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Science and Technology

Forest Pest Research Needs and Priorities Across Canada

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Executive Summary

The National Forest Pest Strategy (NFPS) Science and Technology Technical Advisory Group, made up of federal, provincial and territorial officials, reports to the Canadian Council of Forest Ministers' Forest Pest Working Group. In 2008, this group recommended that a more integrated process be followed for identifying and prioritizing the science and technology needs of Canada's pest management community, and for communicating those needs to research planning decision-makers who can then incorporate them into short- and long-term research programs.

An initial survey of research needs was conducted in 2008/2009, but analysis of the results proved to be challenging for a variety of reasons. In 2012/2013, a new survey was conducted by an NFPS Science and Technology project team.

Any party involved in writing research and funding proposals in forest pest science or management – to public or private organizations, research institutions or funding agencies across Canada – will find the information in this report a useful guide.

TOP 10 RESEARCH TOPIC PRIORITIES

From the 21 research topics that were ranked as a priority, four stand out with 11 of the 12 provinces and territories selecting them as a top 10 research topic. These topics were: 1) climate change influences on pest behaviour (spatial and temporal analysis), pest population trends and pest impacts; 2) pest risk analysis; 3) pest population dynamics and processes; and 4) semiochemical monitoring tools.

TOP 10 PRIORITY PESTS IDENTIFIED FOR RESEARCH

From an initial list of 112 pests, 48 were ranked as being a top 10 priority by one or more jurisdictions. This large

LESSONS LEARNED FROM THE FIRST RESEARCH NEEDS SURVEY HELPED GUIDE THE APPROACH TO THE SECOND SURVEY:

1. A ranking-type Delphi method was chosen as a survey method because it provides a means to group, sort and rank data, and it benefits from the collective knowledge and opinions of forest pest specialists across the country.
2. Participants for the survey were provincial and territorial forest health specialists and staff from the Canadian Food Inspection Agency. To ensure equitable representation across the country, there was only one respondent per jurisdiction who was responsible for ensuring that both entomology and pathology concerns were included.
3. The survey was designed to make a distinction between priority research topics and priority pests requiring research. The rationale for doing this was twofold:
   - Differentiation of research topics is an effective means to communicate to research agencies the need for maintenance of core capacity and competencies.
   - Research topics combined with priority pests requiring research provides a structured means to define research needs in a more consistent manner, thus facilitating both analysis of data and prioritization of research needs.
4. In recognition of the potential for under-representation of regional pest issues at a national level, the final Science and Technology report was written in two sections: one addressing national priorities, and one addressing regional and jurisdictional priorities.

number of pests reflects the vast diversity of Canadian forests and of pests. Some of these pests are regionally significant and not represented at a national level; and they include several pathogens, as well as some less widespread defoliators and forest invasive alien species. Only 18% of the priority pests were pathogens, most of which were ranked as lower priority. The high-priority pests at a national scale included:

- eastern spruce budworm, the most prevalent defoliator of Canadian forests;
- mountain pine beetle, a native turned "invasive";
- spruce beetle, a Canada-wide killing bark beetle; and
- emerald ash borer, a forest invasive alien species.

CLIMATE CHANGE PRIORITIZED

Although not a pest, climate change and its associated abiotic disturbances were the third-ranked research category of priority, highlighting the importance of this issue to forest pest managers.

Of note is that the usual topics of major concern across Canada (such as jack pine budworm, root diseases and dwarf mistletoes) have been displaced by this eclectic mix – so much so that no native pathogens are now on the top 10 list. This may in part be due to the chronic nature of many pathogens. While their impact on forested ecosystems has not decreased, nor has our knowledge of those pests substantially increased, their relative importance has been overshadowed by the "pests of the day." Given that forest pathogens and diseases are recognized as being major contributing factors to forest health, research would result in a better understanding of the factors affecting the development of diseases in forest ecosystems.

Climate change influence on pest behaviour and distribution is a common research theme identified for most pests. Research needs for invasive species focus on gaining a better understanding of the likelihood of those species being introduced and the consequences of that happening; and on developing detection and monitoring tools. Research needs for native species focus on developing publicly acceptable biocontrol tools, improved detection tools, means of quantifying impacts on non-timber resources, and improved management strategies.

NATIONAL-LEVEL RESEARCH NEEDS IDENTIFIED

The following summarizes highlights of the national research needs identified:

- Over half of the survey's respondents, ranging from Yukon to New Brunswick, supported research related to mountain pine beetle introduction, establishment, spread, connectivity and pathways, and climate suitability models.
- The top-ranked research topic was spatial and temporal analysis of pest data to enable detection of changes in pest behaviour and distribution due to climate change, analysis of regional and national population trends, and quantification of losses. Half of the survey respondents supported this work for mountain pine beetle and for the climate change disturbances category (including declines).
- Six jurisdictions, including the Canadian Food Inspection Agency (CFIA), identified the need for semiochemical monitoring tools (including for trap designs, calibration and standardization) for emerald ash borer.
- The most common high-priority pests identified were eastern spruce budworm, mountain pine beetle and emerald ash borer.
- One-third of all the research needs and comments pertained to forest invasive alien species.
- Priority research needs did not differ significantly for most priority research topics. Only efficacy of response options and basic pest biology and life histories were ranked significantly lower than all the other research needs.

