Canadian Council of Forest Ministers

Conseil canadien des ministres des forêts

Forest Pest Monitoring in Canada

Current Situation, Compatibilities, Gaps and Proposed Enhanced Monitoring Program

Cat. no. Fo79-8/2012E-PDF
ISBN 978-1-100-20920-3

A pdf version of this publication is available through the Canadian Forest Service Publications site cfs.nrcan.gc.ca/publications

Design and layout: Julie Piché

Library and Archives Canada Cataloguing in Publication

Forest pest monitoring in Canada [electronic resource]: current situation, compatibilities, gaps and proposed enhanced monitoring program.

Issued also in French under title: Surveillance des ravageurs forestiers au Canada.
Electronic monograph in PDF format.
ISBN 978-1-100-20920-3
Cat. no.: Fo79-8/2012E-PDF

1. Trees—Diseases and pests—Monitoring—Canada. 2. Forest insects—Monitoring—Canada.
I. Canadian Council of Forest Ministers

SB764 C3 F67 2012 634.9'630971 C2012-980131-3

CONTENTS

Executive Summary

The historical occurrence and distribution patterns of native forest pests have been modified, or are expected to be modified in the next decade, as a result of climate change. At the same time, the risks posed by invasive alien species are expected to increase as international trade and traffic grow.

MONITORING: ESSENTIAL TO RISK-BASED FOREST PEST MANAGEMENT

In Canada, the National Forest Pest Strategy (NFPS) promotes a proactive, risk-based approach to forest pest management. The success of this approach is contingent on several factors, with one of the most important being the early detection—through monitoring—and identification of native and invasive alien species.

Monitoring data is required to realize NFPS goals. For this reason, an assessment of forest pest monitoring was undertaken to determine the nature of monitoring in Canada today, learn how compatible present survey methods are across jurisdictions, and identify monitoring gaps.

Currently, 64% of the managed forest (about 51% of the forested land base) is monitored by the provinces and territories (with the exception of Nunavut) through a combination of aerial and ground surveys. Surveys are typically conducted annually or as pest populations dictate. Emphasis is on monitoring major forest pests—most of which are defoliators—on managed forests.

CURRENT COMPATIBILITY OF SURVEY METHODS AND EXTENT OF PEST MONITORING

National reporting and pest risk analysis is most easily facilitated if common survey methods are used by all provinces and territories. For the most part, aerial overview surveys are compatible in terms of their severity scales, given the coarse resolution of the surveys. Although some common ground survey methodologies are being used to monitor a number of major pests, many still differ. The differences are attributable to local conditions and needs.

Across the managed forests of Canada, the major forest insects are being fairly well monitored through aerial survey coverage and ground-based plots. Forest pathogens overall are being less well monitored. The exceptions are foliar diseases and forest declines. Other forest diseases are less easily monitored by air because of their chronic nature and often subtle signature on the landscape.

CURRENT GAPS IN MONITORING

Monitoring gaps exist in northern latitudes, deciduous forests and non-contiguous forest types, most of which are in unmanaged forests. This situation may be significant given that climate change is projected to lead to northern expansion of several pests, including eastern spruce budworm. Pest disturbances in boreal forests may also impact Canada's carbon reserves. Southern deciduous or non-contiguous unmanaged forests are at higher risk of exotic introductions because of their proximity to urban areas and ports.

Based on current monitoring levels, it appears that risk assessments for major insects of managed forests will be most easily facilitated compared with those for less common pests, pathogens, and abiotic events. Assessments for all of the latter will be challenging because of the lack of consistent or landscape-level monitoring. Ecosystem-based risk assessments will also be affected by the lack of monitoring data and lack of knowledge about pest incidence, behaviour and impacts, particularly in northern limits of forested ecosystems.

Current monitoring gaps are probably a function of provincial and territorial forest management policies and of funding availability. Expanding current pest monitoring activities will therefore likely require a shift in these policies to include a climate change or ecosystem component. An enhanced forest health monitoring program should also expand beyond areas with a history of forest pest disturbances and include abiotic events. Such a program may require collaborative efforts between the federal government and provincial and territorial governments.

A LOOK TO THE FUTURE: PROPOSED SCENARIOS FOR NATIONAL PEST MONITORING

Three monitoring scenarios, including approximate costs, have been developed to guide decision-making in developing an ecosystem-based monitoring program.

The goal with this scenario approach—Good, Better, Best—is to enhance existing programs while encouraging nation-wide harmonization and development of best practices.

Background

In 2006, the Canadian Council of Forest Ministers (CCFM)[1] endorsed the vision, principles and approach for a National Forest Pest Strategy (NFPS). The NFPS promotes a proactive, integrated response to the threat of forest pests through a national risk-analysis framework to guide decision-making by the many jurisdictions involved in pest management in Canada.

The ecosystem-based approach recognizes that natural disturbances affect not only trees, but all other forest values, and that multiple disturbance agents can occur simultaneously within an ecosystem. This approach facilitates a move from reactive pest-based based management to proactive ecosystem-based management.

In 2008, the CCFM's Task Force—consisting of representatives from the Canadian Forest Service (CFS) of Natural Resources Canada (NRCan), Canadian Food Inspections Agency (CFIA), and all provinces and territories except Nunavut—released an NFPS implementation plan. The plan identified five broad components of the strategy:

1. Risk Analysis
2. Monitoring and Diagnostics
3. Information and Information Management
4. Science and Technology Priority-Setting
5. Reporting, Communication and Outreach.

Recommendations for the implementation of each component were developed by Technical Advisory Groups (TAGs) made up of federal, provincial and territorial officials and reporting to the CCFM's Forest Pest Working Group. This report addresses gaps identified in the implementation plan for the monitoring aspect of the second component and include the following:

- status of national forest pest monitoring;
- survey methods employed, compatibilities and opportunities for standardization; and
- identification of monitoring gaps.

This information is required to determine whether critical elements of the NFPS, particularly pest risk analysis, can be achieved given the current level and type of forest pest monitoring being conducted in Canada.

Nation-wide surveys targeting federal, provincial and territorial governments were undertaken. (While municipal governments also conduct urban tree pest surveys, mostly for exotic pests, those surveys were not included in this review.)

Ideally, pest survey methods should be similar for a given pest, thereby facilitating compilation of data for analyzing, interpreting and reporting the status of forest pests in a standardized format. Coverage should also be sufficient to inform pest risk analysis. These compatibility aspects of surveys and monitoring were therefore key parts of this review.

Based on the findings, several scenarios for improving monitoring capacity, including the associated potential costs, are proposed.

Overall, this work contributes to the CCFM Forest Pest Working Group's objective of disseminating best practices to facilitate forecasting, preparedness and coordination of pest management activities in Canada.

Forest Health Surveys in Canada

Monitoring of native biotic, established exotics and abiotic forest disturbances is currently undertaken by the provinces and territories. Detection and surveillance of pests of quarantine significance (not established) is the responsibility of the federal Canadian Food Inspection Agency (CFIA). All of these agencies use a combination of ground and aerial surveys to detect and quantify pests (Figure 1).

According to survey responses from these agencies, approximately 289 distinct ground and aerial surveys are conducted for 75 biotic and abiotic forest health factors (FHF) across Canada. Not all surveys are conducted annually, which means that not all FHFs are monitored across the country every year. Some are specific to a geographic area. Others, such

[1] Abbreviations used in this report are listed in Appendix 1.

as defoliators, are monitored as required in some jurisdictions.

Of the surveys:

- 61% concern monitoring pest populations;
- 14% support operational spray programs (management) directed at larval development, spray efficacy, etc.;
- 13% conduct impact assessments; and
- 12% deal with research.

Monitoring efforts are higher for forest insects as they tend to have distinct cycles. Forest diseases, on the other hand, tend to be chronic and therefore lend themselves to research or impact studies (Figure 2).

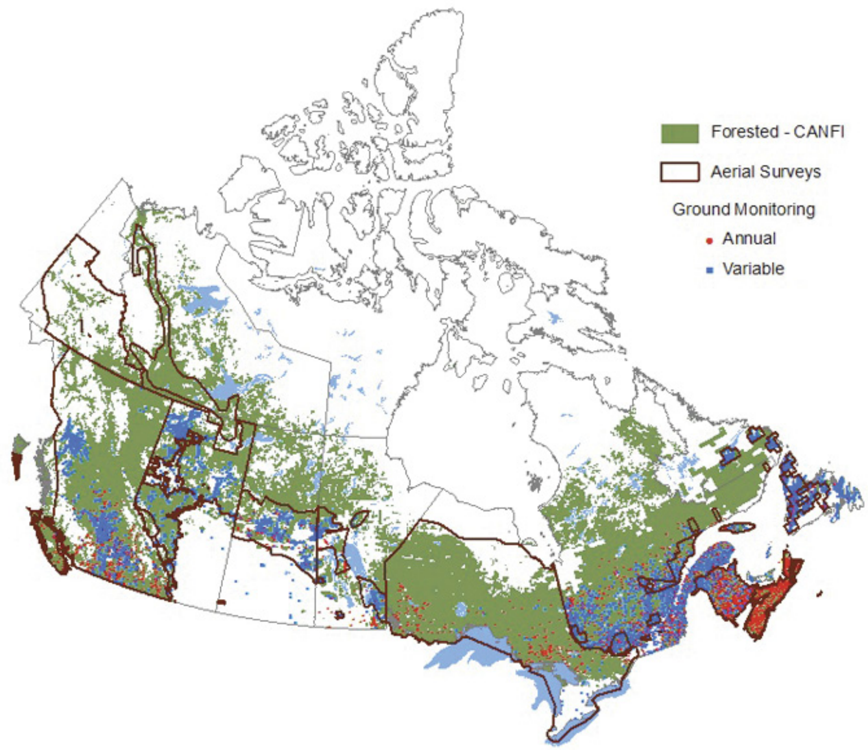

Figure 1. Ground and aerial monitoring of biotic and abiotic forest disturbances currently conducted across Canada (based on 2008, 2009 and 2010 surveys). CANFI = Canada's National Forest Inventory 2001.

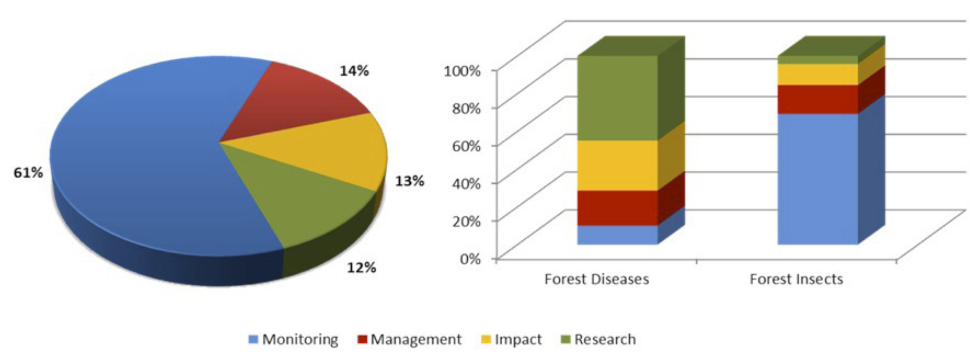

Figure 2. Primary purpose of forest health factor (FHF) surveys across Canada (left), and breakdown for forest diseases and forest insects (right).

AERIAL SURVEYS

Aerial surveys are conducted in all provinces and territories except Prince Edward Island and Nunavut (Figure 1). These surveys involve the use of fixed-wing and helicopter methods. Remote sensing has been tested in some parts of Canada, but is not currently in use operationally. Many aerial surveys have a minor ground component to verify damage agents, intensity and damage boundaries. While some jurisdictions delineate all forest health disturbances, others focus on major forest pests that have the potential to impact timber supply.

Helicopters are generally used to more accurately depict location, often equipped with a Global Positioning System (GPS) or camera/video recorder with geo-referencing capabilities. These detailed surveys are most frequently used to support control efforts. Coarser scale surveys (often referred to as overview surveys) are generally conducted from fixed-wing aircraft. Aerial observers sketch-map disturbances onto PC tablets or hard copy maps. Forest insects are most commonly captured during overview surveys. Forest diseases are generally less visible from the height that these surveys are conducted. The exceptions are foliar diseases and landscape-level forest declines. (A decline is a generally slow, progressive deterioration of tree health and vigour resulting from a complex of biotic and/or abiotic factors.)

