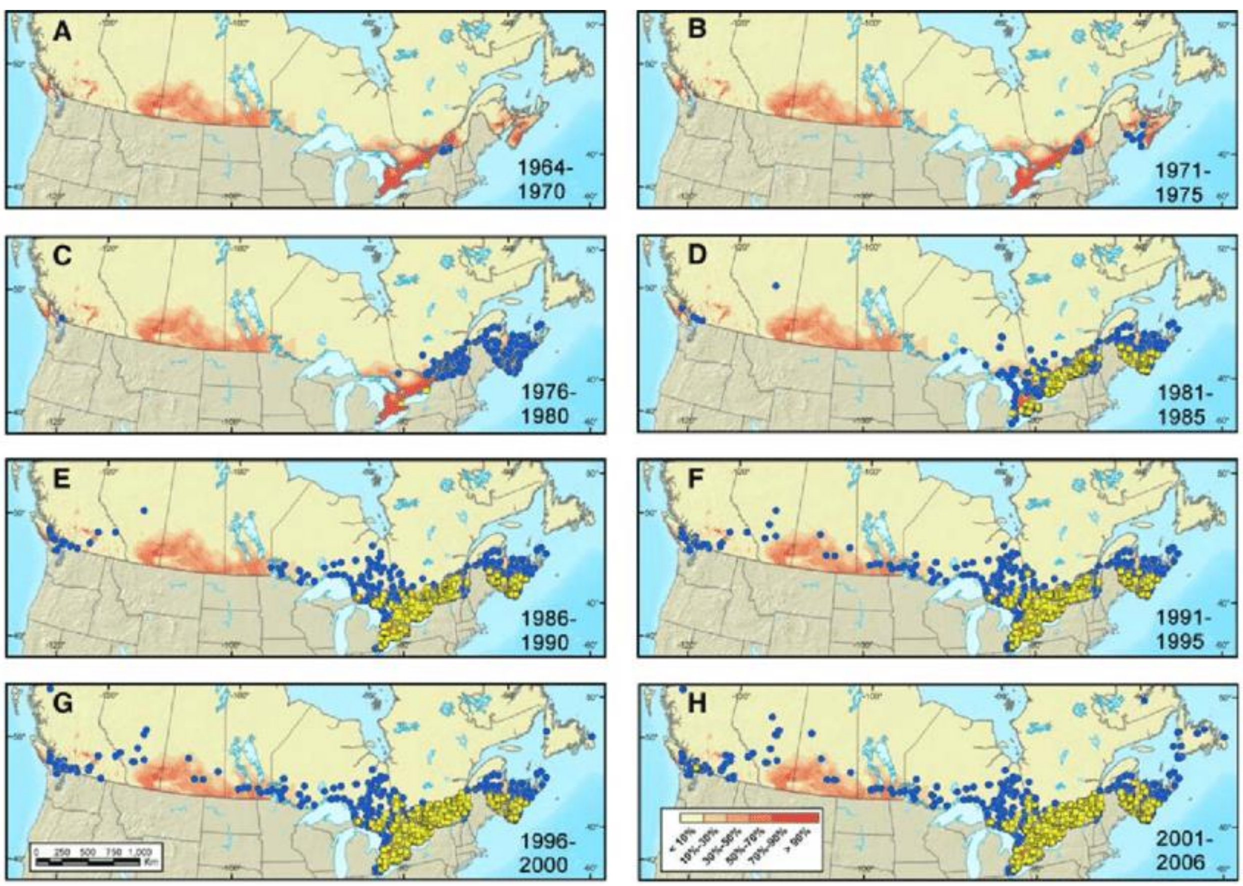

Figure 1: Historical distribution of spongy moth recoveries from pheromone traps (blue) and from sampling of other life stages (yellow) in Canada between 1964 and 2006 (From Régnière et al. 2009).

The taxonomy of spongy moth is somewhat complex, which is important from both a biological, and hence, management and phytosanitary perspectives. Recent genetic studies demonstrate strong evidence for at least three and as many as five subspecies (Pogue and Schaefer 2007; Picq et al. 2023). *Lymantria dispar dispar* is the subspecies whose range covers most of Europe and North Africa. The female moth of the latter subspecies is flightless. *Lymantria dispar asiatica* is distributed throughout most of continental eastern Asia. *Lymantria dispar japonica* is limited to the Japanese Islands. Female moths of both Asian subspecies can fly. A fourth unnamed subspecies may exist geographically in the Caucuses and the Middle East. Between *Lymantria dispar dispar* populations in Europe and *Lymantria dispar asiatica* populations in eastern Asia, a zone of hybridization occurs throughout western Siberia where specimens of spongy moth shows both genetic and biological traits (female moth flight ability) intermediate between the two parent populations. The designation of subspecies (the fifth) might also be given to the present population of spongy moth in eastern North America because of its introduction to a novel habitat and its genetic distancing from the parent population (*Lymantria dispar dispar*) since its introduction in 1868. Another aspect that adds complexity is there are other species of the Lymantriinae subfamily (*Lymantria albescens, Lymantria postalba and Lymantria umbrosa)* that are closely related to *Lymantria dispar* (Picq et al. 2023; Djoumad et al. 2020). Thus, a number of phytosanitary regulatory agencies including those of Canada and the U.S. have identified a "flighted spongy moth complex", which includes the two Asian subspecies of *Lymantria dispar* (*Lymantria dispar asiatica, and Lymantria dispar japonica*), along with 3 other species of Lymantriinae (*Lymantria albescens, Lymantria postalba and Lymantria umbrosa*). The new common name, "flighted spongy moth complex" (FSMC), is now being used to refer to the complex of flighted lymantrid moths formally known as Asian spongy moth. Host suitability studies have also shown that moths under the FSMC develop better on coniferous species than moths of European origin.

The distribution of spongy moth populations in eastern Canada has remained relatively stable for more than a decade, likely indicating that this area corresponds to where climate is most suitable for spongy moth development and where forest ecosystems contain an adequate proportion of susceptible tree hosts (Régnière et al. 2009). Regulatory maps of the Canadian Food Inspection Agency (CFIA) provide relatively course-level depictions (at least from a jurisdictional perspective) of areas where spongy moth is present. In some cases, entire provinces are regulated in this manner, so the actual range is smaller than depicted by regulatory maps (Figure 2). Established populations in Thunder Bay (Ontario) and Minnesota (U.S.) indicate that the western leading edge of the range in Canada exists somewhere between Thunder Bay and the Ontario/Manitoba border. Defoliation data (Figure 3) used in concert with regulatory maps can provide additional insight about locations where spongy moth is present.

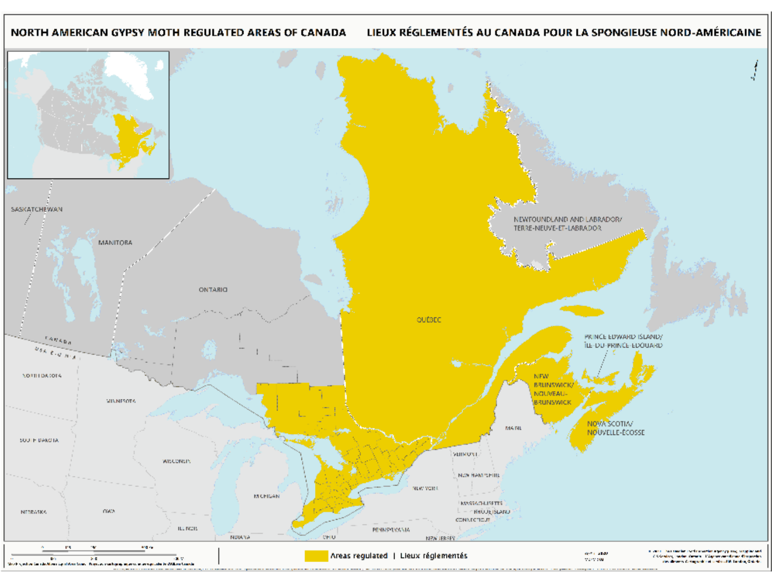

Figure 2: Areas regulated for spongy moth by the CFIA (CFIA 2020).

Another suitable area for spongy moth establishment includes western provinces. For example, detections and spot eradications have been frequent in British Columbia since 1978 to keep the province free of spongy moth (Nealis 2009). In addition, it is possible that climate change could make currently unsuitable areas become more hospitable to spongy moth, facilitating the spread and establishment of this insect in previously uninfested areas where suitable hosts are present.

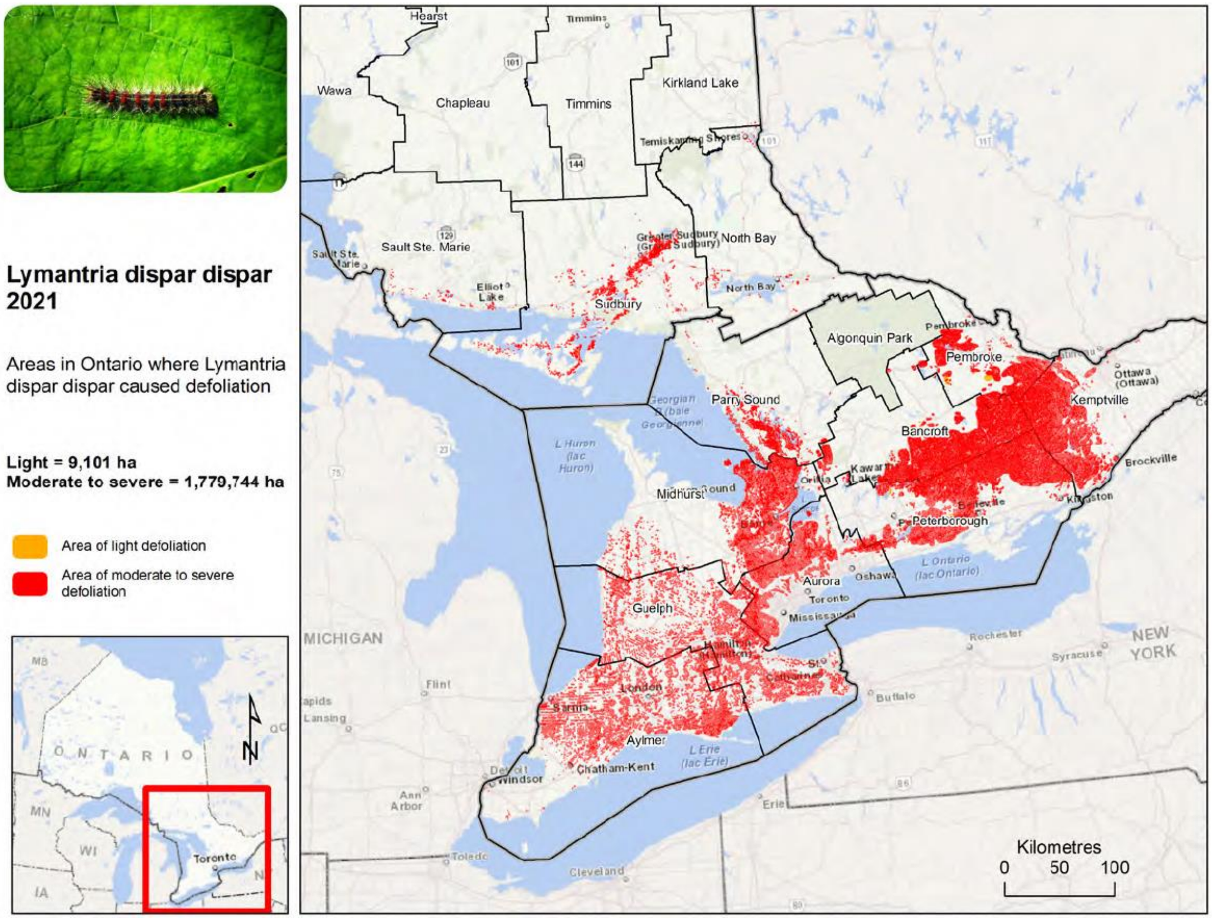

Figure 3: Ontario spongy moth defoliation in 2021 (Ontario Ministry of Natural Resources and Forestry 2021).