MAINTENANCE OF CORE CAPACITIES AND COMPETENCIES IDENTIFIED

The large variety of research topics identified and selected by provinces and territories requires a diverse set of expertise. Addressing the research needs and priorities presented in this report will require maintaining core capacities and competencies by research agencies in those areas.

LOOKING AHEAD

This survey was directed at identifying priority research needs of provincial, territorial and federal agencies responsible for forest pest management across Canada. The responses highlight and rank current forest pest management issues, including forest invasive alien species.

Although similar surveys will likely be conducted every 3 to 5 years, there is a high probability that the science and technology research priorities they identify will have a similar eclectic mix of pests as a result of climate change, increased international trade and traffic, and fewer resources to monitor pests. This means that practising proactive forest pest management, as envisioned by the NFPS, could be compromised or threatened if research and management efforts remain focused strictly on responding to new pest introductions or to uncertainties about native pests.

Introduction

In 2006, the Canadian Council of Forest Ministers (CCFM) endorsed the vision, principles and approach for a National Forest Pest Strategy (NFPS). The basis for the NFPS is an ecosystem-based, proactive, integrated response to the threat of forest pests, using a national risk-analysis framework for decision-making by the multiple 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 management to proactive ecosystem-based management.

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

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) composed of] of federal, provincial and territorial officials and reporting to the CCFM's Forest Pest Working Group.

The NFPS Science and Technology TAG recommended that a more integrated and connected process be followed for identifying and prioritizing the science and technology needs of Canada's pest management community, and for conveying those needs to research planning decision-makers who can then integrate them into short- and long-term research programs. Key gaps had identified that:

1. Current research planning processes were being conducted using internal intellectual capacity within jurisdictions' research agencies, and decisions were not being made with the benefit of input from external members of the Canadian forest pest management community.
2. In jurisdictions with limited formal research planning processes because of limited research capacity, there was no obvious or proactive venue for conveying information needs to those agencies having an established research capacity.
3. Provinces felt that few formal opportunities existed for research users to communicate with providers at the national level. A roundtable on research needs and research priorities was required.

These gaps were used to guide the development of three main implementation tasks:

1. Development and implementation of a brief survey to identify science and technology needs, and then to use the survey findings to inform a roundtable discussion expected to result in national science and technology priorities for distribution to research agencies.
2. Writing by NFPS partners of an annual report on the outcomes of their planning process.
3. Internal analysis on how research planning decisions have been guided by the roundtable on science and technology priorities.
4. Communication of science and technology priorities to external research, funding and granting agencies.

An initial survey of research needs was conducted in 2008/2009, but analysis of the results proved to be challenging for a variety of reasons. A general criticism of the survey was that it did not provide enough direction on the level of detail required in their responses, hence these varied from specific to general making it difficult to group and compare responses.

In 2012/2013, an NFPS Science and Technology project team was formed and tasked with developing and conducting a new survey based on lessons learned from the previous efforts. The overall objective of the project team was to develop a list of science and technology priorities pertaining to forest pest management in Canada, as well as to devise a mechanism to promote those priorities and integrate them into research programs.

This report summarizes the results of the priorities-setting part of the objective. Development of a mechanism for integrating priorities into research programs is proposed for 2013/2014.

Approach

The Science and Technology project team reviewed previous survey efforts and identified lessons learned to help guide development and analysis of a new survey. Their review concluded that the survey design and content should meet the following criteria:

- Facilitate analysis of national and regional priorities;
- Be representative of all potential biotic and abiotic concerns, including forest invasive alien species;
- Differentiate between priority research topics and priority pests;
- Be structured with close-ended questions to eliminate the need for subjective interpretation of responses by the survey facilitator/analyzer;
- Provide statistically robust results where possible; and
- Be repeatable in the future.

Based on these criteria, the project team adopted the following approach to identifying the science and technology research needs and priorities across Canada in 2012/2013:

1. To communicate and emphasize to research agencies where core capacity and competencies need to be maintained, the research topic priority-setting part of the survey would distinguish between priority research topics and priority pests.
2. A Delphi method (see Appendix 1) would be used to identify priority research topics, because it: provides a structured communication process that could be used to collect, group, sort and rank data; and offers some measurement of consensus, and is repeatable in the future. The Delphi method is most suitable for issues that do not lend themselves to precise analytical techniques but rather benefit from the subjective judgements of individuals on a collective basis.
3. A simple ranking and subsequent weighting exercise would be used to identify national priority pests.
4. Specifics regarding research needs would be based on an alignment of national priority research topics and national priority pests, and presented in the context of priority pests.
5. Given the potential for under-representation of regional pest issues at a national level, the final report would include two sections: one for addressing national priorities, and one for addressing regional priorities.
6. To ensure equitable representation, only one response per jurisdiction would be required to represent both entomology and pathology concerns (i.e., collective priorities at a jurisdictional level).
7. As the CFIA mandate differs significantly from that of the provinces and territories, the CFIA's research needs for pests would be sought once the research topic priorities had been defined by the provinces and territories.