GROUND SURVEYS

Across Canada, there are over 14 500 plots, some permanent and some temporary. These are sampled on an annual or variable basis, or as dictated by pest populations (Figure 1). Only one or two pests are usually monitored at most ground plots (Table 1). In some instances, general surveillance along the route to these sites is conducted, although the observations are not adequately reflected in the ground monitoring summary.

The majority of ground surveys are focused on biotic factors (Figure 3). Of those surveys:

- 48% are for forest insects;
- 17% are for forest diseases;
- 15% are for non-pest-specific surveys; and
- 14% are for exotics (i.e., those monitored by the CFIA).

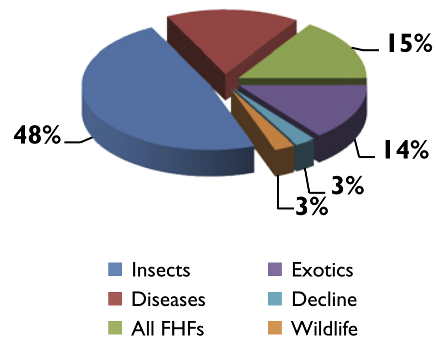

Figure 3. Ground surveys of major forest disturbances in Canada, by pest group (based on 2008/2009 input from provinces and territories and the Canadian Food Inspection Agency). FHFs = forest health factors.

Table 1. Summary of permanent sample plots or sites that have been monitored recently in Canada.

Province/ territory	No. of sites	% Sampled annually	% With multiple pest sampling	% With same pest sampled (life stages)
BC	2614	29	7	2
AB	1493	0[a]	2	4
SK	943	18	-	-
MB	1014	21	2	-
ON	328	0[a]	-	22
QC	2510	0[a]	-	-
NB	675	93	50	16
NS	885	100	35	10
NL	1817	0[a]	-	-
PE	14	0[a]	-	-

[a] Some may be assessed annually but are not considered annual plots.

The remaining 6% of ground surveys are made up of decline and wildlife[2] surveys. (Note: Established exotics, such as white pine blister rust, are accounted for in the appropriate native pest category.)

Of the *forest insects* being monitored from the ground, 42% are native defoliators (Figure 4).

- Eastern spruce budworm, jack pine budworm and forest tent caterpillar are the most commonly monitored (Tables 2 and 3).
- Gypsy moth is the most common exotic pest being monitored (Table 3).

Of the *forest diseases* being monitored from the ground, most are stem diseases, the majority of which are established exotics (Table 4).

Approximately 16 different types of surveys target pest groups rather than a specific pest. Examples include root diseases, non-pest-specific forest health surveys, declines (e.g., climate impacts on productivity and health of aspen [CIPHA]) and wildlife surveys (Table 4).

The largest variety of FHFs monitored across all provinces and territories are specific native or established exotic defoliators (Table 3).

[2] In the context of this report, wildlife is defined as mammals, birds, amphibians and reptiles.

- Eastern spruce budworm and forest tent caterpillar are the most widely monitored defoliators in the country.
- Jack pine budworm is extensively monitored except in western Canada (Alberta, British Columbia and Yukon Territory), where it is not a FHF.
- Western spruce budworm, Douglas-fir tussock moth and two-year-cycle spruce budworm are FHFs found only in western Canada, and hence monitoring efforts for those pests are focused in the western provinces.

Exotic pests are primarily monitored by the CFIA (Tables 3 and 4). Some pest-specific monitoring efforts (e.g., for exotic wood borers and Asian long horned beetle) are being conducted in Vancouver, Toronto, Montreal and Halifax to detect high priority pests before they become established. These cities are considered high risk for the introduction of exotics. Other surveys are focused on addressing the extent of the populations outside known areas in order to define quarantine (i.e., regulated) areas and management zones. In some cases, provinces have provided assistance by conducting monitoring to supplement CFIA efforts. For example, in British Columbia, parks and recreation areas are monitored for gypsy moth by the provincial government.

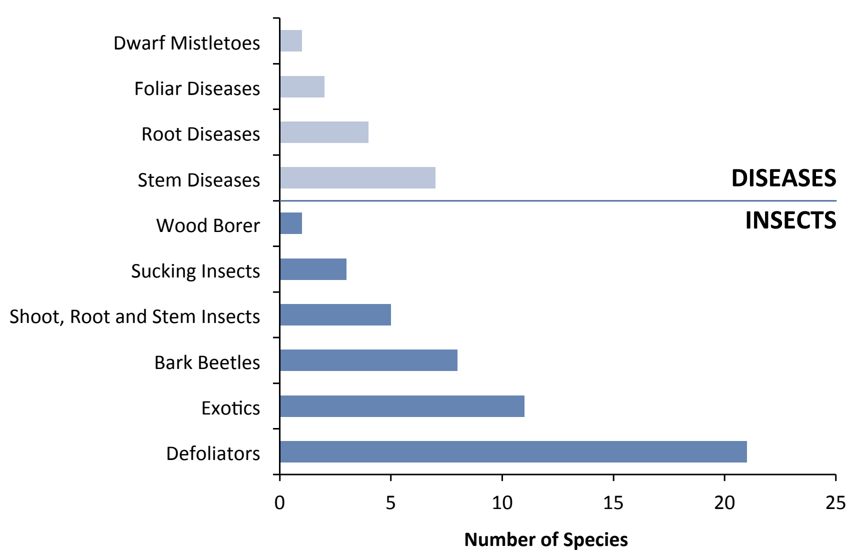

Figure 4. Summary of the number of forest insect and disease ground surveys in Canada, by pest group. Note: Similar surveys are conducted in various jurisdictions.

Table 2. Defoliators currently being monitored by ground in Canada (not necessarily annually).

• = Established exotic pest, but does not necessarily occur in all jurisdictions; CFIA = Canadian Food Inspection Agency

Defoliator	CFIA	BC	YT	AB	SK	MB	ON	QC	NB	NS	NL	PE
Aspen serpentine leafminer			•									
Balsam fir sawfly										•	•	
Douglas-fir tussock moth												
Eastern blackheaded budworm									•	•	•	
Eastern hemlock looper								•	•	•	•	
Eastern spruce budworm				•	•	•	•	•	•	•	•	
European pine shoot moth											•	
Fir spruce budworm			•									
Forest tent caterpillar				•	•	•	•	•	•			•
Green striped forest looper		•										
Gypsy moth	•	•		•					•	•		
Jack pine budworm					•	•	•	•	•	•		
Large aspen tortrix			•									
Pale winged grey										•		
Rusty tussock moth									•		•	
Spruce bud moth											•	
Two-year-cycle spruce budworm		•	•									
Western hemlock looper		•										
Western spruce budworm		•		•								
Whitemarked tussock moth									•	•	•	
Yellowheaded spruce sawfly												•

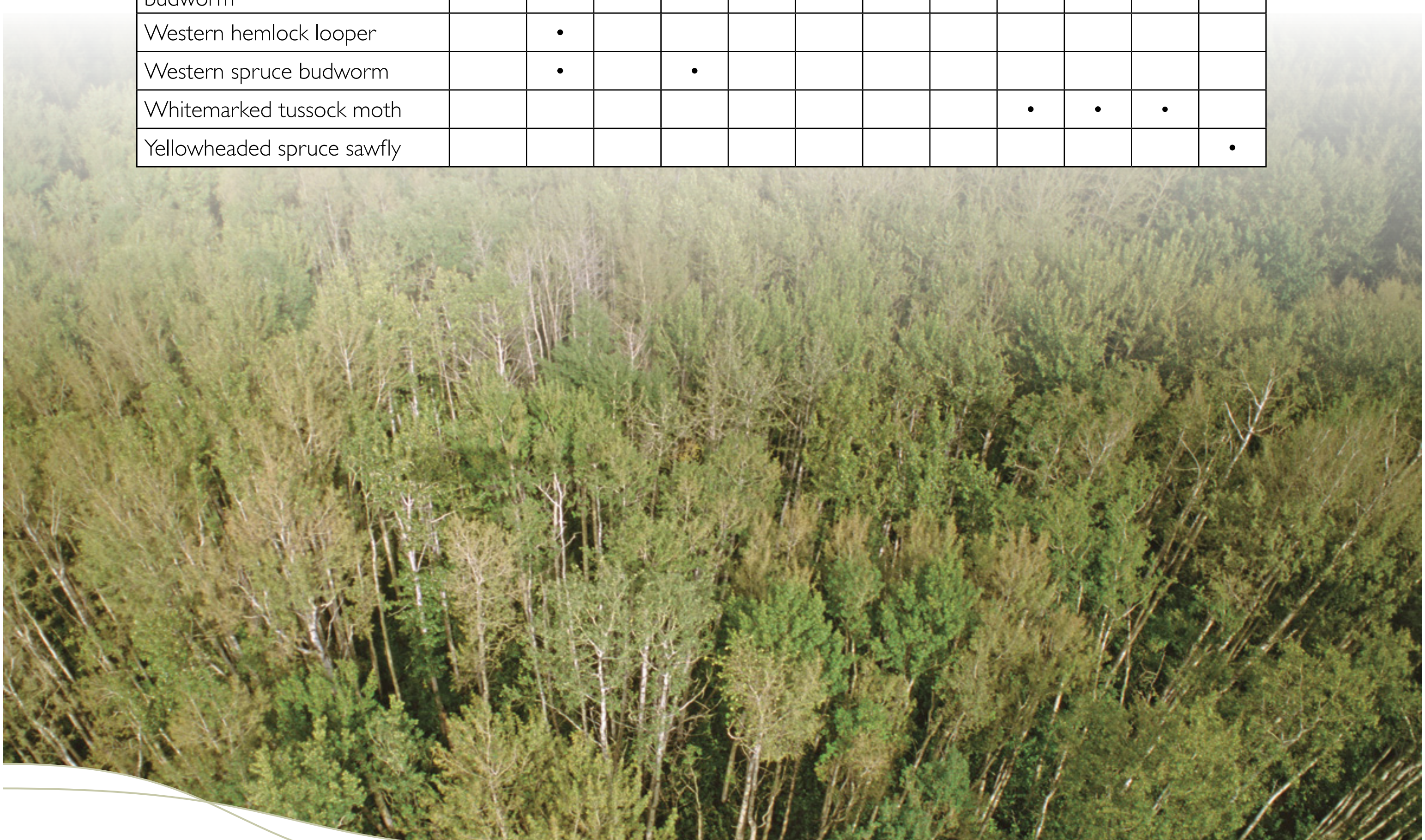

Table 3. Forest insects, excluding defoliators, currently being assessed by ground survey in Canada.

• = Established exotic pest, but does not necessarily occur in all jurisdictions; CFIA = Canadian Food Inspection Agency

Insect Type	CFIA	BC	YT	AB	SK	MB	ON	QB	NB	NS	NL	PE
Unestablished Exotics												
Asian long-horned beetle	•											
Banded elm bark beetle					•	•						
Brown spruce longhorn beetle	•									•		
Emerald ash borer	•						•					
Exotic bark beetles	•											
Exotic wood borers	•											
Hemlock woolly adelgid	•											
Pine shoot beetle	•						•			•		
Sirex woodwasp	•						•					
Sudden oak death	•											
Bark Beetles												
Douglas-fir beetle		•										
Eastern larch beetle						•						
European elm bark beetle						•						
Mountain pine beetle		•	•	•	•							
Native elm bark beetle					•	•						
Spruce beetle		•	•	•						•		
Western balsam bark beetle		•										
Stem, Root and Shoot												
Lodgepole pine terminal weevil		•										
Pitch blister moths		•										
Spruce weevil		•										
Warrens root collar weevil		•										
White pine weevil		•										
Sucking Insects												
Balsam gall midge									•	•	•	
Balsam twig aphid									•		•	
Balsam woolly adelgid									•	•	•	
Other Insect Groups												
Wood borer			•									

Table 4. Ground surveys of forest diseases and miscellaneous surveys currently monitored by ground in Canada.