Likelihood of Occurrence

Affirmative Statement 1: Introduction and spread of spongy moth to new areas will occur primarily through anthropogenic long-distance dispersal, including changing human movement patterns, and natural short-distance dispersal.

Evidence

Populations of spongy moth do not spread continuously along the leading edge of their range. Spongy moth populations expand through a transition zone, where isolated colonies become established between the "generally infested zone" and the "uninfested zone." These colonies will grow and eventually coalesce, advancing the infested zone (Tobin et al. 2004).

Adult spongy moth females from eastern North America are flightless, and therefore local dispersal is limited to larval crawling and ballooning (i.e., larvae dispersing on silk threads in wind currents shortly after they hatch). Larvae have the capacity to move up to 1 km; however, typical ballooning distances are under 50 m (Hunter and Elkinton 2000). This type of dispersal behaviour is most commonly associated with first instar larvae that hatch in areas with heavy host defoliation or poor-quality hosts (Lance and Barbosa 1981; Diss et al. 1996), where larvae may be experiencing nutritional stress and are seeking adequate hosts for feeding. Later instar larvae are larger in size and more difficult to be moved by wind; they disperse by crawling, which is inconsequential for spread dynamics. The effects of climate change on forests may affect the frequency of larval ballooning and local dispersal of spongy moth larvae as they search for adequate nutrition.

There is also evidence that severe weather events, including windstorms and tornadoes, can facilitate the natural long-distance dispersal of spongy moth life stages. Such dispersal events are thought to have moved spongy moth across Lake Michigan into Wisconsin (U.S.) in the 1990s. During the initial spongy moth invasion in Wisconsin, spread rates were on average greater than what was typically seen in other regions (16 km/year vs. 6 km/year). Because anthropogenic movement and regional variations are not unique to Wisconsin, it is speculated that extreme weather events that coincided with spongy moth establishment acted as an additional means of spread, supplementing low-density populations (Tobin and Blackburn 2008).

Long distance spread of this species is primarily facilitated by the anthropogenic movement of various spongy moth life stages. In the U.S., spread rates absent of anthropogenic movement were modelled to be about 2.5 km/year. Observed rates from 1966-1990 reached nearly 21 km/year (Liebhold et al. 1992), indicating that anthropogenic movement increases spread rates dramatically. Frequent introductions of spongy moth into the western provinces provide evidence that anthropogenic dispersal can commonly occur at distances greater than 2000 km. Spongy moth egg masses are not always obvious to detect, blending in with their environment, and are often mistaken for dirt or debris on outdoor household goods, vehicles, or other objects that could be found in the outbreak area. Egg masses are not only difficult to detect, but they can each contain up to 1000 eggs; thus movement of a single egg mass can lead to the establishment of a new population at the receiving destination. In Canada, the CFIA implements regulatory measures that restrict the movement of the following commodities to limit anthropogenic movement of spongy moth (CFIA 2021):

- Christmas trees;
- Nursery stock (woody trees and shrubs);
- Non-propagative forest products with bark attached, including firewood;
- Outdoor household articles;
- Military vehicles and equipment; and
- Recreational, personal, and commercial vehicles and equipment.

The movement of wood products, particularly firewood used for home heating, is positively correlated with the introduction of spongy moth (Bigsby et al. 2011). Recreational vehicles are also particularly high risk as they are generally associated with the movement of outdoor household goods exposed to spongy moth and potentially containing egg masses. These vehicles also tend to visit parks, many of which are forested. Nursery stock and Christmas stock sourced from areas infested by spongy moth are also at risk of carrying egg masses. Specific contributions to spread of other pathways, such as rail containers, construction and other development materials, and e-commerce is not well documented. Areas with susceptible trees and subject to ongoing human activity, such as shelter belts, regional parks, river valleys and urban settings, are generally prone to spongy moth introductions through anthropogenic spread (Régnière et al. 2009).

Changing human travel patterns are thought to be an additional factor affecting the anthropogenic dispersal of spongy moth across the country. In 2021, Ontario saw the largest movement of people relocating to western provinces since the oil boom in the 1980s (Desormeaux 2022). Within the same year, Ontario also saw record numbers both in spongy moth trap catches and in area of defoliation while western provinces saw an increase in spongy moth trap catches.

The current state of evidence indicates that although natural dispersal does occur, anthropogenic movement is the main contributing factor to the risk of future range expansion of spongy moth into previously uninfested areas.

Uncertainty

- Low uncertainty about anthropogenic long-distance dispersal and the effect of human dispersal patterns on spread of spongy moth.
- Low uncertainty about the contribution of meteorological events and larval ballooning to short distance spread.
- Moderate uncertainty surrounding the level of spread risk associated with other specific anthropogenic pathways.

Information Needs

- Quantification of the risk of spread associated with specific anthropogenic pathways (e.g., e-commerce, construction and development, and movement of commodities by rail).
- Quantification of relationships between spongy moth invasion pathways, and establishment likelihood to inform spread prevention and early detection.

Affirmative Statement 2: Climate change will make future spongy moth outbreaks more severe throughout its entire range in Canada and will also facilitate further spread.

Evidence

Some areas of Canada that remain uninfested by spongy moth are assumed to be climatically unsuitable for the insect's complete development. The suitable area for spongy moth, however, is predicted to expand with climate change during the next 30 years (Figure 4), particularly in the prairie provinces. In the latter region, only a small portion of the expected climatically suitable area is susceptible because of the relatively restricted range of trees. (i.e., shelter belts, river valleys and urban settings) (Régnière et al. 2009). Topographical and forest heterogeneity in British Columbia restricts future expansions of spongy moth into what would otherwise be climatically suitable areas (Régnière et al. 2009).

Historically, episodes of rapid global warming have led to increased levels of insect herbivory (Currano et al. 2008). Earlier flight periods, enhanced winter survival, and accelerated development rates are the main consequences exhibited by insects in response to increases in temperatures with climate change (Robinet and Roques 2010). Populations at the most southern and northern parts of the spongy moth range are undergoing strong selective pressures on traits related to thermal tolerance – northern populations selected for shorter development time (associated with shorter growing seasons) and southern populations selected for reduced sensitivity to high temperature (Friedline et al. 2019). Optimum temperatures seem to vary by spongy moth population and location (Thompson et al. 2017), further indicating that in a context of climate change, strong selection pressures could promote local adaptation, and on a relatively short time scale (Pureswaran et al. 2018).

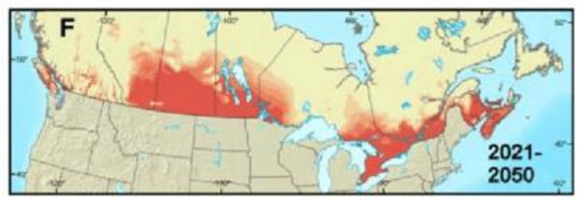

Figure 4: Probability of spongy moth establishment in Canada based on climate modelling for the 2021-2050 period (from Régnière et al. 2009).

With other defoliating moths in North America, climate change-related extreme temperatures and droughts have made hosts more susceptible to biotic and abiotic disturbance agents leading to an increase in tree mortality (Miller and Wallner 1989; Allen et al. 2010; Pureswaran et al. 2018). These events are particularly important when considering future spongy moth establishment and impacts in the Canadian prairies, where increased summer temperatures and drought conditions are expected (Hogg 1994; Hogg and Bernier 2005; Hogg et al. 2005).

Host phenology, a critical element to spongy moth survival, is subject to variation under climate change. However, even if spongy moth eggs hatch out of synchronicity with their preferred host, they may utilize other hosts to survive long enough to disperse and find more suitable ones (Keena and Richards 2020). More than 146 primary host plant species for spongy moth are present in North America and closer to 300 species can act as potential hosts (Liebhold et al. 1995). Spongy moth is highly adaptable, and larvae can utilize many different hosts (Keena and Richards 2020). Increases in temperature can also indirectly affect the spatial extent of defoliator outbreaks through their effects on the expansion of the range of host trees, and in turn, on the range of the pests that feed upon them (Haynes et al. 2022). However, without assisted tree migration, this expansion would be gradual and might only become a notable factor in spongy moth outbreaks in several decades. The presence of susceptible forests is an important predictor of where spongy moth spread will occur, even with alterations in climate (Sharov et al. 1999). In addition, although elevated CO_2 concentrations in the atmosphere (contributing to climate change) may significantly reduce leaf quality, no significant effect is expected on the feeding preference of spongy moth larvae because defoliators often adapt quickly to changes in nutritional quality (Wang et al. 2009; Jactel et al. 2019).