National Priorities

PRIORITY RESEARCH TOPICS

From the initial list of 28 research topics, 21 were considered a priority by at least one province or territory. The majority of those pertained to the risk assessment theme (Appendix 1, Table A1.1 and A1.2).

The survey sought to identify the top 10 research topics. However, given the ranking calculation and the natural breaks in the weighted sums, the final list is composed of 11 research topics (Table 1). Seven of these (68% of the weighted sums) pertain to risk assessment, while four (32% of the weighted sums) pertain to risk response.

CORE CAPACITIES AND COMPETENCIES

The distinction between research topics and pests emphasizes the need for maintenance of particular research skills (core capacities and competencies) by research agencies, regardless of the "pest of the day." In essence, the priority research topics identified in this survey are directly related to the skillsets that jurisdictions are relying on to complete work in these topic areas. These include, but are not limited to, the following as they apply to the research topic priorities.

Table 1. Summary of national science and technology research topic priorities, as determined by iterative Delphi survey rounds of provincial and territorial representatives (n=12) (see Appendix 1, Table A1.2, for a full list of research topics and ranking)

Risk Analysis Theme	Research Topic	Weighted Sum	No. of Top 10 Votes	Final Ranking
Risk Assessment	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	80	11	1
Risk Assessment	Pest risk assessment or analysis, including hazard and risk rating.	77	11	2
Risk Assessment	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	75	11	3
Risk Response	Semiochemical monitoring tools, including those for trap designs, calibration and standardization.	61	11	4
Risk Response	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	53	8	5
Risk Assessment	Introduction, establishment, spread, connectivity, pathways, and climate suitability models.	51	9	6
Risk Assessment	Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values	47	7	7
Risk Response	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	38	7	8
Risk Assessment	Assessment of cost/benefits of control, including for non-timber values.	24	8	9a
Risk Response	Efficacy of response options: cultural, biological, chemical or regulatory.	24	6	9b
Risk Assessment	Basic pest biology and life histories.	30	4	10

- Spatial Analysts and Modellers
- Forest Entomologists, including Insect Population and Spatial Dynamics
- Forest Pathologists, Mycologists
- Insect and Disease Ecologists
- Insect Physiologists and Biochemists
- Climate Change Specialists
- Forest/Wildlife Ecologists
- Forest Fire/Fuel Hazard Specialists
- Forest Economists

PRIORITY PESTS REQUIRING RESEARCH

A total of 48 pests, from a list of 112, were ranked by one or more jurisdiction as being a top 10 priority pest requiring further research (Appendix 1, Table A1.3). **Native forest insects** accounted for 44% of total responses, and **forest invasive alien species** for 31%. **Native forest diseases** were less frequently selected (18% of responses), and those that were selected ranked as a relatively lower priority (Figure 1).

While **climate change and abiotic disturbances** accounted for only 10% of responses, the majority of these were ranked as a high priority, and each vote was a dedicated vote to that category.

With the exception of one disturbance type, all national priority pests were insects. Eastern spruce budworm and mountain pine beetle ranked the highest (Table 2). Climate change disturbances, which included declines, received the third highest ranking. Four of the top 10 pests are considered to be forest invasive alien species.

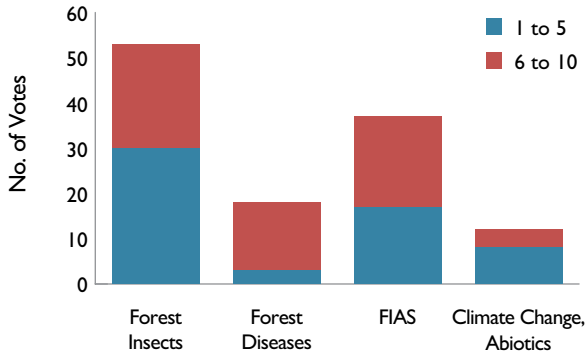


Figure 1. Summary of priority disturbance ranking (1–5 or 6–10) by category.

Table 2. Summary of national top 10 pests and disturbances requiring further research and final ranking*

Disturbance	No. of Votes (n=12)	Weighted Sum	Percent Who Selected in Top 5	Ranking
Eastern spruce budworm	10	87	100	1
Mountain pine beetle	9	64	67	2
Climate change (includes declines)	9	56	78	3
Spruce beetle	6	42	100	4
Emerald ash borer	6	41	83	5
Brown spruce longhorn beetle	4	28	100	6
Jack pine budworm	4	26	75	7
Asian gypsy moth	5	26	40	8
Eastern hemlock looper	3	19	67	9
Gypsy moth (European)	3	19	67	10

*See Figure 1 and the Discussion section for more information on the lack of pathogens in top 10 list.