• = Established exotic pest, but does not necessarily occur in all jurisdictions; CFIA = Canadian Food Inspection Agency; FHFs = forest health factors; CIPHA = climate impacts on productivity and health of aspen

Disease Type	CFIA	BC	YT	AB	SK	MB	ON	QC	NB	NS	NL	PE
Unestablished Exotics												
Sudden oak death	•											
Stem Diseases												
Butternut canker							•					
Comandra blister rust		•										
Diplodia shoot blight and canker	•					•						
Dutch elm disease					•	•				•		
European larch canker												•
Western gall rust		•										
White pine blister rust		•										
Root Diseases												
Armillaria root disease		•				•						
Laminated root disease		•										
Phellinus root disease		•										
Tomentosus root disease		•	•			•						
Dwarf Mistletoes												
Lodgepole pine dwarf mistletoe		•				•						
Foliar Diseases												
Dothistroma needle blight		•										
Pine needle cast		•										
Miscellaneous Surveys												
Aspen decline and CIPHA					•	•	•					
FHFs of ash							•					
FHFs of beech							•					
FHFs of hardwood forests							•					
FHFs of jack pine							•					
FHFs of North American maple							•					
FHFs of spruce and fir							•					
Pests of seeds		•						•				
Pests of young stands		•		•		•		•	•			

The majority of ground-based surveys provide information about insect populations by monitoring various life stages (Table 5). Most of these are for defoliators and consist of egg, adult, bud-mining and larval surveys. Some are conducted to determine presence or absence of the insect, but the majority are designed to assess and predict population levels.

Table 5. Types of defoliator life stage monitoring conducted across Canada. Bm = bud-mining, E = egg, L = larvae, P = pupa, A = adult

Defoliator	BC	YT	NT	AB	SK	MB	ON	QC	NB	NS	NL	PE
Balsam fir sawfly									E, L, P	E	E	
Douglas-fir tussock moth	E, L, A											
Eastern blackheaded budworm									E	E	E	
Eastern hemlock looper								E, A	E, A	E, A	E, A	
Eastern spruce budworm			A	E, L, A	L,A	E,A	L,A	L, A	E, L, A	L, A	E, A	A
European pine shoot moth											A	
Forest tent caterpillar				E, A	A	E	E	E	A			E
Gypsy moth	A								E, A	A		E
Jack pine budworm					A	E, L, A	E, L, A	L, A	L, A	L, A		
Pale winged grey										E		
Rusty tussock moth									A			
Spruce bud moth											E	
Two-year-cycle spruce budworm	E	A										
Western hemlock looper	L, A											
Western spruce budworm	Bm, E, L			E, L, A								
Whitemarked tussock moth									A	E, A		

Compatibility of Survey Methodologies across Jurisdictions

National reporting and analyses of forest pest conditions require a sound understanding of the underlying methods employed to collect pest data. Ideally, survey methods used by provinces and territories should be similar for a given pest and a given life stage. Many factors influence survey methods, including survey objectives, resources, population levels and behaviour of FHFs in different ecosystems or on different host species. As a result, survey methodologies do vary across the country.

AERIAL SURVEYS

SURVEY METHOD

Mapping methods vary in that some provinces and territories map at a landscape level, while others map at a stand level. These differences are generally a function of sketch-mapping on a map versus on a PC tablet. Regardless of mapping method, however, post-processing and GIS software can facilitate reporting at a common scale (e.g., ecoregion, forest stand, net-downs).

SEVERITY CATEGORIES

For the most part, aerial overview survey categories are compatible between jurisdictions given the coarse scale resolution of these surveys (Table 6).

The one exception is Ontario, which maps areas with <50% defoliation as light, whereas most other provinces and territories map areas with <25%–35% defoliation as light.

Only Saskatchewan and Newfoundland/Labrador do not map light, feeling that light defoliation is not visible from the height that aerial surveys are conducted. Their moderate categories therefore start at >30% defoliation.

It is likely that all provinces and territories are mapping defoliation in a similar fashion, but ground confirmation and calibration with aerial survey results is required to confirm this assumption. In the absence of a calibration exercise, aerial surveys can probably be considered compatible given the degree of error associated with severity classification by aerial survey observers.

Tree mortality caused by FHFs is the other primary damage noted in Canada during aerial overview surveys (Table 7). Mortality is generally caused by bark beetles, but it can also be caused by forest decline, root diseases, abiotics and other factors. Intensity classes for mortality are based on the percentage of trees killed within a delineated polygon within the last year. "Spots" record the number of dead or dying trees rather than a polygon with associated severity. Before 2005, thresholds for British Columbia, Yukon Territory and Alberta were identical.

Table 6. Intensity classes (ranges by percent) for defoliation damage as recorded during aerial overview surveys across Canada.

	BC	YT	AB	SK	MB	ON	QC		NB	NS	NL
Defoliation [a]							**Hardwoods**	**Conifers**			
Light	1-25	<25	<35	do not map light	<35	<50	1-25	1-34	1-30	10-29	do not map light
Moderate	26-65	26-65	36-70	30-69	35-70	51-75	26-60	35-69	31-70	30-69	31-70
Severe	>65	>65	>70	>70	>70	>75	>60	>70	>70	>70	>70
Other	dead trees										>70 with mortality

[a] Defoliation severities based on average defoliation characteristics at a polygon level.

A few other aerial overview surveys are conducted in Canada, but they are for specific purposes (e.g., to monitor ice damage and declines) and the thresholds are too different to be compatible with the aforementioned surveys.

Table 7. Intensity classes (ranges by percent) for mortality as recorded during aerial overview surveys across Canada.

	BC		YT	AB	QC[b]
Mortality[a]	**prior to 2005**	**2005+**			
Polygons					
Trace		<1			
Light	1-10	1-10	1-10	<10	<30
Moderate	11-29	11-29	11-29	11-29	31-65
Severe	>30	30-50	>30	>30	>66
Very Severe		>50			100
Spots	No. trees	No. trees	No. trees	No. trees	

[a] Severities based on % of trees dead within an infested area.

[b] Specific to ice and blowdown damage during the 1998 ice storm.

GROUND SURVEYS

As the majority of grounds surveys are for defoliators, this section pertains solely to those types of forest pests. Forest disease monitoring surveys are minimal, generally carried out only by one or two provinces and territories.

ADULTS

Pheromone traps monitoring adult populations of insects are used throughout Canada. Pheromone traps are most commonly used to monitor eastern spruce budworm (Table 8). While lure formulations (Suterra and Contech) are considered compatible for this pest, there are some differences in the trap types being used across Canada.

Jack pine budworm is the second most monitored adult, with several aspects being compatible in five of the six provinces. Most of the insects that are monitored in a couple of provinces and territories have compatible aspects, notably lure formulation (is usually made by the same manufacturer).

Table 8. Compatibility for six aspects of insect pheromone monitoring between provinces and territories in Canada. Items in italics denote established exotic pests, but these do not necessarily occur in all jurisdictions. Y = yes; N = no.

Common name	No. provinces and territories monitoring	Lure/bait formulation	Manufacturer	Lure type	No. traps/ location	Trap type
Douglas-fir tussock moth	1	Y	Y	Y	Y	Y
Eastern hemlock looper	4	Y	Y	Y	Y	Y
Eastern spruce budworm	8	Y	N [a]	N [a]	N	N
European elm bark beetle	1	Y	Y	Y	Y	Y
European pine shoot moth	1	Y	Y	Y	Y	Y
Forest tent caterpillar	3	Y	Y	Y	N	Y
Gypsy moth	4	Y	Y	Y	Y	Y
Jack pine budworm	6	N [b]	N [b]	N [b]	N	N
Mountain pine beetle	2	Y	Y	Y	N	Y
Native elm bark beetle	2	N	N	N	N	Y
Rusty tussock moth	1	Y	Y	Y	Y	Y
Western hemlock looper	1	Y	Y	Y	Y	Y
Western spruce budworm	1	Y	Y	Y	Y	Y
Whitemarked tussock moth	2	Y	Y	Y	Y	Y
Unestablished Exotics						
Banded elm bark beetle	2	Unknown	N	N	N	N
Brown spruce longhorn beetle	1	Y	Y	Y	Y	Y
Pine shoot beetle	2	Y	Y	Y	N	Y
Sirex wood wasp	2	Y	Y	Y	Y	Y

[a] The Suterra 2.8 mg lure and the Contech 330 ug lure are considered compatible.

[b] Five of five provinces and territories are compatible.

DEFOLIATOR EGG AND LARVAL SAMPLING

Defoliator surveys generally have set sampling units such as number of trees to sample, branches per tree, and branch length. Survey results are often expressed as an average per site, or are extrapolated to represent an average number of egg masses or larvae per 10 m^2 of foliage. The latter requires the recording of branch width.

Survey results are used to make population predictions based on certain thresholds. These thresholds are often developed locally (that is, calibrated with subsequent defoliation in area)—which means that the same average number of eggs or larva can imply different predicted defoliation levels between jurisdictions. The reporting unit however (e.g., larvae per 10 m^2 of foliage) may be similar. Thus, assessing compatibility is complicated by local conditions and host species that may warrant different sampling methods and thresholds.

For those defoliators that are monitored in more than one jurisdiction, only jack pine budworm and western spruce budworm egg mass sampling survey methodologies are compatible, i.e., all sample units and sub-units are the same (Table 9). However, reporting units (e.g., average egg masses per 10 m^2 foliage) are similar for five out of seven egg mass surveys. Merely collecting branch width would provide for compatibility with reporting units for eastern blackheaded budworm.

Table 9. Compatibility of sampling units of egg and larval sampling for defoliators in Canada.

	Egg				Larva			
	No. of trees sampled	Branches/ tree	Branch length	Reporting units	No. of trees sampled	Branches/ tree	Branch length	Reporting units
Eastern spruce budworm								
Jack pine budworm								
Western spruce budworm					I	I	I	I
Eastern blackheaded budworm					No larval surveys			
Eastern hemlock looper								
Balsam fir sawfly					I	I	I	I
Forest tent caterpillar					No larval surveys			
Pale winged grey	I	I	I	I				
Spruce bud moth	I	I	I	I				
Two-year-cycle spruce budworm	I	I	I	I				
Western hemlock looper	I	I	I	I	I	I	n/a	I
Whitemarked tussock moth	I	I	I	I	No larval surveys			
Douglas-fir tussock moth	I	I	I	I	I	I	n/a	I

	Not compatible
	Compatible
I	Compatible – only in one jurisdiction

Gaps in Monitoring

One of the underlying principles of the NFPS is an ecosystem-based approach, with pests being assessed in the context of specific or local ecological conditions. Most provinces and territories, however, manage forest pests within the context of their impact on the forest sector (i.e., managed forests). Given these differences, monitoring gaps are discussed below from three perspectives: forest pest, managed forest, and ecosystem.

FOREST PESTS

Based on aerial survey coverage and monitoring plots, it seems that forest insects are being fairly well monitored across the managed forests of Canada.

Forest pathogens, however, are being less well monitored, in part because of the elusive and chronic nature of some pathogens (e.g., root diseases and stem decays) and the associated challenge in the aerial sketch-mapping of these disturbances. Furthermore, pathogens are not cyclical like their insect counterparts, so monitoring population changes is less meaningful. Instead, plots are generally established to assess impacts or responses to different silvicultural treatments.

Foliar diseases have the most distinguishable landscape-level pattern and are generally associated with abnormal climatic conditions. Declines, such as that in aspen, have recently become more pronounced on the landscape in certain portions of Canada. These are being recorded during aerial surveys in several jurisdictions, as are foliar diseases. Although root diseases can have significant impacts on forest volumes or values, their signature at a landscape level is less readily detected from the scale that aerial surveys are conducted.

FORESTS

Today, about half of the forested[3] land base in Canada is monitored through the use of aerial surveys[4] (Figure 5, Table 10). Not all of these areas are monitored annually.