Spongy moth's cold tolerance is adapted to temperate latitudes in North America, with the cold hardiness limit of eggs being around −30°C (Sullivan and Wallace 1972; Madrid and Stewart 1981). At the northern edge of its North American range, environmental factors become increasingly important to enhance tolerance to extreme cold conditions. For example, snow cover can moderate temperature exposure of egg masses laid below snow level – up to 7°C warmer than ambient temperatures (Andresen et al. 2001). It is important to note that spongy moth may lay egg masses almost anywhere, from tree trunks and branches to rocks and outdoor equipment, and thus, not all egg masses may benefit from the protecting effect of snow cover. Nonetheless, northern expansion of spongy moth has been predicted in areas with substantial snowfall (Sullivan and Wallace 2012; Streifel et al. 2018) where oviposition below the snowpack can protect egg masses from cold temperatures and increase overwintering survivability. As climate change projections indicate that winters will become milder, spongy moth may no longer require large snowpack accumulation to protect egg masses from severe cold temperatures in previously unsuitable areas. Climate change could also result in increased occurrence of early warm spring temperatures followed by frost events, which could increase spongy moth egg mass mortality, and thus also reduce population levels (Benoit and Lachance 1990).

Climate change impacts on natural predators, parasitoids, and pathogens will also be an important factor on future outbreaks. The collapse of spongy moth outbreaks typically results from the activities of two pathogens: a naturally occurring non-specific nucleopolyhedrosis virus (NPV) and a fungus, *Entomophaga maimaiga,* introduced into North America as a biological control for spongy moth (Blackburn and Hadjek 2018). The prevalence of these pathogens will influence outbreak severity in new and changing environments, and both pathogens are likely affected by environmental conditions, particularly moisture and temperature. Elevated temperature, atmospheric CO_2 concentration, and drought stress can cause entomopathogenic fungi to lose their capacity to sporulate (Borisade and Magan 2015). This can decrease dispersal ability and reproductive capacity of pathogens that control spongy moth populations. Increasing CO_2 concentrations influence both the temperature range for entomopathogenic growth and conditions for optimal growth and sporulation. Decreased activity of natural enemies and increased feeding (Jactel et al. 2019) can result in prolonged outbreaks with a potential increase in severity and an increased capacity for spongy moth to establish in new areas.

Based on research in the U.S., climate change could cause spongy moth outbreaks to be less severe in some regions. The types and intensity of climate change consequences will vary across the landscape. Thus, implications of climate change on spongy moth populations will also vary by region. For instance, in the most southern parts of the insect's range in the U.S., high summer temperatures that cause increased spongy moth mortality have been shown to result in a reduction in range (Tobin et al. 2014; Faske et al. 2019). More southern populations of spongy moth appear to be less sensitive to high temperatures than more northern populations. These populations do, however, see decreased performance of other fitness traits, indicating that there may be a tradeoff between heat sensitivity and reproductive fitness. Mortality resulting from high temperatures at the southern limits of the insect's range are also evident (Thompson et al. 2017). Conversely, the effect of warmer temperatures is expected to contribute to range expansion at northern latitudes. In these areas, increases in temperatures would accelerate larval development and timing of oviposition, which are critical to meet prediapause requirements and winter survival (Gray 2004). Simulations of a 1.5°C increase in average daily temperatures resulted in a significant increase in the potential northern limit of spongy moth's range (Gray 2004).

During the 2021 spongy moth outbreaks in eastern Canada, there was an increase in defoliation severity but no significant expansion in the insect's geographic range, except for spread in the Thunder

Bay area. It is unclear whether the increased severity is related to climatic conditions.[1] During the same outbreak year, western Canada also saw a significant increase in trap captures. As discussed in the previous section on pathways, this is likely due to increased human travel to western Canada coinciding with the outbreak in the east. The increase in human travel westward in 2021 was likely due, at least in part, to access restrictions at the U.S. border and reduced domestic travel restrictions in the second year of the COVID-19 pandemic.

Based on the evidence discussed in this section, it is likely that climate change will alter future spongy moth outbreak severity both favourably and unfavourably, depending on locations. In areas where severity will increase, the number, frequency and fitness of spongy moth populations will also increase and facilitate spread via anthropogenic pathways.

Uncertainty

- Medium uncertainty about the extent of spongy moth range expansion under climate change
- High uncertainty about the effect of climate change on outbreak severity, including regional differences in severity of climate change consequences that could make forests susceptible to outbreaks.
- High uncertainty about the effects of climate change on spongy moth population dynamics, including local adaptations in host-pest synchrony and interactions with natural enemies.
- High uncertainty about the effects of more frequent extreme weather events on dispersal patterns.
- High uncertainty about the effects of climate change on outbreak frequency.

Information Needs

- Determination of the effects of climate change on spongy moth populations and outbreak dynamics, on its associated hosts, and on the insect's natural enemies.
- Understanding of how climate change will affect spongy moth outbreak severity and frequency.
- Updated delimitation of the current and potential distribution of spongy moth and its hosts, including variations under various climate change scenarios.

Affirmative Statement 3: Current strategies used to prevent spongy moth introductions in uninfested areas require further refinement. Institutional partnerships are a necessary component of such strategies for effective spongy moth risk management and should be strengthened to limit spread.

Evidence

There are a variety of tools used to detect the presence of spongy moth. The latter tools, however, as well as other measures that are part of prevention strategies are not applied consistently across the country or across North America. This is partly due to disparity in status of the species across the country. Western Canadian provinces primarily focus on surveillance to detect and then eradicate any new introductions (i.e., prevent establishment of reproducing populations). From Ontario and eastward, provinces with monitoring programs are focused on quantifying spongy moth damage (i.e., levels of defoliation, outbreak severity, tree mortality) where the insect is long-established. As with other exotic pests, the CFIA supports the monitoring of spongy moth in unregulated areas (i.e., areas where spongy moth is not established). Some provincial and municipal governments provide additional trapping assistance to further support the early detection and rapid response to introductions. Monitoring methodologies and thresholds used across jurisdictions currently vary and are not necessarily compatible. The application of standardized regional detection and monitoring protocols would provide a more accurate depiction of the range of spongy moth and its spread from coast to coast in Canada. The sharing and combination of such monitoring data would provide reasonable estimates of population trends through time.

Pheromone trapping can be used to accurately evaluate the success of spongy moth eradication

[1] Personal communication – Dan Rowlinson, Ontario Ministry of Natural Resources and Forestry / Taylor Scarr, Natural Resources Canada

programs (Sharov et al. 2002a). In both western Canada and the U.S., small, isolated colonies are detected with pheromone-baited traps laid out in a grid along the leading edge of the population and/or in high-risk areas for introduction such as campgrounds and along transportation corridors (Sharov et al. 2002a; Sun et al. 2019).

In areas where spongy moth is not established, commercially available monitoring tools are deployed to detect and delineate introduced populations. Early detection and rapid response are critical elements of successful eradication efforts. However, as introductions from eastern Canada are continuous, improving preventive strategies and tactics to restrict the movement of insects into new areas will serve to reduce the number of detections and the overall cost of spongy moth monitoring and management programs. The ability to continue implementing direct control, usually through aerial application of pesticides, in the effort to eradicate introductions may be challenged by the frequency and persistence of introductions in western Canada and the need to regain public trust.

In areas where spongy moth is already established, monitoring tools such as aerial surveys and remote sensing may be used to assess levels of tree defoliation, dieback, and mortality, and to quantify area disturbed. In these areas, supporting intensive egg-mass surveys can accurately forecast potential spongy moth impacts in the following year. Such forecasts can aid decision makers in determining whether a spray program would be appropriate in a given region. Some regions may also engage the public for community monitoring and reporting through hotlines and online tools.

New populations detected outside areas currently regulated by the CFIA and that cannot be successfully eradicated will lead to an expansion of the regulated area. Regulation imposes movement restrictions on certain commodities in an attempt to limit further spread. The majority of Ontario's hardwood forests are now considered infested by spongy moth and, as such, are included in the federally regulated area. Expansion of this regulated area to include currently climatically unsuitable areas, however, could still promote anthropogenic movement of infested commodities and could accelerate westward spread of spongy moth (CFIA 2019). Currently, the most western regulated area in Canada is Ontario's Algoma District (east of Lake Superior and includes Sault Ste. Marie), which is a large district with many physical (i.e., highways, railways) and biologic/geographic (i.e., lack of host species) barriers. The latter district is only partially regulated (Figure 2), which creates challenges for the enforcement of restrictions on the movements of regulated commodities to limit the spread of spongy moth.

Although regulatory measures to restrict movement of spongy moth are an important component of prevention strategies, they have limited impact on national-scale movement of spongy moth from eastern to western Canada. Studies have also shown that regulations targeted at industry and the movement of its goods are generally effective (but sometimes fail) and, regulations targeted at the public and their movement of commodities are ineffective (Bigsby et al. 2011). The latter regulations are difficult to enforce but could be combined with other measures to enhance their efficacy. For example, public outreach and community awareness can reduce inadvertent movement of insect life stages through anthropogenic pathways (Solano et al. 2022). Regulatory measures are less likely to be effective if community members do not understand the potential negative consequences of their actions. There is a strong correlation between increases in new detections in western Canada and outbreaks in eastern Canada, despite there being regulatory measures in place, further indicating the need for combined measures such as public awareness of spread pathways and impacts. Campaigns targeted at reducing firewood movement have shown to be successful examples of multijurisdictional collaboration and public awareness. Continued public motivation requires persistent and consistent messaging, however, because compliance is typically strong initially before leveling off and even declining with time (Diss-Torrance et al. 2018). Additionally, messaging around "Don't Move Firewood" programs tend to be about invasive species in general, with some mention of high-profile species such as the emerald ash borer, but not necessarily spongy moth. Institutional partnerships, such as memoranda of understanding, collaborative research agreements, or information-sharing agreements, are critical to coordinated efforts to prevent range expansion of spongy moth in Canada. Significant regional cooperation already exists but, in general, cooperation amongst all jurisdictions only occurs during a plant health emergency or an outbreak. Outreach also typically peaks during outbreaks.

The success of the U.S.' *Slow the Spread Program* for spongy moth illustrates the importance of interjurisdictional collaboration and institutional partnerships in preventing spongy moth spread. This Program integrates multi-jurisdictional quarantine regulations, monitoring, insect population suppression, and public outreach. These combined efforts have reduced spongy moth's rate of spread by more than 50% (Sharov et al. 2002b). A critical element of this program is shared stewardship. The *Slow the Spread Foundation, Inc.*, a non-profit organization, was established to aid in the delivery of the program. Technical committees, composed of representatives from all cooperating states, counties, agencies, and universities, meet regularly to advise federal and state agencies on strategies to enhance implementation and scientific issues regarding day-to-day and long-term management of spongy moth. Although rates of spongy moth spread were projected to decrease under the *Slow the Spread Program* (Sharov et al., 2002b), the assessment of efficacy did not take into account the effect of annual weather conditions, which also influence spread rates.