PRIORITY RESEARCH NEEDS

OVERVIEW

In simple terms, "priority research needs" equates to "priority research topics + priority pests." Table 3 summarizes the jurisdictional research needs, by priority research topic and priority pests, for all jurisdictions in Canada.

- Over half the survey respondents supported research on the introduction, establishment, spread, connectivity, pathways and climate suitability models for mountain pine beetle – spanning from Yukon to New Brunswick.
- The top-ranked research topic was spatial and temporal analysis of pest data to enable, detection of changes in pest behaviour and distribution due to climate change, analysis of regional and national population trends, and quantification of losses. Half of the survey respondents supported this work for mountain pine beetle and for the climate change disturbances category (including declines).
- Six jurisdictions, including CFIA, identified the need for calibrating and standardizing semiochemical monitoring tools (including trap designs) for emerald ash borer.

- The most common high-priority pests identified were eastern spruce budworm, mountain pine beetle and emerald ash borer.
- One-third of research needs or comments pertained to forest invasive alien species.
- Priority research needs did not differ significantly for most priority research topics. Only efficacy of response options and basic pest biology and life histories were ranked significantly lower than all the other research needs.

Table 3. Summary of jurisdictional research need priorities, based on a combination of national research topics and national pest priorities.

National Ranking	Research Topic	Eastern Spruce Budworm	Mountain Pine Beetle	Climate Change (includes declines)	Spruce Beetle	Emerald Ash Borer	Brown Spruce Longhorn Beetle	Jack Pine Budworm	Asian Gypsy Moth	Eastern Hemlock Looper	Gypsy Moth (European)	Total Count
1	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	AB, ON, QC, NS, NL	AB, YT, NWT, SK, ON, NB	BC, AB, YT, SK, MB, ON	AB, YT, NS	ON	CFIA	SK, ON	CFIA	NL		**26**
2	Pest risk assessment or analysis, including hazard and risk rating.	ON, QC, NB	YT, NWT, SK, ON	AB, YT, NB	YT, NB, NS	ON, QC, NB, NS	PEI	ON, QC	AB, ON, NB, NS	QC	PEI	**26**
3	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	SK, ON, QC, NB, NS, PEI, NL	NWT, SK, ON, YT	ON, NB	YT, NS	ON, QC, NB	NS	ON	NB, CFIA	QC	PEI	**24**
4	Semiochemical monitoring tools, including those for trap designs, calibration and standardization.	AB, SK, QC	NWT, SK		NS	MB, ON, QC, NB, NS, CFIA	CFIA	SK, ON, QC	AB, ON, NS	QC		**20**
5	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	AB, QC, NS, NL	AB, NWT, SK	BC, AB	AB, NS	MB, QC, NS, CFIA	NS, CFIA	QC	BC, NS, CFIA	QC, NL	BC	**24**
6	Introduction, establishment, spread, connectivity and pathways, and climate suitability models.	ON	YT, NWT, AB, SK, MB, ON, NB	YT, ON	YT	MB, ON, NB	NB, NL	ON	BC, AB, ON, NB, CFIA		BC	**23**
7	Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values.	AB, ON, QC, NB, NL	AB, NWT, MB, ON, NB	AB, NB	AB, NB	ON, QC, NB	NB, CFIA	ON	NB, CFIA	QC, NB, NL		**25**
8	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	SK, QC, NB, PEI, NS	YT, SK, PEI	YT	YT, NB	QC, NB, PEI	PEI, NS, CFIA	QC	NB, CFIA	QC, NB	PEI	**23**
9a	Assessment of cost/benefits of control, including for non-timber values.	AB, SK, ON, PEI, NL	BC, AB, NWT, SK, ON	SK, BC	AB	ON	CFIA	MB, ON	BC, ON	NL	BC	**21**
9b	Efficacy of response options: cultural, biological, chemical or regulatory.	SK, QC, NS	BC, AB, SK			NS	NS		BC, NS	QC	BC	**12**
10	Basic pest biology and life histories.	ON	ON			ON		ON	ON			**5**
	Total Count	**42**	**43**	**20**	**17**	**30**	**15**	**15**	**27**	**13**	**7**	

PEST-SPECIFIC RESEARCH NEEDS AND COMMENTS

The provinces and territories described research topic particulars for priority pests or provided general comments about why research is required in a particular topic area.

Research needs, by national priority pest, are summarized in the following tables.