Sixty-four percent of the forested area that is considered managed forest is monitored aerially (Figure 5). Coverage varies widely from province to province and from partial coverage to full coverage. Coverage can also vary from one year to the next, depending on funding and pest activity. For instance, Quebec has an extensive ground monitoring network that guides where aerial surveys are conducted, which means that coverage varies from year to year.

[3] Forest as defined by Canada's National Forest Inventory 2001 Land Use Classes.

[4] Based on 2008 or 2009 aerial surveys, except in Nova Scotia, which conducted its first provincial aerial surveys in 2010.

ECOSYSTEMS

At an ecosystem level, monitoring gaps exist in the forested portions of the western and eastern boreal shield and taiga shield ecozones (Figure 6). These gaps are of significance in that the boreal west forests (west of Lake Winnipeg) are projected to experience the greatest change in frequency, size and area affected by biotic disturbances as a result of climate change (Johnston et al., 2009). These changes were projected to start in 2011.

Other recent research suggests that climate change could extend the northern boundary of eastern spruce budworm, forest tent caterpillar, hemlock woolly adelgid and beech bark disease (Candau and Fleming, 2011; Dukes et al., 2009). Pest disturbances in these northern forests could also impact Canada's carbon reserves.

Figure 5. Aerial surveys coverage across Canada in relation to managed forests and forested areas (based on 2008, 2009 or 2010 aerial surveys).

Table 10. Proportion of forests, by province and territory, monitored by aerial surveys in Canada (based on 2008, 2009 or 2010 surveys).

Province/ territory	Managed Forests[a]			All Forests[b]		
	Total (millions of ha)	Surveyed (%)	Not Surveyed (%)	Total (millions of ha)	Surveyed (%)	Not Surveyed (%)
YT	5.87	98	2	7.42	98	2
NU	0	0	0	0.4	0	100
NT	32.6	0	100	64.23	0	100
BC	65.55	100	0	65.6	100	0
AB	32.44	83	17	32.44	83	17
SK	15.86	61	39	23.19	42	58
MB	12.27	37	63	22.27	20	80
ON	49.5	100	0	66.28	100	0
QC	53.47	12	88	92.08	8	92
NB	7.24	100	0	7.26	100	0
NS[c]	5.43	100	0	5.47	100	0
PE	0.33	0	100	0.34	0	100
NL	7.39	52	48	12.23	32	68
Total	287.95	64	36	399.22	51	49

[a] Source: Combination of Managed Forest Lands (includes Department of National Defense (DND), Indian Reserve and parks land) theme from NRCan Spatial Carbon Modeling Group and Canada's National Forest Inventory (CANFI) 2001 Land Class Use.

[b] Forest derived from CANFI 2001 Forest Land Use Class.

[c] 100% coverage every other year; alternate grid lines are flown annually.

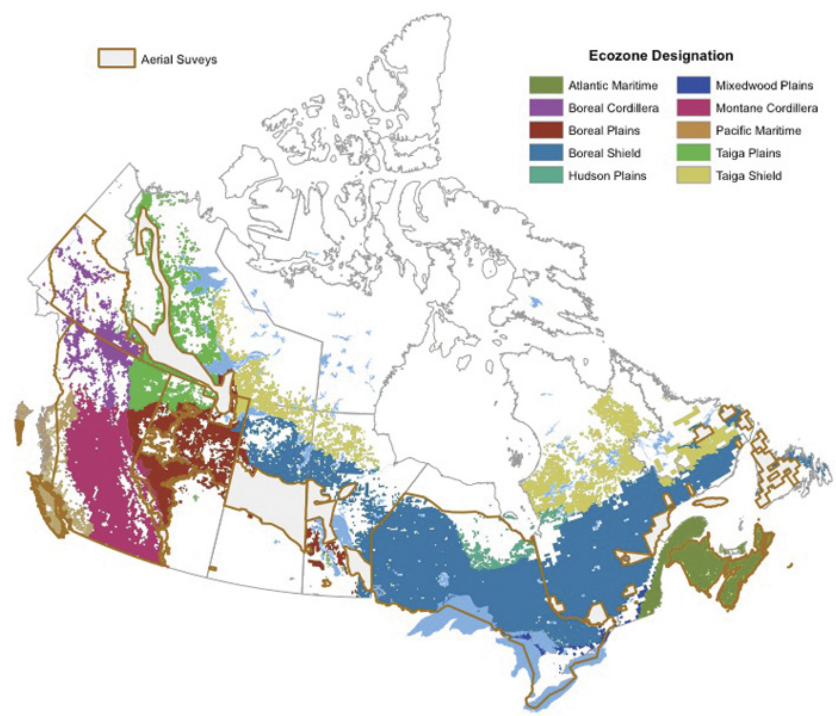

Figure 6. Aerial survey coverage in relation to forested portions of Canada's ecozones (based on 2008, 2009 or 2010 surveys).

Proposed Scenarios for National Pest Monitoring

Scenarios for improvements to national pest monitoring were developed by the CCFM Forest Pest Working Group's Monitoring and Diagnostics Technical Advisory Group in 2010.

Three scenarios have been defined: Good, Better and Best (Table 11). These differ in many ways, but most notably in the forest classification (managed or unmanaged) and the importance of the pest (or pests) being monitored. A national pest list, based on input from the provinces and territories (Appendix 2), identifies which pests would be monitored under different monitoring scenarios.

- The Good scenario includes improvements already realized primarily as a result of better nation-wide communications since the advent of the NFPS.
- The Better scenario involves practical, easily achievable improvements in national monitoring.

Table 11. Proposed national pest monitoring scenarios.

	Good	**Better**	**Best**
Overview surveys (aerial or remote sensing)	Of partial forest (accessible ground checks)	Of all managed forests, including DND,[a] Indian Reserve and park lands (aerial and/or ground checks)	Of all forested (aerial and/or ground checks)
Ground survey monitoring goals	Respond to province or territory's high priority major pests and general surveillance	Annual or periodic monitoring points, with quantitative estimates of all major and potential pests in all managed forests, including DND,[a] Indian Reserve and park lands	Annual monitoring points with quantitative estimates of all pest conditions in all forest (enhanced Forest Insect and Disease Survey [FIDS] program)
Ground survey sampling design	Conduct where historical distribution of major pests	50 sample points per genus for managed forests, including DND,[a] Indian Reserve and park lands (per province or territory)	50 + sample points per genus on all forested lands and enhanced surveillance (per province or territory)
Ecosystem-based reporting	Retrospective	Retrospective	Retrospective
Diagnostics	In-field ID with access to diagnostics for more difficult IDs	Trained field staff and access to dedicated insect and disease diagnosticians. Supported by curated collections and e-database (ID, location, date).	Trained field staff and dedicated insect and disease diagnosticians, with access to taxonomist to confirm ID, identify exotics and develop or improve ID tools and techniques. Supported by curated collections and e-database.
Improved communication (e.g., meetings, Pest Strategy Information System)	Yes	Yes	Yes
Harmonized best practices to meet NFPS objectives	No	Yes	Yes
Ability to inform risk analysis	Increases with monitoring effort		

[a] Possible Department of National Defense (DND) coverage would be variable, depending on accessibility of the area, both by ground and air (this varies by time of year and level of security).

- The Best scenario is, at minimum, a return to the monitoring staffing levels and accompanying activities that were provided by the Canadian Forest Service before 1995 with its Forest Insect and Disease Survey (FIDS) program.

The ability, or need, to move from the Good to the Best scenario will largely depend on the funding and forest health monitoring mandates and objectives of each province and territory. For instance, a pest monitoring program for the purposes of quantifying volume losses would look quite different from that adopted for monitoring climate change or carbon accounting purposes.

Table 12. Top 20 identified pests of concern for the proposed Good and Better national pest monitoring scenarios, by number of provinces and territories.

Items in italics denote established exotic pests, but these do not necessarily occur in all jurisdictions.

Pest	No. of provinces and territories: Good (high priority major pests)	No. of provinces and territories: Better (major pests)
Eastern spruce budworm	10	10
Spruce beetle	6	10
White pine weevil	3	9
Large aspen tortrix	5	8
White pine blister rust	2	7
Armillaria root disease	4	7
Forest tent caterpillar	2	7
Jack pine budworm	6	6
Gypsy moth	4	6
Western gall rust	1	5
Larch sawfly	3	4
Balsam woolly adelgid	4	4
Sirococcus shoot blight	1	4
Lodgepole pine dwarf mistletoe	3	4
Pine sawflies	1	4
Eastern larch beetle	0	4
Eastern hemlock looper	4	4
Warren root collar weevil	1	4
Pine needle cast	2	3
Mountain pine beetle	3	3

TOP PESTS OF CONCERN AS RANKED BY PROVINCES AND TERRITORIES

The national pest list summarizes the top 20 pests of concern, for both currently occurring pests (Table 12) and future potential pests (Table 13). *High priority* lists the number of provinces and territories where these pests are currently of concern and monitored when appropriate. *Major* refers to the number of provinces and territories where these pests would be monitored under the Better scenario. The pests are listed according to the number of provinces that have identified them as a present or future problem. This ranking is not necessarily related to the impact of the pest.

Table 13. Top 20 identified future potential pests of concern for the proposed Good and Better national pest monitoring scenarios, by number of provinces and territories.

Items in bold denote unestablished exotic pests; items in italics denote established exotic pests, but these do not necessarily occur in all jurisdictions.

Pest	No. of provinces and territories: Good (high priority major pests)	No. of provinces and territories: Better (major pests)
Brown spruce longhorn beetle	2	7
Emerald ash borer	5	6
Sirex wood wasp	2	6
Asian longhorn beetle	1	6
Sudden oak death	0	3
Pine shoot beetle	1	3
Oak wilt	1	3
Gypsy moth	3	3
European scleroderris canker	1	2
Forest tent caterpillar	1	2
Mountain pine beetle	1	2
Hemlock woolly adelgid	1	2
Dothistroma needle blight	1	1
Balsam fir sawfly	1	1
Balsam gall midge	1	1
Balsam twig aphid	1	1
Balsam woolly adelgid	1	1
Beech bark disease	1	1
Smaller European elm bark beetle	1	1
European pine shoot moth	1	1

Appendix 3 expands on the components of each monitoring scenario, and includes a ground survey sampling design.

ANTICIPATED COSTS OF IMPROVED MONITORING PRACTICES

OVERVIEW SURVEYS

At present, 36% of Canada's managed forests, or half of all forest lands, are not monitored by overview surveys (Table 10). Under the Better and Best scenarios, these forests would require some form of aerial monitoring, either fixed-wing or remote sensing. Remote sensing is currently limited in its ability to identify a broad spectrum of specific pests, although it is capable of identifying general disturbances. However, costs associated with remote sensing at the scale required for overview surveys are uncertain. Therefore, cost estimates here are based on the use of fixed-wing aircraft.

Aerial overview monitoring surveys have been conducted by a number of jurisdictions for several years. For this review, the average cost per hectare of aerial overview surveys for British Columbia was used to estimate additional costs associated with expanding aerial surveys. These costs ($0.13/ha) are based on use of a small fixed-wing aircraft with two surveyors and cover administration, training, aerial auditing, ground checks, data digitization and annual reporting. Coverage intensity is based on a grid pattern of approximately 7–9 km wide.

Based on those figures, it is estimated that aerial overview monitoring would require (see Table 14):

- for the unsurveyed managed forests (Better scenario): approximately $13.7 million; and
- for all unsurveyed forests: $25.7 million (Best scenario).

These are rough estimates as they are based on aerial overview survey costs in British Columbia and coarse resolution spatial data. Each province and territory would have a better sense of anticipated costs based on finer resolution spatial data and aerial overview survey costs pertinent to its jurisdiction. This rate would also likely drop if lower priority areas could be monitored with remote sensing or were surveyed less frequently or at a lower resolution.

Table 14. Summary of costs associated with aerial overview monitoring surveys for currently unsurveyed forests, by forest type.