Uncertainty

- Low uncertainty that institutional partnerships and knowledge sharing are necessary for spongy moth spread prevention.
- Low uncertainty that existing strategies to prevent spongy moth introductions could be improved through better and more coordination and harmonization of risk management approaches across jurisdictions.
- Low uncertainty that currently available monitoring tools are effective at detecting spongy moth introductions.
- Low uncertainty about the need for recurring eradication programs in areas where spongy moths are not currently established and for more effective prevention strategies.

Information Needs

- Quantification of risks associated with specific anthropogenic spread pathways to inform public outreach and tactics for preventative actions.
- Behavioural studies to characterize public travelling and transportation behaviours that facilitate spongy moth spread.
- Approaches to regain public trust.

Magnitude of Consequences

Affirmative Statement 4: Spongy moth introductions and establishment in new areas threaten economically, socially, and ecologically important forest ecosystems and resources.

Evidence

Ecological impacts

Through defoliation, spongy moth directly causes reduced tree growth, poor tree vigour, crown dieback, and, in some cases, mortality. Mortality can occur, especially during periods of severe defoliation across multiple years. Also, a significant factor is the cumulative impact caused by additional stressors (e.g., drought). Mortality appears to be directly related to the proportion of susceptible hosts in the area (Davidson et al. 1999). Studies have shown that spongy moth outbreaks can alter stand composition through time, mainly through growth loss and tree mortality. Changes in stand composition create challenges for regeneration. Changes in stand composition are expected to be exacerbated by interactions between spongy moth and the effects of climate change (Fajvan and Wood 1996; Davidson et al. 1999; Kretchun et al. 2014; Morin and Liebhold 2015).

Studies have also shown a short-term increase in abundance of some bird species (i.e., Yellow-billed Cuckoos [*Coccyzus americanus*], Black-billed Cuckoos [*C. erythropthalmus*], and Indigo Buntings [*Passerina cyanea*]) in defoliated areas (Gale et al. 2001) but bird nest predation is also augmented in these areas, by more than 40% based on one study using artificial nests (Thurber et al. 1994).

Temporary impacts to soil characteristics (i.e., temperature, moisture level) are associated with gaps and openings in the canopy caused by defoliation in forested or urban areas (Twery 1991). Severe loss of canopy cover can have an indirect and relatively short-term effect on water drainage (Corbett and Lynch 1987) and nutrient leaching, such as nitrogen (Lovett at al. 2002).

Other insect species are known to be indirectly affected by spongy moth and its management (USDA Forest Service 1995). Although non-target impacts of treatments used to manage spongy moth populations are not discussed in this document, many studies have been published on this topic (Miller 1990; Sample et al 1996; Wagner et al. 1996; Butler et al. 1997; Rastall et al. 2003; Scriber 2004; Boulton et al. 2007; Manderino et al. 2014).

There is particular concern in British Columbia regarding spongy moth impacts to hydrology that may affect salmon-bearing streams. Red alder (*Alnus rubra*) is an important riparian species but is also an adequate host for spongy moth (Miller et al. 1991). Red alder is a primary successional species that occupies floodplains and streambanks, and a particularly important species following disturbances like fire. Red alder also fixes nitrogen, and its presence will result in increased nitrogen content and availability in the soil, which is important for the establishment of other tree species, especially in nutrient poor soils. Defoliation reduces tree leaf area and its associated evapotranspiration capacity and can result in increased growing-season runoff, with more severe defoliation resulting in higher instantaneous streamflow compared to historical conditions (Smith-Tripp et al. 2021). Sustained defoliation by spongy moth resulting in tree mortality in riparian areas could result in a seasonal increase in water temperature of small streams, which could last for more than a decade and may result in decline of some fish populations (USDA Forest Service 1995).

Garry oak (*Quercus garryana*) grows in ecologically sensitive ecosystems in coastal British Columbia. It is the only native oak species found in this province. Less than 1% of low-elevation Garry oak habitat and about 5% of upland habitat remain in Canada today (Nature Conservancy of Canada, 2023). Furthermore, Garry oak foliage is suitable food for spongy moth larvae and as such the Garry oak ecosystem could serve as habitat for spongy moth during establishment (Miller et al. 1991). These ecosystems contain a variety of other rare and threatened species that could also be negatively affected if spongy moth were to become established.

Specific concerns for the prairie provinces include impacts on forest ecosystems dynamics and their carbon budget, particularly from interactions between potential spongy moth infestations and repeated severe abiotic stress. Widespread dieback of trembling aspen (*Populus tremuloides*) has been observed in central and western Canada following severe drought events in the 1990s and early 2000s, and such dieback is known to be amplified by factors such as defoliation by insects. (Hogg et al. 2002; Hogg et al. 2005; Michaelian et al. 2011). Trembling aspen is the most widespread tree species in North America (Perala 1990) and the predominant tree in the aspen parkland ecoregion (Bird 1961) of the prairie provinces. Additional concerns in this region relate to Burr oak (*Quercus* macrocarpa) decline in Manitoba (Catton et al. 2007), and susceptibility of river valley forests that have more substantial hardwood content and are also under pressure from other abiotic and biotic damage agents such as regional drought as well as Dutch elm disease (*Ophiostoma novo-ulmi*), another non-native, invasive species. Another concern comes from potential long-term ecological impacts stemming from the loss of the few deciduous tree species growing in the Prairies grassland ecoregion. The potential introduction of spongy moth is a threat that adds to the cumulative effect of existing abiotic (drought, salinity, flooding) and biotic (forest tent caterpillar [*Malacosoma disstria]*, Dutch elm disease, western ash bark beetle [*Hylesinus californicus]*) stressors already affecting trees in this region as well as looming invasion of new species, such as the emerald ash borer (*Agrilus planipennis)*.

Social impacts

Social reactions are heavily dependent on spongy moth outbreak severity. Severity of impacts in urban municipalities will be related to the prevalence and distribution of host species in these communities. Many impacts are mostly considered a nuisance, including appearance of extremely large numbers of larvae crawling about and the excrement they drop from infested trees, but other impacts, such as shade loss or tree mortality, can be much more critical in urban environments, especially in the context of climate change.

Spongy moth outbreaks can also affect human health directly. The hairs on the larvae can cause an allergic reaction in susceptible people, particularly during large outbreaks (Haq et al. 2021). Cases of dermatitis caused by exposure to the hairs of early instar larvae have been documented since 1900 and typically occur during severe outbreaks (Allen et al. 1991).

Economic Impacts

Impacts on trade and market access are a major concern in regions where spongy moth is not established. Quarantine measures can be imposed on products exported to areas or jurisdictions that are considered free of spongy moth (Leuschner et al. 1996). Establishment of an invasive pest can therefore affect movement of key commodities being imported and exported, including wood products, grain, nursery stock, Christmas trees.

Outbreaks can occur across extensive forested landscapes, affecting revenues from wood harvesting and generating costs associated with hazard tree removal (Humble and Stewart 1994). Attempts to control these large outbreaks are costly and will ultimately result in economic losses. Based on a study from 2019, Ontario municipalities and conservation authorities spend an estimated $4.5 million per year on spongy moth control initiatives during outbreaks (Vyn 2019).

There is little published empirical work on the aesthetic impact of spongy moth damage. Some impact on tourism and recreation is expected from the presence of high numbers of insects, frass, tree defoliation, dieback, and mortality in infested areas (Leuschner et al. 1996).

Impacts on real estate have also been shown, where the cost of treatment/suppression is much less than the potential loss in the real estate market. In the U.S., spongy moth defoliation caused a loss of more than USD$120 million annually to residential property value (Aukema et al. 2011).

The impacts of spongy moth on agriculture have not been quantified for Canada but the insect is known to affect food crops, such as fruit trees (Humble and Stewart 1994). Negative effects on agricultural species would add an additional economic loss to local communities and beyond.

Uncertainty

- Low uncertainty that spongy moth outbreaks will have negative impacts on sensitive ecosystems, such as Garry oak ecosystems, but moderate to high uncertainty about the specific effects.
- Low overall uncertainty that new spongy moth establishments pose an economic threat, but moderate uncertainty about the magnitude of impacts.
- Low overall uncertainty that spongy moth infestations have social effects, but uncertainty is high regarding the magnitude of impacts.
- Moderate uncertainty regarding the successional and species compositional changes to forest that are likely to occur from repeated defoliation, especially in novel environments.
- Moderate uncertainty surrounding the effects of spongy moth defoliation on avian communities, especially in novel environments.
- Moderate uncertainty about human health impacts.
- Moderate uncertainty about effects on agricultural species of economic interest (e.g., fruit trees, blueberries).

Information Needs

- Delineation of the range of suitable hosts of spongy moth in areas where the insect is not yet established but at risk, and how these hosts integrate into ecosystems and communities to accurately predict ecological, social, and economic impacts.

- Understanding of how tree species susceptibility rank in relation to each other.
- Potential spongy moth ecological impacts on, and potential treatment options in, novel sensitive ecosystems.
- Identification of the minimum amount of host species needed to support an outbreak in novel ecosystems.
- Analyses of spongy moth economic impacts on trade, and on urban, forest and agricultural values, including valuation of short-term impacts on ecosystem services and biodiversity.

Affirmative Statement 5: Managing spongy moth invasions in novel areas where the insect has been recently detected is currently feasible and cost-effective but also poses potential challenges.

Evidence

Governance frameworks for responding to new introductions of forest invasive species exist in western Canada, although not all of them are specific to spongy moth nor were they recently tested. The British Columbia Plant Protection Advisory Council is a forum advancing an active framework that includes both federal and provincial government agencies, municipal governments, universities, and industry. The council addresses plant health and quarantine issues for British Columbia and is an example of a multi-jurisdictional partnership. Technical advisory committees are also in place to provide updates on priority pests to decision-makers, including spongy moth (Nealis 2009). Other examples include the *Alberta Invasive Alien Species Management Framework* and the *Framework for the Prevention and Management of Invasive Species in Saskatchewan*, which provide guidance for managing risks and coordinating responses to invasive species of concern in these provinces (Government of Alberta 2010; Government of Saskatchewan 2022).

There are many examples of successful eradication of recently introduced spongy moth populations outside its current range in Canada. For example, eradication programs were delivered in Manitoba and British Columbia, and eliminated persistent populations of introduced spongy moths (Manitoba Natural Resources and Northern Development 2022; British Columbia Ministry of Forests 2023). The next paragraphs will provide a more detailed description of how the British Columbia response framework is applied, as an example, because the application of other frameworks to spongy moth has not been documented extensively. Spongy moth prevention in British Columbia is primarily focused on monitoring and eradication of any introduced populations. Positive spongy moth detections trigger delimitation surveys. Spongy moth population increases in subsequent years trigger eradication programs (Figure 5). The most common treatment used in the province is spraying of *Btk* (Sun et al. 2019; Government of British Columbia 2023).