PRIORITY PEST NO. 1

EASTERN SPRUCE BUDWORM (ESBW)

Research Topic Ranking	Research Needs/Comments by Provincial and Territorial Respondents *Interest in …*
1	• Understanding how climate change will affect the distribution and severity of damage from ESBW in Newfoundland and Labrador (ongoing outbreak in Labrador). (NL) • Understanding the influence of climate on population dynamics, impacts and changes in distribution to support efforts for designing monitoring programs, forecasting impacts and developing management options. (ON)
2	• Developing a pest risk assessment or analysis (PRA) for planning the response to the next outbreak. (ON) • Developing a PRA for ESBW infestation in managed stands (thinning, plantations). (QC) • Expanding the analysis of benefits associated with pest management of ESBW to include not only timber but also ecosystem services and long-range increase in fire hazard; and determining whether this alters how areas for protection are prioritized. (NB)
3	• Obtaining detailed information on the population dynamics and biology of ESBW and its associated control factors, to model its spread and impacts and the efficacy of control options, as part of modelling climate change and developing management strategies for this insect. (ON) • Understanding mechanisms involved in the switching between endemic and epidemic phases of the ESBW cycle (parasitoids, predators, diseases). (QC) • Understanding the evolution of parasitoid, predator and disease populations from their level during the endemic phase of a cycle to what we see in declining ESBW populations. (QC) • Enhancing understanding of what factors initiate ESBW outbreaks, to determine whether early intervention strategies will work. *Comment:* This is a priority for accelerated research, given imminent outbreak in New Brunswick. The opportunity will not present itself again for many decades. (NB) • Detecting ESBW populations early on the island, and determining why trap catches are increasing on the west coast (immigrants, other triggers)? (NL)
4	• Being able to correlate ESBW moth trap catch with population predictions (for consideration in early intervention). (SK)
6	• Having data and models to predict changes in ESBW population dynamics, range and impacts under changing climate. (ON)
7	• Understanding the impacts (positive and negative) of ESBW outbreak (e.g., different scenarios, different management practices, different stand types). (QC) • Having better information on the impact of ESBW on young, intensively managed stands during the increasing phase of outbreak. (NB) • Being able to assess non-timber values using existing decision support system (DSS) tools. (NL)
8	• Improving our understanding of and efficacy of existing response tools (not as efficacious as historical products, such as fenitrothion and aminocarb) for foliage protection from ESBW, as well as developing new options, given the small number of registered products. (NB) • Developing improved and new biological formulations (all defoliators). (QC) • Exploring new biocontrol options. (NS)
9a	• As part of risk analysis, conducting cost/benefit assessments in order to plan risk response and communicate pest management decisions. (ON) • Being able to assess non-timber values using existing DSS tools. (NL)
9b	• Understanding the efficacy of silviculture treatments to reduce stand vulnerability. (QC) • Determining the efficacy and impacts of ESBW response options. (NS)
10	• Obtaining data to better understand population dynamics and to plan management programs. (ON)

PRIORITY PEST NO. 2

MOUNTAIN PINE BEETLE (MPB)

Research Topic Ranking	Research Needs/Comments by Provincial and Territorial Respondents *Interest in …*
1	• Better understanding of the population drivers and mechanisms in naïve hosts (jack pine) in a novel environment (boreal) that influence spread dynamics (long and short distance), and in understanding mortality factors. (SK) • Modelling climate suitability. (SK) • Better understanding the influence of climate on population dynamics, impacts and rates of spread in order to model spread, forecast impacts and conduct cost/benefit analysis. (ON)
2	• Improving existing DSS tools used to guide field response and inform policy and procedures. Comment: What are the conditions that might lead to the decision on how many trees in any given cluster would trigger a response (fall and burn). (SK) • Understanding of potential impacts and mitigation options. (NT) • Assessing the risk to jack pine and other pines east of Alberta. (ON)
3	• Better understanding MPB behaviour and population dynamics of naïve pine or novel forests, including the ability of low levels of overwintering MPB (below the snowline) to maintain endemic populations or support increasing populations. (YT) • Understanding MPB behaviour as it moves and establishes itself further north. (NT) • Obtaining detailed information on the population dynamics and biology of MPB and its associated control factors, to model MPB spread and impacts. (ON)
4	• Better understanding of semiochemicals, including tree-baiting systems, for early detection, and of the use of antiaggregants such as verbenone and green leaf volatiles. (SK)
5	• Given reduced staffing and budgets, obtaining better information to help increase efficiencies in detecting forest health problems. (AB)
6	• Better understanding the threat to the rest of Canada. (AB) • Obtaining better information about the spread, connectivity, pathways and potential for establishment and spread in northern novel forests. (YT) • As part of the risk analysis for MPB, obtaining better information about the insect's introduction and spread in order to predict arrival times and impacts. (ON) • Being able to predict potential spread and spread rates for MPB. (NT)
7	• Understanding the impact of outbreaks on non-timber values such as caribou, watersheds and fire risk. (AB) • Obtaining more information about the impact this pest will have within jack pine forests, including looking at the loss of habitat for some endangered species in Manitoba (e.g., Woodland Caribou). (MB) • Understanding how caribou, water and other ecosystem functions would be affected if MPB were to reach outbreak status in the Northwest Territories. (NT)
8	• Developing new tools that might be implemented in tree-level controls (e.g., mechanical devices such as a tree monkey to de-bark tree). (SK)
9a	• Understanding what the cost implications are of various control options. (NT) • As part of risk analysis, conducting cost/benefit assessments in order to plan risk response and communicate pest management decisions. (ON)
9b	• Obtaining good efficacy data on MPB control programs with which to justify and continue using them. (AB) • Knowing the most effective treatment for a set of circumstances (e.g., pest, habitat type) in order to enable programs to maximize their efficacy with limited resources. (BC) • Developing new and improved products and pest control methods, given the ongoing threat of invasive species and increasing pressure to reduce the number of pesticides being used on the land base. (BC)
10	• Obtaining more information as MPB moves eastward into novel habitat and naïve trees. (ON)