Province/ territory	Managed forest not surveyed (ha)	Cost ($)	All forests not surveyed (ha)	Cost ($)
YT	102 290	13 298	167 402	21 762
NU	0	-	403 794	52 493
NT	32 604 753	4 238 618	64 231 405	8 350 083
BC	0	-	0	-
AB	5 513 607	716 769	5 513 607	716 769
SK	6 163 835	801 299	13 497 085	1 754 621
MB	7 745 285	1 006 887	17 741 519	2 306 397
ON	0	-	0	-
QC	47 042 939	6 115 582	84 802 650	11 024 345
NB	0	-	0	-
NS [a]	2 717 431	353 266	2 733 285	355 327
NL	3 524 864	458 232	8 285 009	1 077 051
PE	329 391	42 821	338 715	44 033
Total		**$13 746 772**		**$25 702 881**

[a] Aerial surveys cover alternate lines. Therefore, full coverage occurs every other year.

GROUND SURVEYS

Current ground survey expenditures vary nation-wide because of many factors, including monitoring objectives, staffing levels and salary costs. These differences are difficult to reconcile. Therefore, the anticipated staffing levels for implementing the monitoring regime for the Best scenario are based on the approximate staffing levels of the CFS FIDS program in the early 1990s. These were reduced by 25% to reflect efficiencies gained from technical advances in both field and office duties. (The FIDS level of staffing was chosen as a benchmark because the monitoring activities proposed for the Best scenario closely resemble those activities conducted under FIDS.)

Staffing costs and their associated activities were determined by polling the provinces and territories for their present monitoring expenditures (for each expenditure category) and averaging these costs (Table 15). Based on these assumptions, the nation-wide cost for the ground monitoring activities of the Best scenario is projected to be approximately $6.3 million.

The costs of the Better scenario were estimated by using about one-third the cost of the field and GIS staff expenditures used in the Best scenario, and maintaining the same level of diagnostics. A nation-wide cost for ground monitoring activities of the Better scenario is estimated to be about $3.5 million (Table 15).

Conclusions

Pest monitoring is currently being conducted at varying levels throughout Canada, with the exception of Nunavut. Monitoring efforts are generally undertaken on managed forests and vary with provincial and territorial mandates, human and fiscal resources, and pest populations and their anticipated impact on forests. Overall:

- Forest insects, particularly defoliators, are the most common forest health factors (FHFs) being monitored across all jurisdictions.
- Ground surveys provide annual information on life stages (egg, larvae, pupa, adult) of various defoliators, and are generally used to predict population levels and guide management decisions.
- Aerial surveys provide annual extent and severity of mostly defoliators, bark beetles and some pathogens and abiotic events (in some jurisdictions).
- Monitoring of forest pathogens is low compared with that of forest insects, in part because of the chronic and subtle signature of many forest diseases and lack of distinct cycles.

COMPATIBILITY AMONG SURVEY METHODOLOGIES

Although some common ground survey methodologies are being used to monitor a number of major

Table 15. Anticipated additional cost assumptions for the ground monitoring conducted under the Better and Best scenarios.

Item	Average annual cost ($)	Number	Best scenario cost total ($)	Better scenario cost total ($)
Diagnosticians	76 800	10 people	768 000	768 000
Taxonomist	76 800	10 people	768 000	768 000
Pathologists	76 800	4 people	307 200	307 200
Field staff salary	44 000	53 people	2 332 000	777 333
GIS support	44 000	5 people	220 000	73 333
Salary overhead		15%	659 280	404 080
Office costs	5 000	63 people	315 000	105 000
Vehicle costs	10 000	57 trucks	570 000	188 100
Accommodation, etc.	6 000	53 people	318 000	106 000
Total			**$6 257 480**	**$3 497 046**

pests, many of those methodologies still differ because of local conditions and needs. These differences reduce standardization opportunities.

In some cases, the differences are small and would require minor changes to sampling methods to facilitate standardization.

Despite differences in sampling methods many jurisdictions use similar reporting units. The metadata associated with each pest survey will provide information on survey methodology and on thresholds used to define or forecast populations. This allows users to compare methodologies and thresholds across jurisdictions even if those methodologies differ.

For the most part, the severity scales of aerial overview surveys are compatible, given the coarse resolution of the surveys.

Based on existing methodologies being used by the provinces and territories, aerial surveys (which capture outbreak years) combined with pheromone trapping data (which capture non-outbreak years) can provide a reasonable estimate of population trends over time. However, this approach may not be sufficient for pest risk analysis. Pest risk analysis should be supplemented with other life stage sampling data, as long as there is a clear understanding (through documentation) of the methodology used to capture such data.

ADDRESSING MONITORING GAPS

Currently, only half of Canada's forests are being monitored. Gaps in monitoring exist in the northern latitudes (boreal shield [east and west], and the taiga shield); deciduous forests; and non-contiguous forest types. Including these unmanaged forest types in a monitoring program is important for three key reasons:

- The northern forests may serve as climate change indicators (as suggested by the projected northern expansions of several pests).
- Boreal forests contribute significantly to Canada's carbon reserves.
- Southern deciduous and non-contiguous forest types are at higher risk to exotic introductions given their proximity to large urban areas or entry ports.

Climate change is expected to increase the frequency and severity of biotic and abiotic disturbances, so it is possible that today's less common or minor pests will become major pests in the future. There may be a need to expand, or at least maintain, monitoring efforts in areas other than those where historical major pest disturbances have been documented.

Monitoring should not be limited to forest insects and diseases, as the frequency of abiotic events will likely increase as a result of climate change. These events could potentially result in tree mortality over large tracts of forests, and predisposition of trees to biotic factors. Drought, for example, can affect host susceptibility to insect damage, pathogens and pathogen aggressiveness (Kliejunas et al. 2009), as well as contribute to tree species declines.

Risk assessments for major pests of managed forests will be most easily facilitated compared with those for less common pests, endemic or chronic pathogens, and abiotic events. Assessments for all of the latter will be challenging because of the lack of consistent or landscape-level monitoring. Ecosystem-based risk assessments will also be affected by the lack of monitoring data and lack of knowledge about pest incidence, behaviour and impacts in northern limits of forested ecosystems.

Current monitoring gaps in northern limits and in some non-contiguous forest types are probably a function of provincial and territorial forest management policies and of funding availability. Expanding pest monitoring activities will therefore likely require a shift in those policies to include a climate change or ecosystem component. An expanded monitoring program may require collaborative efforts between federal, provincial and territorial governments.

ESTIMATING THE COSTS OF IMPROVED MONITORING

The three monitoring scenarios outlined above—Good, Better, Best—offer guidance towards developing an ecosystem-based monitoring program that will enhance existing programs and provide for nation-wide harmonization and development of best practices.

Anticipated annual costs of an enhanced monitoring program range from \$3.5 million to \$6.3 million.

References

Canadian Council of Forest Ministers. 2007. National Forest Pest Strategy Ministers' meeting. Ottawa, ON.

Canadian Council of Forest Ministers. 2008a. CCFM Forest Pest Working Group, Monitoring and Diagnostics Technical Advisory Group, Monitoring and Diagnostics, Final Report. Internal report. Unpublished. April 2008. 19 p.

Canadian Council of Forest Ministers. 2008b. CCFM Forest Pest Working Group. National Forest Pest Strategy Implementation Plan. Internal report. Unpublished. July 2008. 31 p.

Canadian Forest Service and Ontario Ministry of Natural Resources (OMNR). 2008. Forest health monitoring field manual. OMNR internal document.

Candau, J.N. and Fleming, R.A. 2011. Forecasting the response of spruce budworm defoliation to climate change in Ontario. Can. J. For. Res. 41: 1948–1960.

D'Eon S.P., Magasi, L.P., Lachance, D. and DesRochers, P. 1994. ARNEWS: Canada's National Forest Health Monitoring Plot Network: Manual on plot establishment and monitoring. [Revised]. Canadian Forest Service, Petawawa National Forestry Institute, Chalk River, ON. Information Report PI-X-117. 104 p.

Dukes, J.S., Pontius, J., Orwig, D., Garnas, J.R., Rodgers, V.L., Brazee, N., Cooke, B., Theoharides, K.A., Stange, E.E., Harrington, R., Ehrenfeld, J., Gurevitch, J., Lerdau, M., Stinson, K., Wick, R. and Ayres, M. 2009. Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: what can we predict? Can. J. For. Res. 39: 231–248. Doi: 10.1139/X08-171.

Forest Adaptation. 2008. Adaptation of forests and forest management to changing climate with emphasis on forest health: A review of science, policies and practices. http://www.forestadaptation2008.net/en

Hodge, J. and Westfall, J. 2009. National Forest Pest Strategy monitoring capacity analysis – year two. Unpublished. Forest Practices Branch, BC Ministry of Forests, Lands, and Natural Resources Operations, Victoria, BC. 38 p.

Johnston, M.H., Campagna, M., Gray, P.A., Kope, H. H., Loo, J.A., Ogden, A.E., O'Neill, G.A., Price, D.T. and Williamson, T.B. 2009. Vulnerability of Canada's tree species to climate change and management options for adaptation: an overview for policy makers and practitioners. Canadian Council of Forest Ministers, Ottawa, ON. 44 p.

Kliejunas, J.T., Geils, B.W., Glaeser, J.M., Goheen, E.M., Hennon, P., Kim, M., Kope, H.H., Stone, J., Sturrock, R. and Frankel, S.J. 2009. Review of literature on climate change and forest diseases of Western North America. U.S. Dep. Agric. Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-225.

Power, K. and Gillis, M. 2006. Canada's Forest Inventory 2001. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC. Information Report BC-X-408. 128 p.

Westfall, J. and Hodge, J. 2008. National Forest Pest Strategy monitoring capacity analysis: year one. Forest Practices Branch, BC Ministry of Forests, Lands, and Natural Resources Operations, Victoria, BC. 22 p.

APPENDIX 1. ABBREVIATIONS

CANFI	Canada's National Forest Inventory
CCFM	Canadian Council of Forest Ministers
CFIA	Canadian Food Inspection Agency
CFS	Canadian Forest Service
CIPHA	climate impacts on productivity and health of aspen
FHF	forest health factor
FIDS	Forest Insect and Disease Survey
NFPS	National Forest Pest Strategy
NRCan	Natural Resources Canada

APPENDIX 2. MAJOR AND POTENTIAL PESTS BY PROVINCE AND TERRITORY

P = potential; U = urban only; CT = Christmas trees; SO = seed orchard. Highlighted = current high priority

Pest (common name)	Pest (scientific name)	AB	BC[a]	MB	NB	NL	NS	ON	PE	QC	SK	YT
Annosus root disease	*Heterobasidion annosum*							×		×		
Aphids	*Cinara* spp.											
Armillaria root disease	*Armillaria ostoyae*	×	×	×		×			×	×	×	
Ash psyllid	*Psyllopsis discrepans*										×(U)	
Asian longhorn beetle	*Anoplophora glabripennis*	×(P)	×(P)	×(P)	×(P)		×(P)			×(P)		
Aspen dieback[b]												×
Aspen serpentine leafminer	*Phyllocnistis populiella*											×
Aspen trunk rot	*Phellinus tremulae*	×		×								
Balsam fir sawfly	*Neodiprion abietis*				×	×	×					
Balsam gall midge	*Dasineura balsamicola*				×(CT)	×(P)	×					
Balsam twig aphid	*Mindarus abietinus*				×(CT)	×(P)	×					
Balsam woolly adelgid	*Adelges piceae*		×		×	×	×		×			
Banded elm bark beetle	*Scolytus schevyrewi*			×							×	
Beech bark disease	*Neonectria faginata*				×			×	×	×		
Birch leaf miner(s)			×					×				
Blackheaded budworm	*Acleris gloverana*		×									
Black spruce cone maggot	*Strobilomyia appalachensis*			×	×(SO)							
Boxelder leafroller	*Archips negundana*										×(U)	
Bronze birch borer	*Agrilus anxius*			×	×	×			×(U)		×(U)	
Brown spruce longhorn beetle	*Tetropium fuscum*	×(P)	×(P)	×(P)	×(P)	×(P)	×	×(P)	×(P)	×(P)		
Bruce spanworm	*Operophtera bruceata*	×	×		×			×	×(U)			
Butternut canker	*Sirococcus clavigignenti-juglandacearum*							×		×		
Butt rots						×						
Cone and seed insects				×		×				×		
Comandra blister rust	*Cronartium comandrae*		×	×								
Cytospora stem canker on spruce and/or fir	*Cytospora* spp.			×		×				×		
Diplodia stem canker	*Diplodia pinea*			×					×(U)	×		
Dothistroma needle blight	*Dothistroma septospora*		×									×(P)
Douglas-fir beetle	*Dendroctonus pseudotsugae*		×									
Douglas-fir tussock moth	*Orgyia pseudotsugata*		×									
Dutch elm disease	*Ophiostoma ulmi*			×					×(U)	×(U)	×	
Eastern blackheaded budworm	*Acleris variana*				×	×	×					
Eastern hemlock looper	*Lambdina fiscellaria fiscellaria*				×	×	×	×		×		
Eastern larch beetle	*Dendroctonus simplex*			×	×		×		×			
Eastern pine shootborer	*Eucosma gloriola*			×								
Eastern spruce budworm	*Choristoneura fumiferana*	×	×	×	×	×	×	×	×	×	×	×