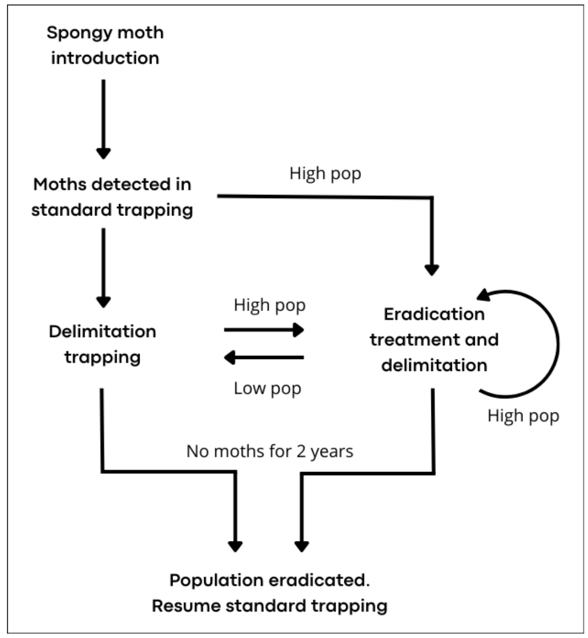

Figure 5: Conceptual model of the spongy moth management strategy in British Columbia used to prevent the establishment of spongy moth populations (pop) in the province (adapted from Sun et al. 2019).

Under most circumstances, eradication is currently deemed feasible and cost-effective in British Columbia relative to the potential costs anticipated with no action (Sun et al. 2019). Similar cost-benefit analyses from other Canadian provincial jurisdictions are lacking. Estimated costs of future impacts if spongy moth were to establish in British Columbia exceed those of the provincial prevention program by a 3:1 ratio, based on assumptions of low tree damage and limited trade restrictions (Sun et al. 2019). Further evidence from the U.S.' spongy moth *Slow the Spread Program* also indicates that costs associated with spongy moth impacts through spread into new areas exceed those of monitoring and eradication by a 4:1 ratio (Sharov et al. 2002b).

Historically, the highest number of spongy moth detections in British Columbia occurred in 1999. This was the only year where a federal quarantine was imposed in the province, and the quarantine prompted the most expensive provincial eradication program up to that year. It is thought that the high number of detections in 1999 was caused by the combination of a delayed response to a building population established in previous years and the increased intensity in detection surveys that year (Nealis 2009). Currently, two years of increasing trap captures in British Columbia prompts an eradication program (Figure 5). The delay in response in 1999 was partially due to public resistance to aerial application of insecticides (Sun et al. 2019). This 1999 incident provides further evidence of the importance of sharing science-based evidence and interpretation of this evidence across all levels to better inform decision-makers and citizens in affected communities (Nealis 2009).

Some challenges in spongy moth management may be addressed by improving social license. The identification and communication of local ecological impacts can aid in public support for spray programs and other measures related to invasive species management. However, recurring treatment programs may lead to a decline in public support. Another barrier to improved social licence is access to information, which could be constrained by capacity of smaller organizations (municipalities, conservation authorities, regional landowners) as well as the level of expertise required to absorb it. Governance structures established to address spongy moth, and associated roles and responsibilities, should account for this reality. Examples from other pest management programs in Canada demonstrate the importance of multi-level communication and outreach for the success of these programs. This has been the case for the *Early Intervention Strategy for Spruce Budworm* initiative in Atlantic Canada, where significant effort has been invested since 2014 in interactions with provincial government agencies, regional forest industry, private woodlot owners, researchers, and the public (MacLean et al. 2019). However, this initiative is largely focused on pest management in natural and rural forest areas, which may be a factor influencing public acceptance compared to a programs delivered in urban forest areas.

In areas where spongy moth eradication is not feasible, strategic releases of *Entomophaga maimaiga* and NPV could serve as a long-term management tool to suppress an outbreak and reduce associated negative impacts (Hajek et al. 2021). *Entomophaga maimaiga* can kill spongy moth larvae even when populations are low if spring weather conditions are favourable to the pathogen. In contrast, NPV is not affected by weather and will only cause mortality when spongy moth populations are high. *Entomophaga maimaiga* plays an important role in the dynamics of spongy moth at the leading edge of an outbreak (Villedieu and Frankenhuyzen 2004). Although contributing to the eventual collapse of outbreaks, these pathogens alone cannot reliably prevent impacts on communities as they are also dependent on other environmental conditions not under pest managers' control. In addition, areas where spongy moth is not yet established will lack these natural enemies. As such, there is uncertainty around spongy moth population dynamics in novel environments.

Uncertainty

- Low uncertainty that information exchange and communication will improve social license for spongy moth treatment programs.
- Low uncertainty around the efficacy and cost-effectiveness of existing frameworks to respond to spongy moth in British Columbia.
- Moderate uncertainty regarding frameworks in other jurisdictions because their application to spongy moth or other invasive species has been both limited and not well documented.

Information Needs

- Evaluation and cost-benefit analyses for response frameworks outside of British Columbia. This could include national-level analyses.
- Identification and understanding of spongy moth impacts in novel environments to inform risk management and public outreach.

Affirmative Statement 6: Establishment of spongy moth in western Canada would increase the risk of other exotic *Lymantria* escaping detection and potentially becoming established.

Evidence

Despite mechanisms for preventing exotic *Lymantria* introductions at ports, they still occur. The ability to detect exotic *Lymantria* will become more difficult if spongy moth establishes in western Canada. Upon establishment, monitoring and control efforts could be reduced and in turn, could affect the level of monitoring effort for other exotic *Lymantria* species and subspecies as the same traps are often used to detect moths of other subspecies. Distinguishing between spongy moth and other exotic *Lymantria* currently requires genetic testing. Increasing numbers of spongy moths in these traps would significantly increase the delay and cost of detecting other exotic species. Maintaining spongy-moth free areas in western Canada will decrease the amount of genetic screening and facilitate detection of other exotic *Lymantria* (Régnière et al. 2009).

One key difference between the FSMC and spongy moth subspecies of European origin, as the name suggests, is the ability of flight. As hybridization can occur between subspecies and flight is a polygenic trait, it is possible that flight ability can get diluted where spongy moth of European origin already exists (Srivastava et al. 2021). Unintended alterations to spongy moth biology, including retention of traits such as ability of females to fly long distances would result in increased risk of spread. Suitable conditions do exist for the establishment of FSMC in British Columbia, New Brunswick, Nova Scotia, Ontario, and Québec (Srivastava et al. 2020).

Uncertainty

- Low uncertainty that reducing spongy moth monitoring and control efforts in western Canada would increase the risk of establishment of other exotic *Lymantria*.
- Moderate uncertainty around the ability to sustain monitoring for other exotic *Lymantria* in regions where spongy moth has established.
- Moderate uncertainty around our ability to effectively intercept new introductions of FSMC prior to their establishment and spread across Canada.

Information Needs

- Evaluations of efficacy and specificity of pheromone lures currently used to detect insects of the Lymantriinae subfamily. This may include development of trapping systems, such as light traps, that are more specific for FSMC.
- Assessments of risk response for spongy moth versus FSMC.

Overall Risk Characterization

In eastern Canada, the maximum extent of suitable range for spongy moth has likely been reached. This assessment concludes that the insect's range in eastern Canada is unlikely to expand geographically in the near future. A large portion of western Canada, where spongy moth is not considered established, has a suitable climate and available hosts for the insect's development. Western Canada, especially British Columbia, is subject to recuring spongy moth introductions and eradication programs. Because much of the climatically suitable range in the prairie provinces has relatively few hosts for spongy moth and has limited areas of contiguous forest containing these hosts (i.e., mostly grasslands and agricultural land), these factors impede direct westward spread via natural ecosystems. It is the movement of people and commodities that pose the greatest risk, and this movement will continue to facilitate future introductions.

Climate change is expected to increase the potential susceptible areas for spongy moth establishment in the next 30 years, including at the leading edge of the current range of the insect in eastern Canada and across uninfested areas of western Canada. As climatically suitable areas for the insect increase, existing resources dedicated to current monitoring and eradication efforts might not be enough to absorb additional susceptible area and associated expenses. This assessment also points to additional risks associated with the potential introduction of FSMC should spongy moth of European origin became established in western Canada. Although spongy moth long distance dispersal and introductions are expected to continue and potentially increase in western Canada, it is deemed cost-effective to maintain prevention and eradications efforts in the latter region.

Establishment of this insect in currently uninfested and unregulated areas can lead to significant ecological, economic, and social impacts, and could be better prevented or mitigated through improvements to existing spread prevention strategies. A combination of elements, such as continued research, regulatory and control measures, collaborative partnerships, and effective public outreach, could improve both the probability of success and sustainability of spread prevention and risk mitigation in areas currently free of spongy moth populations.

Several gaps in current knowledge were identified in this assessment and should be targeted for future research to assist spongy moth risk management decisions. Key information needs that will aid in reducing important uncertainties include, but are not limited to:

- The current and projected distribution of primary host species and their vulnerability in a changing climate;
- The risk of long-distance dispersal of the various spongy moth life stages on lesser-researched pathways, such as rail;
- The indirect, interacting effects of climate change on ecosystems and how they could affect spongy moth population dynamics;
- A more complete understanding of the short- and long-term ecological and economic impacts of spongy moth outbreaks in established areas and in novel habitats.;
- The enhancement of communication tools to better inform and educate the public about spongy moth impacts and control; and,
- Enhanced information on trapping systems efficacy and opportunities for enhancements, especially where both spongy moth of European origin and flighted spongy moth are present together.

References

Allen, V.G.; Miller, O.F.; Tyler, W.J. 1991. Gypsy moth caterpillar dermatitis—revisited. J. Am. Acad. Dermatol. **24**(6): 979–981. https://doi.org/10.1016/0190-9622(91)70157-w.

Allen, C.D.; Macalady, A.K.; Chenchouni, H.; Bachelet, D.; McDowell, N.; Vennetier, M.; Kitzberger, T.; Rigling, A.; Breshears, D.D.; Hogg, E.H.; Gonzalez, P.; Fensham, R.; Zhang, Z.; Castro, J.; Demidova, N.; Lim, J.-H.; Allard, G.; Running, S.W.; Semerci, A.; Cobb, N. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management. 259(4): 660–684. https://doi.org/10.1016/j.foreco.2009.09.001.