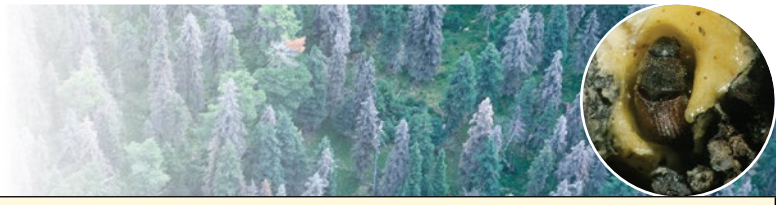
PRIORITY NO. 3

CLIMATE CHANGE (including declines)

Research Topic Ranking	Research Needs/Comments by Provincial and Territorial Respondents *Interest in …*
1	• Understanding climate-related changes to secondary pest behaviour, particularly in northern forests. (YT) • Understanding the effects of climate change on pests in Canada. • *Comment:* Some pests appear to have changed, both in their historical ranges and population levels. More information is required to identify the reasons for these changes and assist with predicting future populations. (MB)
2	• Understanding the implications of climate change for pest management in New Brunswick. *Comment:* Is there a probable scenario of how our list of major forest pests will change in the next 25, 50 and 100 years? What lessons/direction can this provide to current forest management strategies/regimes? (NB)
3	• Better understanding how climate change will alter the spatial distribution of pest outbreaks and how the severity/duration of pest outbreaks will change under varying future climate scenarios. *Comment:* This work is needed to support the forecasting of potential impacts of climate change and designing of appropriate adaptation/mitigation strategies. It will also support robust pest risk analysis of climate change impacts. (NB)
5	• Receiving data from monitoring and detection programs that is placed in the context of population dynamics (calibration) and to damage levels (treatment thresholds). Most agencies have a limited social licence to carry out eradication programs. Consequently, programs should only be implemented when a threshold for insect establishment (exotics) or unacceptable damage level (natives) is exceeded. (BC)
9a	• Monetizing non-timber values such as wildlife habitat and water conservation will allow a more accurate accounting of the impacts of forest health agents on ecosystem services. (BC) *Comment:* As the climate continues to change, non-timber values will likely surpass timber values over large forest areas.

PRIORITY PEST NO. 4

SPRUCE BEETLE (SB)

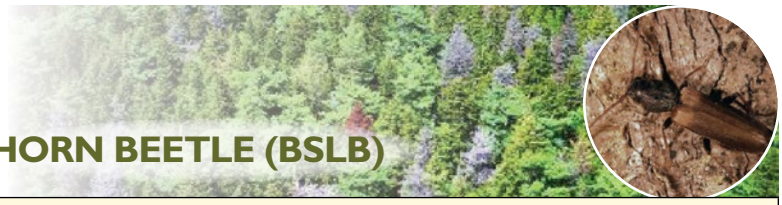


Research Topic Ranking	Research Needs/Comments by Provincial and Territorial Respondents *Interest in …*
2	• Determining the potential impacts on New Brunswick forests from SB given different ESBW outbreak/ protection scenarios. Results of this analysis may have implications of how ESBW is managed. (NB) • *Comment:* Given that we likely will be unable to protect all area against ESBW, risk of a widespread spruce beetle epidemic in future is high (it will likely be a much worse problem than after the last ESBW outbreak due to the probable reduction in amount of area protected). • Estimating thresholds for response. (NS)
3	• Better understanding the differences in behaviour in northern forests compared with the known pest behaviour in other parts of their range. (YT)
5	• Given reduced staffing and budgets, obtaining better information to help increase efficiencies in detecting forest health problems. (AB) • Measuring SB populations and relating this data to populations and damage. (NS)
8	• *Comment:* Given that we likely will be unable to protect all area against ESBW, risk of a widespread spruce beetle epidemic in future is high. Therefore we need to explore alternate techniques to salvage harvesting for managing SB across large areas. (NB)

PRIORITY PEST NO. 5

EMERALD ASH BORER (EAB)