Pest (common name)	Pest (scientific name)	AB	BC[a]	MB	NB	NL	NS	ON	PE	QC	SK	YT
Emerald ash borer	*Agrilus planipennis*			×(P)	×(P)		×(P)	×	×(P)	×	×(P)	
European pine shoot moth	*Rhyacionia buoliana*				×	×(P)						
European scleroderris canker	*Gremmeniella abietina*			×(P)	×(P)	×(P)				×		
European spruce sawfly	*Gilpinia hercyniae*				×							
Fall cankerworm	*Alsophila pometaria*			×				×	×(U)		×(U)	
False hemlock looper	*Nepytia freemani*		×									
Filament bearer	*Nematocampa filamentaria*		×									
Fir coneworm	*Dioryctria abietella*			×	×(SO)	×(P)						
Forest tent caterpillar	*Malacosoma disstria*	×	×	×	×		×(P)	×	×	×	×	
Green-striped forest looper	*Melanolophia imitata*		×									
Gray spruce looper	*Caripeta divisata*		×									
Gypsy moth	*Lymantria dispar*	×(P)	×	×	×		×	×	×		×(P)	
Hemlock looper	*Lambdina fiscellaria*											
Hemlock woolly adelgid	*Adelges tsugae*				×(P)		×		×(P)			
Hypoxylon canker	*Hypoxylon* spp.	×			×							
Introduced pine sawfly	*Diprion similis*			×	×			×				
Jack pine budworm	*Choristoneura pinus pinus*			×	×		×	×		×	×	
Japanese beetle	*Popillia japonica*								×			
Laminated root rot	*Phellinus weirii*		×									
Larch budmoth	*Zeiraphera improbana*											
Larch casebearer	*Coleophora laricella*		×					×				
Larch needle blight	*Hypodermella laricis*		×									
Larch sawfly	*Pristiphora erichsonii*		×		×	×						×
Large aspen tortrix	*Choristoneura conflictana*	×	×	×	×			×		×	×	×
Leafminer/Needleminer	*Coleotechnites* spp.											
Linden looper	*Erannis tiliaria*										×(U)	
Lodgepole pine dwarf mistletoe	*Arceuthobium americanum*	×	×	×		×					×	×(P)
Lodgepole pine terminal weevil	*Pissodes terminalis*		×	×								
Mountain pine beetle	*Dendroctonus ponderosae*	×	×	×(P)							×	×(P)
Native elm bark beetle	*Hylurgopinus rufipes*			×							×	
Northern pitch twig moth	*Petrova albicapitana*			×	×							
Northern spruce engraver	*Ips perturbatus*											×
Oak wilt	*Ceratocystis fagacearum*			×(P)				×(P)		×(P)		
Pale winged grey	*Iridopsis ephyraria*						×					
Pine needle cast	*Lophodermella concolor*		×	×								×
Pine needle scale	*Chionaspis pinifoliae*			×								
Pine needle sheathminer	*Zellaria haimbachi*		×					×				
Pine sawflies	*Neodiprion* spp.			×	×	×				×		
Pine shoot beetle	*Tomicus piniperda*	×(P)	×(P)	×(P)	×		×	×				
Poplar borer	*Saperda calcarata*	×										

Pest (common name)	Pest (scientific name)	AB	BC[a]	MB	NB	NL	NS	ON	PE	QC	SK	YT
Rusty tussock moth	*Orgyia antiqua*				×	×						
Saddleback looper	*Ectropis crepuscularia*		×									
Satin moth	*Leucoma salicis*		×		×	×						
Seedling debarking weevil	*Hylobius congener*			×	×		×					
Serpentine leaf miner	*Phyllocnistis populiella*		×					×				
Sirex wood wasp	*Sirex noctilio*	×(P)	×(P)	×(P)	×(P)		×(P)	×		×(P)		
Sirococcus shoot blight	*Sirococcus conigenus*				×		×		×	×		
Smaller European elm bark beetle	*Scolytus multistriatus*			×(P)		×(P)						
Spring cankerworm	*Paleacrita vernata*			×							×(U)	
Spruce beetle	*Dendroctonus rufipennis*	×	×	×	×	×	×	×	×	×		×
Spruce bud midge	*Rhabdophaga swainei*			×		×						
Spruce budmoth	*Zieraphera canadensis*			×	×	×						
Spruce cone axis midge	*Dasineura rachiphaga*			×	×(SO)							
Spruce cone rust	*Chrysomyxa pirolata*			×	×(SO)							
Spruce coneworm	*Dioryctria reniculleloides*			×	×	×						
Spruce gall adelgid	*Adelges lariciatus*			×		×						
Spruce seed moth	*Cydia strobilella*			×	×(SO)							
Stalactiform blister rust	*Cronartium coleosporioides*	×	×	×								
Sudden oak death	*Phytophthora ramorum*			×(P)	×(P)			×(P)				
Tomentosus root rot	*Inonotus tomentosus*		×			×(P)				×		×
Two-year-cycle spruce budworm	*Choristoneura biennis*		×									×
Warren's root collar weevil	*Hylobius warreni*	×	×	×		×						
Western balsam bark beetle	*Dryocoetes confusus*		×									×
Western black-headed budworm	*Acleris gloverana*		×	×								×
Western gall rust	*Endocronartium harknessii*	×	×	×				×		×		
Western hemlock dwarf mistletoe	*Arceuthobium tsugense*		×									
Western hemlock looper	*Lambdina fiscellaria lugubrosa*		×									
Western spruce budworm	*Choristoneura occidentalis*	×	×									
White pine blister rust	*Cronartium ribicola*	×	×	×	×	×			×	×		
White pine weevil	*Pissodes strobi*	×	×	×	×		×	×	×	×	×	
White spruce cone maggot	*Strobilomyia neanthracina*			×	×(SO)					×		
Whitemarked tussock moth	*Orgyia leucostigma*				×	×	×					
Yellow-headed spruce sawfly	*Pikonema alaskensis*			×	×	×						

[a] Most captured during aerial surveys and not ground surveys.

[b] Abiotics currently not considered part of NFPS, but identified as a concern by some jurisdictions.

APPENDIX 3. COMPONENTS OF MONITORING SCENARIOS AND GROUND SURVEY SAMPLING DESIGN

OVERVIEW SURVEYS

Overview surveys refer to pest monitoring from a position other than the ground. Two choices are available: aerial surveys and remote sensing. Aerial surveys, usually conducted with a small fixed-wing aircraft, are the primary landscape-level tool for monitoring several forest health factors (FHFs) in a cost-effective, efficient manner. Forest insects are the most easily identified from the air, but some forest pathogens such as foliar disease and declines may also be visible. Identification is assisted by historical information, local knowledge, ecosystem, tree species and damage symptoms observed. Ground checks are generally used to confirm unidentifiable causal agents.

Remote sensing is a technology that may prove very useful for forest health monitoring purposes, particularly in unmanaged northern forests. Depending on provincial mandates, these northern latitude forests may be deemed as high priority because they are predicted to be more sensitive to events induced by climate change. Although remote sensing is currently limited in its ability to identify specific causal agents, it does provide a means by which to quantify the extent and frequency of landscape-level disturbances. An additional benefit may be the ability to conduct retrospective disturbance analyses (depending on the availability of historical imagery for a particular area). The imagery, however, must also coincide with the time of year when disturbance events are most visible. Ground checks and aerial surveys could be conducted to confirm the causal agent, as funding permits.

The distinction between the Good, Better and Best monitoring scenarios is a move from partial aerial survey coverage to coverage of all managed forests (including those on Department of National Defence [DND], Indian Reserve [IR] and parks land) and finally to coverage of all forests. Overview surveys refer to both aerial and remote sensing methodologies. Which proportion is done by which method will likely change over time, particularly as remote sensing technologies improve and become more affordable.

GROUND SURVEYS

The three monitoring scenarios recommend an approach for a ground monitoring scheme that differs by importance of the pests sampled, land base being surveyed, intensity of the monitoring system, type of data collected, and assessment frequency. In the Good scenario, high priority major pests are monitored—those that are currently causing, or are predicted to cause, significant damage to the forests in the near future (see Table 13 and Appendix 2 in the main report). With a few exceptions, the current ground monitoring efforts fall into this category because they are based largely on the historical distribution of *known* pests, and tend to focus on one pest at a time. The goal for the Better and Best scenarios is to build on established plot systems where possible, and add additional plots where gaps exist.

In the Better scenario, permanent points would be established in all managed forests, and monitoring would be conducted annually or at regular intervals. At these points, quantitative observations would be conducted to ascertain, at a minimum, the presence or absence of all major and potentially major forest pests in the sampling area. These damaging agents would also include those of concern listed in Appendix 2. Recording negatives is equally as important as recording positives, as it enables tracking of pest levels over time with the confidence that lack of a positive recording was the result of the pest not being present rather than being an artefact of low sampling effort.

In the Best scenario, more plots would be established to include all forested land which would be monitored for all pest conditions on an annual basis. In both the Better and Best scenarios, the expectation is that Department of National Defence (DND) and Indian Reserves (IR) lands would be the responsibility of the Federal Government to monitor.

If the Better scenario was pursued, a definition for "all pests" would need to be developed. It is highly recommended that abiotic factors be included under this definition, and preferably included in both the Good and Better scenarios at some point. Abiotic events are important in many regards. First, they are capable of causing significant landscape-level damage; second, they may be important indicators of climate change; and third, they may predispose trees to other forest pests.

GROUND SURVEY SAMPLING DESIGN

The forest parameters recommended for a national pest ground monitoring network are predominant genus and leading species as these attributes are most closely linked to host and pest distribution (Figure A3-1). For each province and territory, a target of 30–50 plots per predominant genus is recommended. Within each predominant genus, plot distribution would be proportionately based on area occupied by leading species. It is possible that in a given cell, the predominant genus is not necessarily the leading species, depending on the individual percentage of each tree species belonging to that genus. It is important that proposed sampling sites be reasonably accessible, as costs for monitoring inaccessible plots on an annual basis would be prohibitive.

The best-suited national data for representation and stratification is Canada's National Forest Inventory (CANFI) 2001, which provides a variety of standardized forest themes. These themes have been derived from the compilation of provincial and territorial forest inventories and satellite imagery (Power and Gillis, 2006). CANFI spatial data is available in a raster format, which facilitates a relatively easy means by which to stratify the land base by relevant forest parameters.

The combination of predominant genera and leading species was selected because it may capture more tree species and pest diversity. For example, a leading spruce stand in the *Spruce* genus may be very different from a leading spruce stand in the *Pine* genus.

The target number of plots per predominant genus for the Better scenario is based on the National Forest Inventory (NFI) ground sampling guidelines, which suggest establishing a minimum of 50 plots per terrestrial ecozone. This target has been recommended for managed forests in most of the provinces and territories for genera that occupy >5% of the forested land base. The exception occurs in the Maritime Provinces, where the target has been adjusted to 30 plots to reflect their smaller size.