Andresen, J.A.; McCullough, D.G.; Potter, B.E.; Koller, C.N.; Bauer, L.S.; Lusch, D.P.; Ramm, C.W. 2001. Effects of winter temperatures on Gypsy moth egg masses in the Great Lakes region of the United States. Agric. For. Meteorol. **110**(2): 85–100. https://doi.org/10.1016/S0168-1923(01)00282-9.

Aukema, J.E.; Leung, B.; Kovacs, K.; Chivers, C.; Britton, K.O.; Englin, J.; Frankel, S.J.; Haight, R.G.; Holmes, T.J.; Liebhold, A.M.; McCullough, D.G.; Von Holle, B. 2011. Economic impacts of non-native forest insects in the continental United States. PLOS ONE **6**(9): 1–7. https://doi.org/10.1371/journal.pone.0024587.

Benoit, P.; Lachance, D. 1990. Gypsy moth in Canada: behavior and control. Information Report No. DPC-X-32. Forestry Canada, Sainte-Foy, Québec, 26 p. https://cfs.nrcan.gc.ca/pubwarehouse/pdfs/10041_e.pdf

Bigsby, K.M.; Tobin, P.C.; Sills, E.O. 2011. Anthropogenic drivers of gypsy moth spread. Biol. Invasions **13**(9): 2077–2090. https://doi.org/10.1007/s10530-011-0027-6.

Bird, R.D. 1961. Ecology of the aspen parkland of Western Canada in relation to land use. Agriculture Canada, Research Branch, Ottawa, Ontario, 184 p. https://publications.gc.ca/collections/collection_2013/aac-aafc/agrhist/A43-1066-1961-eng.pdf

British Columbia Ministry of Forests. 2023. Detailed history of spongy moth treatments in B.C. https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-health/invasive-forest-pests/spongy-moth/treatment-history

Blackburn, L.M.; Hajek, A.E. 2018. Gypsy moth larval necropsy guide. General Technical Report. NRS-179. Newtown Square, PA. U.S. Department of Agriculture, Forest Service, Northern Research Station. 30 p. https://doi.org/10.2737/NRS-GTR-179.

Borisade, O.A.; Magan, N. 2015. Resilience and relative virulence of strains of entomopathogenic fungi under interactions of abiotic stress. Afr. J. Microbiol. Res. **9**(14): 988–1000. https://doi.org/10.5897/AJMR2015.7416.

Boulton, T.J.; Otvos, I.S.; Halwas, K.L.; Rohlfs, D.A. 2007. Recovery of nontarget Lepidoptera on Vancouver Island, Canada: one and four years after a gypsy moth eradication program. Environmental Toxicology and Chemistry **26**: 738–748. https://doi.org/10.1897/06-079r1.1.

Butler, L.; Kondo, V.; Blue, D. 1997. Effects of tebufenozide (RH-5992) for gypsy moth (Lepidoptera: Lymantriidae) suppression on nontarget canopy arthropods. Environmental Entomology **26**: 1009–1015. https://doi.org/10.1093/ee/26.5.1009.

Canadian Council of Forest Ministers Forest Pest Working Group. 2015. National forest pest strategy – pest risk analysis framework: User's guide. Compiled by Janice Hodge. Ottawa, Ontario. 38 p. https://www.ccfm.org/releases/national-forest-pest-strategy-pest-risk-analysis-framework-users-guide-2/

Canadian Food Inspection Agency. 2019. Pest risk management document for the expansion of the regulated area of *Lymantria Dispar* (European gypsy moth) in eastern Canada. RMD-19-01, Ottawa, Ontario. 12 p.

Canadian Food Inspection Agency. 2020. Appendix 1: List of spongy moth (*Lymantria dispar dispar*) infested areas of Canada and the United States. https://inspection.canada.ca/plant-health/invasive-species/directives/forest-products/d-98-09/appendix-1/eng/1343832991660/1343834043533

Canadian Food Inspection Agency. 2021. D-98-09: Comprehensive policy to control the spread of the LDD moth (*Lymantria dispar dispar*) in Canada and the United States https://inspection.canada.ca/plant-health/invasive-species/directives/forest-products/d-98-09/eng/1323885774950/1323886065560

Catton, H.; St. George, S.; Remphrey, W. 2007. An Evaluation of Bur Oak (*Quercus macrocarpa*) Decline in the Urban Forest of Winnipeg, Manitoba, Canada. Arboriculture and Urban Forestry **33**(1): 22-30. https://doi.org/10.48044/jauf.2007.003.

Corbett, E.S.; Lynch, J.A. 1987. The gypsy moth - does it affect soil and water resources? p. 39–46 In: Fosbroke, S. and R.R. Hicks, Jr., eds.; Proceedings, Coping with the Gypsy Moth in the New Frontier; August 4-6, 1987; West Virginia Univ. Books, Morgantown.

Currano, E.D.; Wilf, P.; Wing, S.L.; Labandeira, C.C.; Lovelock, E.C.; Royer, D.L. 2008. Sharply increased insect herbivory during the Paleocene–Eocene Thermal Maximum. P. Natl. Acad. Sci-Biol. **105**(6): 1960–1964. https://doi.org/10.1073/pnas.0708646105.

Davidson, C.B.; Gottschalk, K.W.; Johnson, J.E. 1999. Tree mortality following defoliation by the European gypsy moth (*Lymantria dispar L.)* in the United States: a review. Forest Sci. **45**(1): 74–84. https://doi.org/10.1093/forestscience/45.1.74.

Desormeaux, M. 2022. A sudden move: Understanding interprovincial migration out of Ontario [online]. Scotiabank Global Economics – Provincial Pulse, March 17, 2022. Available at: https://www.scotiabank.com/ca/en/about/economics/economics-publications/post.other-publications.the-provinces.ontario-interprovincial-migration--march-17-2022-.html

Diss, A.L.; Kunkel, J.G.; Montgomery, M.E.; Leonard, D.E. 1996. Effects of maternal nutrition and egg pro-visioning on parameters of larval hatch, survival and dispersal in the gypsy moth, *Lymantria dispar L*. Oecologia **106**: 470–477. https://doi.org/10.1007/bf00329704.

Diss-Torrance, A.; Peterson, K; Robinson, C. 2018. Reducing firewood movement by the public: use of survey data to assess and improve efficacy of a regulatory and educational program, 2006–2015. Forests **9**(2): 90. https://doi.org/10.3390/f9020090.

Djoumad, A.; Nisole, A.; Stewart, D.; Holden, D.; Zahiri, R.; Inoue, M.N.; Martemyanov, V.V.; Levesque, R.C.; Hamelin, R.C.; Cusson, M. 2020. Reassessment of the status of *Lymantria albescens* and *Lymantria postalba* (Lepidoptera: Erebidae: Lymantriinae) as distinct 'Asian gypsy moth' species, using both mitochondrial and nuclear sequence data. Syst. Entomol. **45**: 493–504. https://doi.org/10.1111/syen.12410.

Faske, T.M.; Thompson, L.M.; Banahene, N.; Levorse, A.; Quiroga Herrera, M.; Sherman, K.; Timko, S.E.; Yang, B.; Gray, D.R.; Parry, D.; Tobin, P.C.; Eckert, A.J.; Johnson, D.M.; Grayson, K.L. 2019. Can gypsy moth stand the heat? A reciprocal transplant experiment with an invasive forest pest across its southern range margin. Biol. Invasions **21**(4): 1365–1378. https://doi.org/10.1007/s10530-018-1907-9.

Fajvan, M. A.; Wood, J.M. 1996. Stand structure and development after gypsy moth defoliation in the Appalachian Plateau. Forest Ecol. and Manag. **89**(1): 79–88. https://doi.org/10.1016/S0378-1127(96)03865-0.

Friedline, C.J.; Faske, T.M.; Lind, B.M.; Hobson, E.M.; Parry, D.; Dyer, R.J.; Johnson, D.M.; Thompson, L.M.; Grayson, K.L.; Eckert, A.J. 2019. Evolutionary genomics of gypsy moth populations sampled along a latitudinal gradient. Mol. Ecol. **29**: 2206–2223. https://doi.org/10.1111/mec.15069.

Gale, G.A.; DeCecco, J.A.; Marshall, M.R.; McClain, W.R.; Cooper, R.J. 2001. Effects of gypsy moth defoliation on forest birds: An assessment using breeding bird census data. J. Field Ornithol. 72(2): 291–304. https://doi.org/10.1648/0273-8570-72.2.291.

Gray, D. 2004. The gypsy moth life stage model: landscape-wide estimates of gypsy moth establishment using a multi-generational phenology model. Ecol. Model. **176**(1–2): 155–171. https://doi.org/10.1016/j.ecolmodel.2003.11.010.

Government of Alberta. 2010. Alberta Invasive Species Management Framework. 24 p. https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/prm13262/$file/frame.pdf

Government of British Columbia. 2023. Spongy moth (formerly referred to as gypsy moth) in British Columbia. British Columbia Ministry of Forests. https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-health/invasive-forest-pests/spongy-moth

Government of Saskatchewan. 2022. Framework for the Prevention and Management of Invasive Species in Saskatchewan. 22 p. https://publications.saskatchewan.ca/api/v1/products/119660/formats/137975/download

Hajek, A.E.; Diss-Torrance, A.L.; Siegert, N.W.; Liebhold, A.M. 2021. Inoculative releases and natural spread of the fungal pathogen *Entomophaga maimaiga* (Entomophthorales: Entomophthoraceae) into US populations of gypsy moth, *Lymantria dispar* (Lepidoptera: Erebidae). Environ. Entomol. **50**(5): 1007–1015. https://doi.org/10.1093/ee/nvab068.

Haq, M.; O'Toole, A.; Beecker, J.; Gooderham, M. 2021. Return of *Lymantria dispar dispar* (gypsy moth): A case report. SAGE Open Med. Case Rep. **9**: 1–3. https://doi.org/10.1177/2050313x211057926.

Haynes, K.J.; Liebhold, A.M.; Lefcheck, J.S.; Morin, R.S.; Wang, G. 2022. Climate affects the outbreaks of a forest defoliator indirectly through its tree hosts. Oecologia **198**(2): 407–418. https://doi.org/10.1007/s00442-022-05123-w.

Hennigar, C.R.; MacLean, D.A.; Norfolk, C.J. 2007. Effects of Gypsy Moth Defoliation on Softwood and Hardwood Growth and Mortality in New Brunswick, Canada. Northern Journal of Applied Forestry **24**(2): 138–145. https://doi.org/10.1093/njaf/24.2.138.