Research Topic Ranking	Research Needs/Comments by Provincial and Territorial Respondents *Interest in …*
1	• Better understanding the influence of climate on population dynamics, impacts and rates of spread in order to model spread, forecast impacts and conduct cost/benefit analysis. (ON)
2	• Addressing the risk to uninfested parts of Ontario and the rest of Canada. (ON) • Better understanding what the overall impact of EAB will be on New Brunswick forests (including municipal). (NB) • *Comment:* Will there be extensive ecological impacts (e.g., on water quality)? Are there actions that we should be doing now to help mitigate future impacts? • Estimating thresholds for response. (NS)
3	• Obtaining detailed information on the population dynamics and biology of EAB and its associated control factors, to model its spread and impacts and the efficacy of control options, as part of modelling climate change and developing management strategies for this insect. (ON)
4	• Developing tools to detect this insect and estimate its population densities. In particular, research is needed to elucidate the ash-specific chemicals used by this insect to find ash trees. (ON) • Developing the ability to detect low populations – a critical step to management for EAB within urban communities. More information is required to develop the best options for communities when monitoring for this invasive pest at low population levels. (MB) • Developing approaches to reduce the delay between EAB arrival and detection in an area. (QC)
5	• Developing better tools and options for detecting infestations early, at low population levels. These tools need to be cost-effective to be considered for implementation. (MB) • Developing approaches to reduce the delay between EAB arrival and detection in an area. (QC)
6	• Looking closer at the main pathways and climate suitability for this pest, in order to develop options to prevent or delay entry. (MB) *Comment:* We know the risk for movement of the pest into Manitoba is high. • As part of the risk analysis for this insect, obtaining better information about the insect's introduction and spread in order to predict arrival times and impacts. (ON)
9a	• As part of risk analysis, conducting cost/benefit assessments in order to plan risk response and communicate pest management decisions. (ON)
10	• Obtaining more information, as the insect moves on to the Canadian Shield, for pest risk analysis purposes. (ON)



PRIORITY PEST NO. 6

BROWN SPRUCE LONGHORN BEETLE (BSLB)

Research Topic Ranking	Research Needs/Comments by Provincial and Territorial Respondents *Interest in …*
3	• Determining what the regulatory factors for BSLB are (e.g., predators, competition). (NS)
5	• Determining what is relationship is between trap catch and damage levels? (NS)
8	• Determining feasible response options for slowing the spread of BSLB. (NS)
9b	• Determining the efficacy and impacts of response options. (NS)

PRIORITY PEST NO. 7

JACK PINE BUDWORM

Research Topic Ranking	Research Needs/Comments by Provincial and Territorial Respondents *Interest in …*
1	• Understanding the influence of climate on population dynamics, impacts and changes in distribution to support efforts for designing monitoring programs, forecasting impacts and developing management options. (ON)
2	• Developing a pest risk assessment or analysis (PRA) for planning response to next outbreak. (ON)
3	• Obtaining detailed information on the population dynamics and biology of this pest and its associated control factors, to model its spread and impacts and the efficacy of control options, as part of modelling climate change and developing management strategies for this insect. (ON)
4	• Using trapping techniques in decision support. (SK) • Resolving inconsistent pheromone trap captures to identify the best trap for this insect, optimum placement in or below the canopy. (ON)
6	• Developing data and models to predict changes in population dynamics, range and impacts under changing climates. (ON)
9a	• Developing a better understanding of the cost/benefit of controlling this pest for non-timber values. (MB) • As part of risk analysis, conducting cost/benefit assessments in order to plan risk response and communicate pest management decisions. (ON)
10	• Acquiring a better understanding of population dynamics and plan management programs. (ON)

PRIORITY PEST NO. 8

ASIAN GYPSY MOTH

Research Topic Ranking	Research Needs/Comments by Provincial and Territorial Respondents *Interest in …*
2	• Developing a pest risk assessment or analysis (PRA) for Ontario and Canada in advance of next find, based on the latest understanding of the pathways and the insect's biology. (ON) • Determining whether this pest poses a greater threat to New Brunswick forests than the European gypsy moth does. (NB)
4	• Better understanding of type, number and distribution to help in detection of early introductions. (AB)
5	• Receiving data from monitoring and detection programs that is placed in the context of population dynamics (calibration) and to damage levels (treatment thresholds). Most agencies have a limited social licence to carry out eradication programs. Consequently, programs should only be implemented when a threshold for insect establishment (exotics) or unacceptable damage level (natives) is exceeded. (BC)
6	• Understanding how various insects become established, and how quickly they can spread through different habitat types, in order to implement a response program and to know when planning forest management activities that may either increase or decrease the ability of the species to survive in a stand or affect the spread of the species throughout the landscape. (BC) *Comment:* Critical to understand our risk of introduction. (AB) • As part of the risk analysis for this insect, obtaining better information about the insect's introduction and spread in order to predict arrival times and impacts. (ON)
9a	• As part of risk analysis, conducting cost/benefit assessments in order to plan risk response and communicate pest management decisions. (ON)
10	• Understanding how the insect will behave in various parts of Canada. (ON)