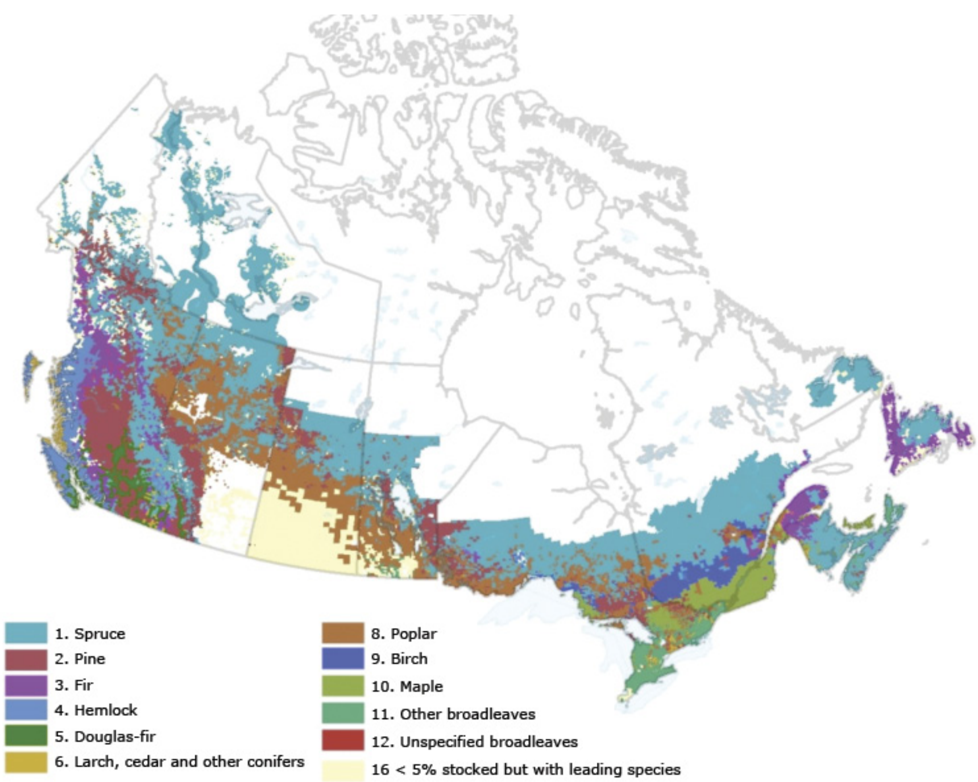

Figure A3-1. Distribution of predominant tree genera within managed forests in Canada.

Genera that occupy <5% of the forested land base were assigned 5 plots per province or territory. The predominant genus category includes some categories that lump several genera (e.g., *Other hardwoods* and *Larch, cedar and other conifers*). One genus category named <5% stocked was further refined to include only forest types with leading species (labelled *Non-contiguous forest types*). In some parts of Canada, these are unique types and should be included in the monitoring scheme. These types were allocated a minimum of 5 plots.

For the Best scenario, the number of plots is increased and expanded beyond managed forest lands.

Within many genera, various leading species did not proportionally reach the minimum to require a plot (within the 30- or 50-plot target). For example, the *Spruce* genus may have been assigned 40 spruce-leading stand plots and 10 lodgepole-pine-leading stand plots (proportional for the land base to the 50 required), but a significant component of larch-leading stands were proport ionally too small to warrant a plot. These plots were examined further to determine whether they were accessible and how well they were spatially distributed. If they were inaccessible, they were simply assigned a zero to indicate they were there but not accessible (Appendix 5). If they were accessible, they were assigned 1 to 5 plots, depending on stand distribution and how many other plots were in that leading species type across the province or territory. A leading species, regardless of which genus it was in, was assigned a minimum of 3 plots province or territory (Table A3-1).

Important to note is that when extra plots were incurred, the target number of plots per genus was exceeded. This increase was most obvious for Other broadleaves in Ontario and Non-contiguous forest types in Manitoba (Table A3-2).

A total of 1889 monitoring plots across Canada were obtained by applying the stratification criteria to the managed forest land base (Table A3-2). A total of 27% are in the spruce genus, followed by 18% in pine and 14% in poplar. Ontario, British Columbia and Quebec have the highest percentage of plots. Spatial tools were used to determine which predominant genera (and leading species within the genera) are being monitored with the existing plot system (Appendix 5). The *Spruce* and *Poplar* genera have the highest levels of monitoring, while the non-contiguous forest types are less frequently visited or not visited at all in some jurisdictions (Table A3-2). Caution should be used when interpreting these results, as they do not necessarily mean that the predominant genera are adequately monitored, only that established plots are being visited either annually or on a variable basis to assess one or two FHFs.

Depending on the monitoring objectives, we recommend using historical disturbance information to further assist with plot location, and locating a larger proportion of plots at the northern ranges of tree species. These forests may be more sensitive to climate-change-induced events. For the genera in Table A3-2 that are not adequately monitored, either at the genus (orange-highlighted) or leading species (yellow-highlighted) level, details on which leading species are underrepresented can be reviewed by comparing the proposed stratification details (Appendix 4) with the current plot situation (Appendix 5). This review is recommended to determine where gaps exist when a jurisdiction is moving towards the Better scenario. If gaps are identified, we recommend placing plots in areas where FIDS permanent sample sites existed, as long as they provided adequate spatial representation. The FIDS plot information will eventually be available through the Pest Strategy Information System of the National Forest Pest Strategy (NFPS). Good access to plots is important for efficiencies in field staff allocations and costs.

Table A3-1. Allocation of national pest monitoring plots for the Better scenario.

Managed Forests	Non-Maritime Provinces and territories (no. of plots, minimum)	Maritime Provinces: NB, NS, PE, NL (no. of plots, minimum)
Contiguous Forest Types		
Predominant Genus ≥ 5% of managed forests	50 per genus	30 per genus
Predominant Genus <5% of managed forests	5 per genus	5 per genus
Non-Contiguous Forest Types	3 to 5 per leading species	3 to 5 per leading species
All Genus Categories		
Leading Species not represented in initial stratification	3 to 5 per leading species	3 to 5 per leading species

Table A3-2. Proposed national pest monitoring plot distribution for the Better scenario, by predominant genus and current monitoring status.

Provinces or territories	Birch	Douglas-fir	Fir	Hemlock	Larch, cedar and other conifers	Maple	Non-contiguous forest types	Other broadleaves	Pine	Poplar	Spruce	Unspecified broadleaves	Total plots	% of Total plots
AB	0	5	0	0	0	0	4	0	50	50	53	0	161	8.5
BC	6	53	51	52	9	0	5	2	58	5	53	0	294	15.5
MB	0	0	0	0	5	5	27	5	50	50	53	0	195	10.3
NB	5	0	33	0	8	34	5	0	8	5	38	0	136	7.2
NL	5	0	33	0	0	0	5	0	0	0	30	0	73	3.9
NS	0	0	5	0	0	0	5	30	9	5	31	0	85	4.5
NT	0	0	0	0	0	0	5	0	0	0	50	0	55	2.9
NU	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
ON	5	0	5	5	5	51	5	71	51	50	50	5	298	15.8
PE	0	0	0	0	0	32	0	0	0	0	0	0	32	1.7
QC	51	0	50	0	6	50	5	6	9	50	50	0	276	14.6
SK	0	0	0	0	0	0	5	0	52	52	51	0	160	8.5
YT	0	0	5	0	6	0	4	0	50	6	53	0	124	6.6
Total Plots	72	58	182	57	39	172	75	114	337	273	512	5	1,889	
% of Total	3.8	3.0	9.6	3.0	2.0	9.0	4.0	6.0	17.8	14.4	27.1	0.3		

(green)	Adequate plots in current monitoring system by leading species within genus.
(orange)	Not sufficient plots by genus or leading species.
(yellow)	Adequate plots by genus, but not leading species.

ECOSYSTEM-BASED REPORTING

Ecosystem-based reporting is a goal of the NFPS which will be achieved relatively easily through the use of spatial analysis tools. The most appropriate theme for this purpose is that prepared for the National Ecological Framework for Canada (Ecological Stratification Working Group 1995), which describes terrestrial ecosystems at three levels: ecozone, ecoregions and ecodistricts. The Information and Information Management Technical Advisory Group of the CCFM's Forest Pest Working Group will incorporate this aspect of reporting into the national Pest Strategy Information System.

DIAGNOSTICS

The success or strength of a monitoring program is directly linked to diagnostic capacity. Currently the majority of provinces and territories do not employ, nor have consistent access to, diagnosticians and taxonomists (see the report *National Forest Insect and Disease Diagnostic and Taxonomic Resources and Tools: Current Situation and Future Considerations)*. Most FHF identifications are done in the field, with some access to diagnostic tools (pest identification manuals or software) for more difficult identifications. This system works well for common pests, but may not be sufficient for an enhanced monitoring program. In the proposed Better and Best scenarios, increasing levels of field staff training and access to dedicated insect and disease diagnosticians and taxonomists are critical. Other features of these scenarios include curated collections, an electronic database, and improved identification tools and monitoring techniques.

IMPROVED COMMUNICATION

Improved communication between the various monitoring agencies and provinces and territories is an important component of improved monitoring practices. For example, knowing that an expanding insect infestation is in an adjacent jurisdiction is invaluable. As well, sharing of monitoring methodologies and diagnostic tools can only lead to improved monitoring. All of these aspects will be facilitated through the national Pest Strategy Information System.

Improved levels of communication have already been realized since the initiation of the NFPS. It is recommended these levels of communication continue through venues such as the National Forest Pest Management Forum, Spray Efficacy Research Group International (SERG-I), Forest Protection Technology Committee meetings, and other provincial and territorial forest health workshops.

HARMONIZING BEST PRACTICES

Through improved communication efforts (see above), one of the primary goals should be to work towards harmonizing best practices, as well as continual improvement as new and improved technologies and methodologies emerge or are agreed on.

A standardization workshop held with provincial and territorial representatives acknowledged that pest survey methodologies and pest thresholds can and will continue to vary between jurisdictions as a result of local conditions or needs. A potential solution to deal with these compatibility issues is to ensure that users are aware of the underlying survey methodologies and protocols. This will alleviate interpretation errors.

INFORMING RISK ANALYSIS

Risk analysis is directly related to the quality and quantity of data available. Thus, as various aspects of provincial and territorial monitoring improve, so will the ability to inform risk analysis processes.

APPENDIX 4. BETTER MONITORING STRATIFICATION BY GENUS AND LEADING SPECIES, BY PROVINCE AND TERRITORY

Yellow highlights = insufficient current plots; green highlights = sufficient current plots

Province/ territory	Common name	Birch	Douglas-fir	Fir	Hemlock	Larch, cedar and other conifers	Maple	Non-contiguous forest types	Other broadleaves	Pine	Poplar	Spruce	Unspecified broadleaves
AB	Alaska paper and white birch											0	
AB	Balsam poplar										0		
AB	Black spruce									6	2	19	
AB	Douglas-fir and Rocky Mountain Douglas-fir		4					0		0		0	
AB	Engelmann spruce									1		2	
AB	Hybrid jack and lodgepole pine							0		2	0	1	
AB	Intolerant hardwoods							0		0	11	2	
AB	Jack pine							0		8	0	4	
AB	Lodgepole pine							0		31	0	1	
AB	Pine										0	1	
AB	Poplar		1					4		2	28	10	
AB	Subalpine fir											0	
AB	Tamarack							0				3	
AB	Trembling aspen							0		0	8	4	
AB	White spruce									0	0	6	
AB Total			**5**					**4**		**50**	**49**	**53**	
BC	Amabilis fir			2	1								
BC	Balsam poplar							0			0	0	
BC	Birch	3										0	
BC	Black spruce			0						0	0	4	
BC	Douglas-fir and Rocky Mountain Douglas-fir		47	0	2	0			2	1		0	
BC	Engelmann spruce			1						1		3	
BC	Fir			25	0	0		2		0	0	2	
BC	Hemlock			0	30	0		1				0	
BC	Larch			0		0						0	
BC	Lodgepole pine		2	2	0	0		1		47	0	6	
BC	Mountain hemlock			1	2			0					
BC	Ponderosa pine		4							1			
BC	Spruce		0	1	0	0				1	0	28	
BC	Subalpine fir			19	0	0		0		0		1	
BC	Trembling aspen	3	0	0	0			0		1	5	5	
BC	Western hemlock				12	0		0				0	