Hogg, E.H. 1994. Climate and the southern limit of the western Canadian boreal forest. Can. J. For. Res. **24**(9): 1835–1845. https://doi.org/10.1139/x94-237.

Hogg, E.H.; Brandt, J.P.; Kochtubajda, B. 2002. Growth and dieback of aspen forests in northwestern Alberta, Canada, in relation to climate and insects. Can. J. For. Res. **32**: 823–832. https://doi.org/10.1139/x01-152

Hogg, E.H.; Bernier, P.Y. 2005. Climate change impacts on drought-prone forests in western Canada. For. Chron. **81**(5): 675–682. https://doi.org/10.5558/tfc81675-5.

Hogg, E.H.; Brandt J.P.; Kochtubajda, B. 2005. Factors affecting interannual variation in growth of western Canadian aspen forests during 1951–2000. Can. J. For. Res. **35**: 610–622. https://doi.org/10.1139/x04-211.

Hunter, A.F.; Elkinton, J.S. 2000. Effects of synchrony with host plant on populations of a spring-feeding lepidopteran. Ecology **81**(5): 1248–1261. https://doi.org/10.2307/177205.

Humble, L.; Stewart, A.J. 1994. Gypsy moth. Forest Pest Leaflet. Natural Resources Canada, Canadian Forest Service, Ottawa, Ontario. 8 p. https://cfs.nrcan.gc.ca/publications/download-pdf/3456

Jactel, H.; Koricheva, J.; Castagneyrol, B. 2019. Responses of forest insect pests to climate change: not so simple. Curr. Opin. Insect Sci. **35**: 103–108. https://doi.org/10.1016/j.cois.2019.07.010.

Kretchun, A.M.; Scheller, R.M.; Lucash, M.S.; Clark, K.L.; Hom, J.; Van Tuyl, S. 2014. Predicted effects of gypsy moth defoliation and climate change on forest carbon dynamics in the New Jersey pine barrens. PLOS ONE **9**(8): e102531. https://doi.org/10.1371/journal.pone.0102531.

Keena, M.A.; Côté, M.J.; Grinberg, P.S.; Wallner, W.E. 2014. World distribution of female flight and genetic variation in *Lymantria dispar* (Lepidoptera: Lymantriidae). Environ. Entomol. **37**: 636–649. https://doi.org/10.1603/0046-225X(2008)37[636:WDOFFA]2.0.CO;2

Keena, M.A.; Richards, J.M. 2020. Comparison of survival and development of gypsy moth *Lymantria dispar L.* (Lepidoptera: Erebidae) populations from different geographic areas on North American conifers. *Insects*, **11**(4): 260. https://doi.org/10.3390/insects11040260.

Lance, D.R.; Barbosa, P. 1981. Host tree influences on the dispersal of first instar gypsy moths, *Lymantria dispar* (L.). Ecol. Entomol. **6**(4): 411–416. https://doi.org/10.1111/j.1365-2311.1981.tb00632.x.

Leuschner, W.A.; Young, J.A.; Ravlin, F.W. 1996. Potential benefits of slowing the gypsy moth's spread. South. J. Appl. For. **20**(2): 65–73. https://doi.org/10.1093/sjaf/20.2.65.

Liebhold, A.M.; Halverson, J.; Elmes, G.A. 1992. Gypsy moth invasion in North America: A quantitative analysis. *J. Biogeogr.* **19**(5): 513. https://doi.org/10.2307/2845770.

Liebhold, A.M.; Gottschalk, K.; Muzika, R.; Montgomery, M.E.; Young, R.; O'Day, K.; Kelley, B. 1995. Suitability of North American tree species to the gypsy moth: A summary of field and laboratory tests. United States Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Radnor, Pennsylvania. 34 p. https://www.fs.usda.gov/research/treesearch/4327.

Lovett, G.M.; Christenson, L.M.; Groffman, P.M.; Jones, C.G.; Hart, J.E.; Mitchell, M.J. 2002. Insect defoliation and nitrogen cycling in forests. BioScience 52(4): 335–341. https://doi.org/10.1641/0006-3568(2002)052[0335:IDANCI]2.0.CO;2

MacLean, D.A.; Amirault, P.; Amos-Binks, L.; Carleton, D.; Hennigar, C.; Johns, R.; Régnière, J. 2019. Positive results of an early intervention strategy to suppress a spruce budworm outbreak after five years of trials. Forests **10**(5): 448. https://doi.org/10.3390/f10050448

Madrid, F.J.; Stewart, R.K. 1981. Ecological significance of cold hardiness and winter mortality of eggs of the gypsy moth *Lymantria dispar* L. in Quebec. Environ. Entomol. 10: 586–589. https://doi.org/10.1093/ee/10.5.586.

Manderino, R.; Crist, T.O.; Haynes, K.J. 2014. Lepidoptera-specific insecticide used to suppress gypsy moth outbreaks may benefit non-target forest Lepidoptera. Agricultural and Forest Entomology **16**: 359–368. https://doi.org/10.1111/afe.12066.

Manitoba Natural Resources and Northern Development. 2022. Manitoba's Five Year Report on the Status of Forestry. April 2016 - March 2021. Forestry and Peatlands Branch. November 22, 2022. https://www.gov.mb.ca/nrnd/forest/pubs/forest_lands/5yr_report2022.pdf

Michaelian, M.; Hogg, E.H.; Hall, R.J.; Arsenault, E. 2011. Massive mortality of aspen following severe drought along the southern edge of the Canadian boreal forest. Glob. Chang. Biol. **17**: 2084–2094. https://doi.org/10.1111/j.1365-2486.2010.02357.x.

Miller, D.R.; Mo, T.K.; Wallner, W.E. 1989. Influence of climate on gypsy moth defoliation in southern New England. Environ. Entomol. **18**: 646–650. https://doi.org/10.1093/ee/18.4.646.

Miller, J.C. 1990. Field assessment of the effects of a microbial pest control agent on nontarget Lepidoptera. The American Entomologist **36**: 135–140. https://doi.org/10.1093/ae/36.2.135.

Miller, J.S.; Hanson, P.R.; Kimberling, D.N. 1991. Development of the gypsy moth (Lepidoptera: Lymantriidae) on Garry oak and red alder in western North America. Environ. Entomol. **20**(4): 1097–1101. https://doi.org/10.1093/ee/20.4.1097.

Morin, R.S.; Liebhold, A.M. 2015. Invasive forest defoliator contributes to the impending downward trend of oak dominance in eastern North America. Forestry **89**(3): 284–289. https://doi.org/10.1093/forestry/cpv053.

Nature Conservancy of Canada. 2023. Garry oak parkland and savannah. https://www.natureconservancy.ca/en/what-we-do/resource-centre/forests-101/garry-oak-parkland-savannah.html

Nealis, V.G. 2009. Still invasive after all these years: Keeping gypsy moth out of British Columbia. Forest. Chron. **85**(4): 593–603. https://doi.org/10.5558/tfc85593-4.

Nealis, V.G. 2015. A risk analysis framework for forest pest management. Forest. Chron. **91**(1): 32–39. https://doi.org/10.5558/tfc2015-008.

Ontario Ministry of Natural Resources and Forestry. 2021. Forest health conditions in Ontario 2021. Science and Research Branch, Ontario. 138 p.

Perala, D.A. 1990. *Populus tremuloides* Michx. Quaking aspen. In Silvics of North America, Vol. 2. Hardwoods. Agriculture Handbook, No. 654 (eds R.M. Burns, B.H. Honkala). USDA Forest Service, Washington, DC, USA. pp. 555–569.

Picq, S.; Wu, Y.; Martemyanov, V.V.; Pouliot, E.; Pfister, S.E.; Hamelin, R.; Cusson, M. 2023. Range-wide population genomics of the spongy moth, *Lymantria dispar* (Erebidae): Implications for biosurveillance, subspecies classification and phylogeography of a destructive moth. Evolutionary Applications **16**: 638–656. https://doi.org/10.1111/eva.13522.

Pogue, M.G.; Schaefer, P.W., 2007. A review of selected species of Lymantria Hübner [1819] including three new species (Lepidoptera: Noctuidae: Lymantriinae) from subtropical and temperate regions of Asia, some potentially invasive to North America. USDA Forest Service Forest Health Technology Enterprise Team. Morgantown, West Virginia USA, 232 p.

Pureswaran, D.S.; Roques, A.; Battisti, A. 2018. Forest insects and climate change. Curr. For. Rep. **4**: 35–50. https://doi.org/10.1007/s40725-018-0075-6.

Rastall, K.; Kondo, V.; Strazanac, J.S.; Butler, L. 2003. Lethal effects of biological insecticide applications on nontarget lepidopterans in two Appalachian forests. Environmental Entomology **32**: 1364–1369. https://doi.org/10.1603/0046-225X-32.6.1364.

Régnière, J.; Nealis, V.; Porter, K. 2009. Climate suitability and management of the gypsy moth invasion into Canada. Biol. Invasions **11**: 135–148. https://doi.org/10.1007/s10530-008-9325-z.

Robinet, C.; Roques, A. 2010. Direct impacts of recent climate warming on insect populations. Integr. Zool. **5**(2): 132–142. https://doi.org/10.1111/j.1749-4877.2010.00196.x.

Sample, E.; Butler, L.; Zivkovich, C.; Whitmore, R.; Reardon, R. 1996. Effects of *Bacillus thuringiensis* Berliner var. *kurstaki* and defoliation by the gypsy moth (*Lymantria dispar* (L.) (Lepidoptera: Lymantriidae)) on native arthropods in West Virginia. The Canadian Entomologist **128**: 573–592. https://doi.org/10.4039/Ent128573-4.

Scriber, J.M. 2004. Non-target impacts of forest defoliator management options: decision for no spraying may have worse impacts on non-target Lepidoptera than *Bacillus thuringiensis* insecticides. Journal of Insect Conservation **8**: 241–261. https://doi.org/10.1007/s10841-004-1357-9.

Sharov, A.A.; Pijanowski, B.C.; Liebhold, A.M.; Gage, S.H. 1999. What affects the rate of gypsy moth (Lepidoptera: Lymantriidae) spread: winter temperature or forest susceptibility? Agric. For. Entomol. **1**(1): 37–45. https://doi.org/10.1046/j.1461-9563.1999.00006.x.

Sharov, A.A.; Leonard, D.; Liebhold, A.M.; Clemens, N.S. 2002a. Evaluation of preventive treatments in low-density gypsy moth populations using pheromone traps. J. Econ. Entomol. **95**(6): 1205–1215. https://doi.org/10.1603/0022-0493-95.6.1205.

Sharov, A.A.; Leonard, D.; Liebhold, A.M.; Roberts, E.; Dickerson, W. 2002b. "Slow The Spread": A national program to contain the gypsy moth. J. For. **100**(5): 30–35. https://doi.org/10.1093/jof/100.5.30.

Shi, J.; Chen, F.; Keena, M.A. 2015. Differences in wing morphometrics of *Lymantria dispar* (Lepidoptera: Erebidae) between populations that vary in female flight capability. Annals of the Entomological Society of America **108**, 528–535. tps://doi.org/10.1093/aesa/sav045

Smith-Tripp, S.; Griffith, A.; Pasquarella, V.J.; Matthes, J.H. 2021. Impacts of a regional multiyear insect defoliation event on growing-season runoff ratios and instantaneous streamflow characteristics. Ecohydrology **14**(7): e2332. https://doi.org/10.1002/eco.2332.

Solano, A.; Rodriguez, S.L.; Greenwood, L.; Rosopa, P.J.; Coyle, D.R. 2022. Achieving effective outreach for invasive species : firewood case studies from 2005 to 2016. Biol. Invasions **24**(10): 3321–3339. https://doi.org/10.1007/s10530-022-02848-w.

Srivastava, V.; Griess, V.C.; Keena, M.A. 2020. Assessing the potential distribution of Asian gypsy moth in Canada: A compari son of two methodological approaches. Sci. Rep. **10**(1): 22. https://doi.org/10.1038/s41598-019-57020-7.

Srivastava, V.; Keena, M.A.; Maennicke, G.E.; Hamelin, R.C.; Griess, V.C. 2021. Potential differences and methods of deter mining gypsy moth female flight capabilities: Implications for the establishment and spread in novel habitats. Forests **12**(1): 103. https://doi.org/10.3390/f12010103.

Streifel, M.A.; Tobin, P.C.; Kees, A.M.; Aukema, B.H. 2018. Range expansion of *Lymantria dispar dispar (L.)* (Lepidoptera: Erebidae) along its north-western margin in North America despite low predicted climatic suitability. J. Biogeogr. **1**(46): 58–69. https://doi.org/10.1111/jbi.13474.

Sullivan, C.R.; Wallace, D.R. 1972. The potential northern dispersal of the gypsy moth, *Porthetria dispar* (Lepidoptera: Lymantriidae). Can. Entomol. 104: 1349–1355. https://doi.org/10.4039/Ent1041349-9.

Sun, B.; Bogdanski, B.; Van Hezewijk, B. 2019. The economic feasibility of the gypsy moth eradication program in British Columbia. Natural resources Canada, Canadian Forest Service, Victoria, Canada. 26 p. https://cfs.nrcan.gc.ca/publications?id=39964.

Thompson, L.M.; Faske, T.M.; Banahene, N.; Grim, D.; Agosta, S.J.; Parry, D.; Tobin, P.C.; Johnson, D.M.; Grayson, K.L. 2017. Variation in growth and developmental responses to supraoptimal temperatures near latitudinal range limits of gypsy moth *Lymantria dispar* (L.), an expanding invasive species. Physiol. Entomol. **42**(2): 181–190. *https://doi.org/10.1111/phen.12190.*

Thurber, D.K.; McClain, W.R.; Whitmore, R.C. 1994. Indirect effects of gypsy moth defoliation on nest predation. The J. Wildl . Manage. 493–500. https://doi.org/10.2307/3809321.

Tobin, P.C.; Sharov, A.A.; Liebhold, A.M.; Leonard, D.S.; Roberts, A.E.; Learn, M.R. 2004. Management of the gypsy moth through a decision algorithm under the STS project. Am. Entomol. **50**(4): 200–209. https://doi.org/10.1093/ae/50.4.200.

Tobin, P.C.; Blackburn, L. 2008. Long-distance dispersal of the gypsy moth (Lepidoptera: Lymantriidae) facilitated its initial invasion of Wisconsin. Environ. Entomol. **37**(1): 87–93. https://doi.org/10.1603/0046-225x(2008)37[87:ldotgm]2.0.co;2.

Tobin, P.C.; Gray, D.; Liebhold, A.M. 2014. Supraoptimal temperatures influence the range dyna mics of a non-native insect. Divers. Distrib. **20**(7): 813–823. https://doi.org/10.1111/ddi.12197.

Twery, M.J. 1991. Effects of defoliation by gypsy moth. In Gottschalk, K.W.; Twery, M.J.; Smith, S.I., eds. Proceedings, U.S. Department of Agriculture interagency gypsy moth research review 1990; East Windsor, CT. Gen. Tech. Rep. NE-146. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 27–39. https://www.nrs.fs.usda.gov/pubs/gtr/gtr_ne146/gtr_ne146_027.pdf

USDA Animal and Plant Health Inspection Service (APHIS). 2023. Flighted spongy moth complex. https://www.aphis.usda.gov/plant-pests-diseases/flighted-spongy-moth-complex.

USDA Forest Service. 1995. Gypsy moth management in the United States: a cooperative approach. Final Environmental Impact Statement. Summary, November 1995, 26 p.

Villedieu, Y.; van Frankenhuyzen, K. 2004. Epizootic occurrence of *Entomophaga maimaiga* at the leading edge of an expanding population of the gypsy moth (Lepidoptera: Lymantriidae) in north-central Ontario. Can. Entomol. **136**(6): 875–878. https://doi.org/10.4039/n04-002.

Vyn, R. 2019. Estimated expenditures on invasive species in Ontario: 2019 survey results. Invasive Species Centre, Sault Ste. Marie, Ontario. 37 p. https://www.invasivespeciescentre.ca/wp-content/uploads/2020/02/Final-Report-2019-Survey-Results-No-Appendix-A.pdf

Wagner, D.L.; Peacock, J.W.; Carter, J.L.; Talley, S.E. 1996. Field assessment of *Bacillus thuringiensis* on nontarget Lepidoptera. Environmental Entomology **25**: 1444–1454. https://doi.org/10.1093/ee/25.6.1444.

Wang, X.F.; Ji, L.; Zhang, Q.; Liu, Y.W.; Wang, G. 2009. Effects of elevated CO2 on feeding preference and performance of the gypsy moth (*Lymantria dispar*) larvae. J. Appl. Entomol. **133**(1): 47–57. https://doi.org/10.1111/j.1439-0418.2008.01320.x.

Annex

New Common Name

In March 2022, Entomological Societies of Canada and America adopted the name spongy moth as the new common name for the moth species *Lymantria dispar*, formally 'gypsy moth'.

Risk Assessment Process

This report provides an evidence-based assessment of the threat posed by spongy moth by applying the risk analysis framework (Figure 6) developed in support of the concept of a National Forest Pest Strategy (Nealis, 2015; Canadian Council of Forest Ministers Forest Pest Working Group, 2015). Two virtual knowledge synthesis workshops were held on November 1st and 2nd, 2022 with experts from governments and academia invited to participate. Affirmative statements, proposed by the task team providing guidance to the risk assessment project (see Acknowledgement), were presented for discussion of current knowledge about spongy moth. Uncertainty around the evidence in each statement was characterized as either low, moderate, or high, as per the table below. The information from the workshops, including additional evidence from the literature, has been summarized in this report. A list of workshop participants can be found in the Annex of this report.

Low Uncertainty	Indicated that the supporting evidence and scientific data are locally applicable, consistent, and comprehensive, and expected variability will not change the validity of the statement or assertion.
Moderate Uncertainty	Indicated that either (a) the statement is supported by preliminary evidence that could significantly lower the uncertainty, or (b) there is inherent variability that could significantly change the magnitude of the statement/assertion but not its truth.
High Uncertainty	Indicated that supporting evidence and scientific data are missing, are not locally applicable, and/or are inconsistent, and the expected variability could change the validity of the statement.

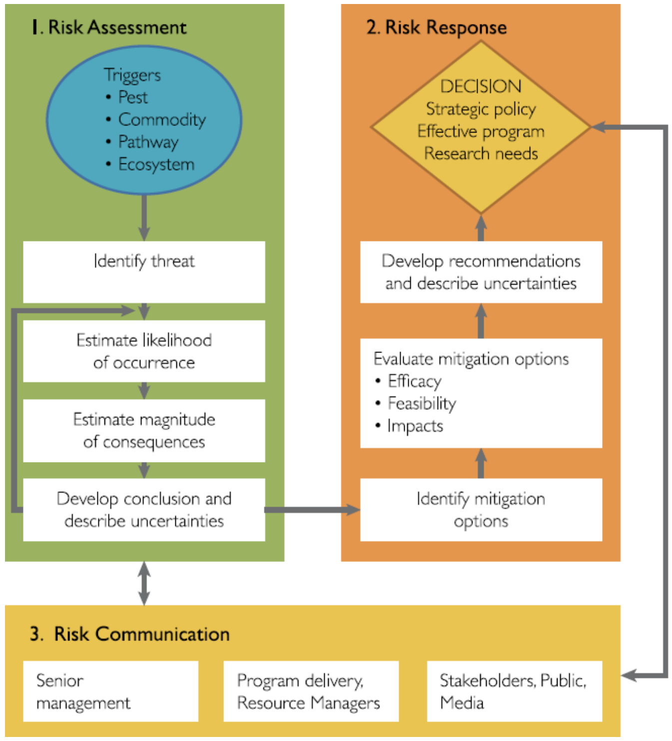

Figure 6: Conceptual diagram of the risk analysis process (Canadian Council of Forest Ministers Forest Pest Working Group 2015).

Knowledge Synthesis Workshop Participants

(November 1-2, 2022)

Arvind Vasudevan
Babita Bains
Brent Postlethwaite
Brian Grantham
Brian Van Hezewijk
Bryan Bogdanski
Caroline Whitehouse
Dan Rowlinson
Dave Holden
Derissa Vincentini (Note-taker)
Dominique Pelletier
Drew Carleton
Erin Bullas-Appleton
Emma Despland
Fiona Ross
Francine MacDonald
Gwylim Blackburn
Jason Pollard
Jean-Luc St-Germain
Jeff Motty
Jeremy Downe
Jim Saunders
Josh Pol
Justin Gaudon
Krista deMilliano
Leah Flaherty
Lauren Bell (Note-taker)
Mackenzie DiGasparro (Facilitator)
Madison Sturba (Note-taker)
Marnie Duthie-Holt
Melody Keena
Michel Cusson
Mike Undershultz
Nadir Erbilgin
Pierre Therrien
Richard Hamelin
Rory McIntosh
Ryan Lalonde
Sadia Butt
Sandrine Picq
Sharon Reed
Taylor Scarr
Tim Ebata
Violet Butterwort
Vince Nealis