Province/ territory	Common name	Birch	Douglas-fir	Fir	Hemlock	Larch, cedar and other conifers	Maple	Non-contiguous forest types	Other broadleaves	Pine	Poplar	Spruce	Unspecified broadleaves
BC	Western larch					3				2			
BC	Western redcedar				3	3		0				0	
BC	White birch											0	
BC	White spruce			0							0	4	
BC	Whitebark pine							1		4			
BC	Yellow cypress				2	3							
BC Total		**6**	**53**	**51**	**52**	**9**		**5**	**2**	**58**	**5**	**53**	
MB	Alaska paper and white birch							0					
MB	Ash							5					
MB	Balsam fir							3			0	0	
MB	Balsam poplar							3			0		
MB	Black spruce									2	2	39	
MB	Bur oak							1	3		0		
MB	Eastern cottonwood							5					
MB	Jack pine					1		0		48	2	8	
MB	Manitoba maple						2	1	0				
MB	Red ash							3	0				
MB	Tamarack					3					0	0	
MB	Trembling aspen					1	3	3	2	0	46	3	
MB	White elm							3	0				
MB	White spruce										0	3	
MB Total						**5**	**5**	**27**	**5**	**50**	**50**	**53**	
NB	Balsam fir			17		0	2					3	
NB	Beech						3						
NB	Black spruce			2			0					7	
NB	Eastern white cedar					2						1	
NB	Eastern white pine									3		0	
NB	Intolerant hardwoods			1		1					1	3	
NB	Jack pine									5		1	
NB	Poplar			2		1	3				3	2	
NB	Red and white spruce					0	1					8	
NB	Red maple			0			3				0	0	
NB	Red pine										0		
NB	Red Spruce											0	
NB	Spruce											3	
NB	Spruce and balsam fir											3	
NB	Sugar maple			2		0	14	5				1	
NB	Tamarack					3							

Province/ territory	Common name	Birch	Douglas-fir	Fir	Hemlock	Larch, cedar and other conifers	Maple	Non-contiguous forest types	Other broadleaves	Pine	Poplar	Spruce	Unspecified broadleaves
NB	Tolerant hardwoods			4		1	7					4	
NB	White and gray birch	5		2		0	1	0			1	2	
NB	White spruce			3			0					0	
NB Total		**5**		**33**		**8**	**34**	**5**		**8**	**5**	**38**	
NL	Alaska paper and white birch	0		0									
NL	Balsam fir	4		29				5				4	
NL	Black spruce	1		1								26	
NL	White spruce			3								0	
NL Total		**5**		**33**				**5**				**30**	
NS	Balsam fir			4					1			1	
NS	Black and red spruce			1					4	3		24	
NS	Black spruce											2	
NS	Eastern white pine									3			
NS	Intolerant hardwoods			0				5	16	0		3	
NS	Jack pine									3			
NS	Poplar										5	0	
NS	Tolerant hardwoods								9			0	
NS	White spruce								0			1	
NS Total				**5**				**5**	**30**	**9**	**5**	**31**	
NT	Unspecified conifers							5				50	
NT Total								**5**				**50**	
ON	Alaska paper and white birch	5		0		0	1	1	0	4	4	2	
ON	Balsam fir			5				0	0	0	0	0	
ON	Basswood						1	0	4				
ON	Beech						1	0	4				
ON	Black ash					0	0	1	2	0	0		0
ON	Black spruce	0				0				2	6	45	
ON	Eastern hemlock				5		0		0	0			
ON	Eastern white cedar					4	0		6	2	2	0	
ON	Eastern white pine					0	0	0	0	6	0		
ON	Ironwood								3				
ON	Jack pine									30	3	2	
ON	Poplar					0	0	0	1	2	33	0	
ON	Red oak							0	3	0	0		
ON	Red pine								1	4			
ON	Scots pine								0	0			
ON	Silver and red maple					0		1	11	0	0		5
ON	Sugar and black maple	0			0	0	48	1	25	1	1		

Province/ territory	Common name	Birch	Douglas-fir	Fir	Hemlock	Larch, cedar and other conifers	Maple	Non-contiguous forest types	Other broadleaves	Pine	Poplar	Spruce	Unspecified broadleaves
ON	Tamarack					0							
ON	White ash								3				
ON	White oak							1	2				
ON	White spruce								2	0	1	1	
ON	Yellow birch					1			4				
ON Total		**5**		**5**	**5**	**5**	**51**	**5**	**71**	**51**	**50**	**50**	**5**
PE	Black spruce						6						
PE	Poplar						3						
PE	Red maple						11						
PE	Tamarack						0						
PE	White spruce						12						
PE Total							**32**						
QC	Alaska paper and white birch	31					0	1		1	2	2	
QC	Balsam fir	4		47		1	8	1			2	2	
QC	Balsam poplar										0		
QC	Black and red spruce	0		2			0			0	1	36	
QC	Black spruce	0		0			0			0	1	10	
QC	Eastern hemlock	3											
QC	Eastern white cedar	0				3	0	1		0	0		
QC	Eastern white pine	0					1		0	2	0		
QC	Jack pine									3	0	0	
QC	Largetooth aspen									3			
QC	Red Maple						16			0			
QC	Red oak						0		3		0		
QC	Speckled alder											0	
QC	Sugar maple	2					22	0	3				
QC	Trembling aspen	2		1		2	1	2		0	44	0	
QC	White spruce												
QC	Yellow birch	9					2						
QC Total		**51**		**50**		**6**	**50**	**5**	**6**	**9**	**50**	**50**	
SK	Balsam poplar							1		0	3	0	
SK	Black spruce									0	0	30	
SK	Jack pine									49	2	10	
SK	Lodgepole pine									3			
SK	Tamarack										3	0	
SK	Trembling aspen							4		0	44	2	
SK	White spruce									0	0	9	
SK Total								**5**		**52**	**52**	**51**	

Province/ territory	Common name	Birch	Douglas-fir	Fir	Hemlock	Larch, cedar and other conifers	Maple	Non-contiguous forest types	Other broadleaves	Pine	Poplar	Spruce	Unspecified broadleaves
YT	Alaska paper and white birch							0			0	0	
YT	Balsam poplar										2	1	
YT	Black spruce									4		16	
YT	Lodgepole pine							1		44	0	2	
YT	Subalpine fir			5		1		2			0	1	
YT	Tamarack					4		1					
YT	Trembling aspen							0			4	1	
YT	White spruce					1				2	0	32	
YT Total				**5**		**6**		**4**		**50**	**6**	**53**	

APPENDIX 5. CURRENT PLOT DISTRIBUTION BY GENUS AND LEADING SPECIES, BY PROVINCE

(Note: currently no plots in the territories)

Province	Common name	Birch	Douglas-fir	Fir	Hemlock	Larch, cedar and other conifers	Maple	Non-contiguous forest types	Other broadleaves	Pine	Poplar	Spruce
AB	Balsam poplar										1	
AB	Black spruce										3	53
AB	Douglas-fir and Rocky Mountain Douglas-fir		1							1		
AB	Engelmann spruce									2		7
AB	Hybrid jack and lodgepole pine									3		4
AB	Intolerant hardwoods										15	1
AB	Jack pine									1		1
AB	Lodgepole pine									45		5
AB	Poplar										273	303
AB	Subalpine fir			1								
AB	Trembling aspen										62	178
AB	White spruce											377
AB Total		**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**52**	**354**	**929**
BC	Douglas-fir and Rocky Mountain Douglas-fir		643	1	11	13				40		4
BC	Engelmann spruce			1								
BC	Fir			94	17							2
BC	Hemlock				179	1						
BC	Lodgepole pine		4	1	83					366		4
BC	Ponderosa pine		5									
BC	Spruce		1	30	3					1		53
BC	Subalpine fir			77	21	2				2		
BC	Trembling aspen				6						55	2
BC	Western hemlock				556							
BC	Western larch					2						
BC	Western redcedar					15						
BC	White spruce											3
BC Total		**0**	**653**	**204**	**876**	**33**	**0**	**0**	**0**	**409**	**55**	**68**

Province	Common name	Birch	Douglas-fir	Fir	Hemlock	Larch, cedar and other conifers	Maple	Non-contiguous forest types	Other broadleaves	Pine	Poplar	Spruce
MB	Balsam poplar										5	
MB	Black spruce									7	20	1195
MB	Bur oak							15				
MB	Jack pine									173	11	50
MB	Red ash							12				
MB	Tamarack										2	
MB	Trembling aspen							5	3	1	346	92
MB	White elm							6				
MB	White spruce											8
MB Total		**0**	**0**	**0**	**0**	**0**	**0**	**38**	**3**	**181**	**384**	**1345**
NB	Balsam fir			121		1	8					117
NB	Balsam poplar										2	
NB	Beech						4					
NB	Black spruce			10			4					131
NB	Eastern white cedar					8						28
NB	Eastern white pine											2
NB	Intolerant hardwoods			5		7					12	85
NB	Jack pine											14
NB	Poplar			18			14				25	57
NB	Red and white spruce						3					282
NB	Red maple			2			16					20
NB	Sugar maple			27			37					11
NB	Tolerant hardwoods			54		1	7					83
NB	White and gray birch			14		8	7				13	36
NB Total		**0**	**0**	**251**	**0**	**25**	**100**	**0**	**0**	**0**	**52**	**866**
NL	Balsam fir			1375				5				55
NL	Black spruce			7								370
NL	White spruce			1								
NL Total		**0**	**0**	**1383**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**425**
NS	Balsam fir			31					68			125
NS	Black and red spruce			2					77	47		451
NS	Eastern white pine									8		
NS	Intolerant hardwoods			5					181	2		49
NS	Jack pine									4		
NS	Poplar										1	
NS	Tolerant hardwoods								145			3
NS	White spruce								14			15
NS Total		**0**	**0**	**38**	**0**	**0**	**0**	**0**	**485**	**61**	**1**	**643**

Province	Common name	Birch	Douglas-fir	Fir	Hemlock	Larch, cedar and other conifers	Maple	Non-contiguous forest types	Other broadleaves	Pine	Poplar	Spruce
ON	Alaska paper and white birch	1								18	2	1
ON	Balsam fir			3								2
ON	Black spruce									2	6	50
ON	Eastern white cedar								2			
ON	Eastern white pine									9		
ON	Jack pine									66	7	13
ON	Poplar									3	37	
ON	Red oak								1		1	
ON	Red pine									2		
ON	Silver and red maple								2			
ON	Sugar and black maple						16		7	1		
ON Total		**1**	**0**	**3**	**0**	**0**	**16**	**0**	**12**	**101**	**53**	**66**
PE	Black spruce						3					
PE	Poplar						1					
PE	Red maple						3					
PE	White spruce						6					
PE Total		**0**	**0**	**0**	**0**	**0**	**13**	**0**	**0**	**0**	**0**	**0**
QC	Alaska paper and white birch	191					4			6	17	35
QC	Balsam fir	53		247		2	137	1			10	62
QC	Black and red spruce	5		4			2			3	3	237
QC	Black spruce	2		3			5			3	2	173
QC	Eastern white cedar	3				6	4	1		1	3	
QC	Eastern white pine	3					12			10	5	
QC	Jack pine									40		4
QC	Poplar									1	2	
QC	Red maple						245			2		
QC	Red oak						4		3		3	
QC	Silver and red maple										7	
QC	Speckled alder											1
QC	Sugar maple	29					443		4			
QC	Trembling aspen	20		5		6	19			6	438	14
QC	Yellow birch	56					19					
QC Total		**362**	**0**	**259**	**0**	**14**	**894**	**2**	**7**	**72**	**490**	**526**
SK	Balsam poplar							1			7	
SK	Black spruce									1	2	197
SK	Jack pine									19	13	37
SK	Trembling aspen							32		2	533	74
SK	White spruce							1				24
SK Total		**0**	**0**	**0**	**0**	**0**	**0**	**34**	**0**	**22**	**555**	**332**