PRIORITY PEST NO. 9

EASTERN HEMLOCK LOOPER

Research Topic Ranking	Research Needs/Comments by Provincial and Territorial Respondents *Interest in …*
1	• Understanding how climate change will affect the distribution and severity of damage from this insect in Newfoundland and Labrador. (NL)
5	• Improving predictive surveys of populations and damage-integrating parasitism. (QC)
7	• Understanding the impacts (positive and negative) of an outbreak. (QC) • Being able to assess non-timber values using existing DSS tools. (NL)

PRIORITY PEST NO. 10

EUROPEAN GYPSY MOTH (EGM)

Research Topic Ranking	Research Needs/Comments by Provincial and Territorial Respondents *Interest in …*
5	• Receiving data from monitoring and detection programs that is placed in the context of population dynamics (calibration) and to damage levels (treatment thresholds). Most agencies have a limited social licence to carry out eradication programs. Consequently, programs should only be implemented when a threshold for insect establishment (exotics) or unacceptable damage level (natives) is exceeded. (BC)

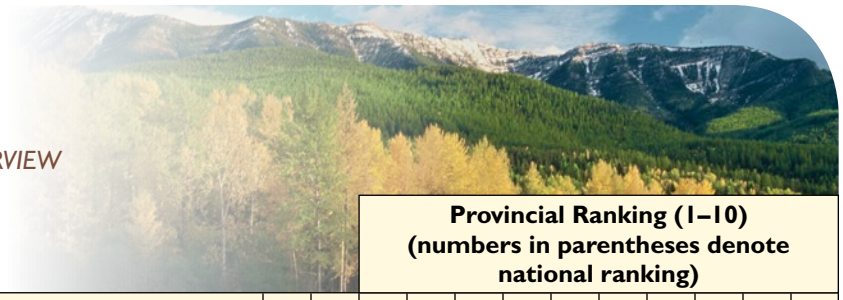
Jurisdictional Research Needs and Priorities

This section highlights the research needs identified by the survey for each jurisdiction and the CFIA. It was included to ensure that the forest pest research community is aware of regional pest disparities and the regional differences in research topics of interest.

National priorities and jurisdictional priorities vary in several ways, with significant differences occurring in priority pests in jurisdictions outside the boreal forest.

Acronyms used in the following tables are defined below:

Acronym	Pest
ESBW	Eastern spruce budworm
MPB	Mountain pine beetle
SB	Spruce beetle
EAB	Emerald ash borer
BSLB	Brown spruce longhorn beetle
JPBW	Jack pine budworm
HL	Eastern hemlock looper
DED	Dutch elm disease
BFS	Balsam fir sawfly
BWA	Balsam woolly adelgid
BBD	Beech bark disease
ALHB	Asian longhorn beetle



BRITISH COLUMBIA

PRIORITY RESEARCH NEEDS – OVERVIEW

Research Topic	Provincial Ranking	National Ranking	Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			Western Spruce Budworm	Douglas-fir Beetle	Asian Gypsy Moth (8)	Gypsy Moth (European) (10)	Armillaria Root Disease	Sirex Wood Wasp	Sudden Oak Death	Mountain Pine Beetle (2)	Climate Change (includes declines) (3)	Hard Pine Stem Rusts
Basic pest biology and life histories.	1	10		X								
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	2	4						X				
Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	3	5			X	X		X	X		X	
Phytosanitary treatments: standards, methodologies and efficacy.	4	20			X				X			
Pest risk assessment or analysis, including hazard and risk rating.	5	2					X	X				X
Introduction, establishment, spread, connectivity and pathways, and climate suitability models.	6	6			X	X		X				
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	7	3	X	X								
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	8	1	X				X				X	X
Assessment of cost/benefits of control, including for non-timber values.	9a	9a		X	X	X	X	X	X	X	X	X
Efficacy of response options: cultural, biological, chemical or regulatory.	9b	9b		X	X	X	X		X	X		X

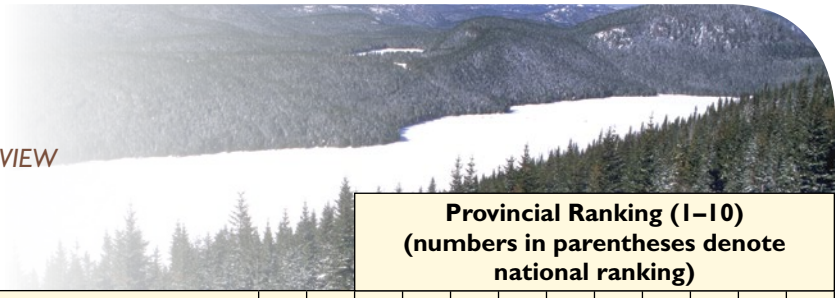
PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
1	Western spruce budworm	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	While we can no longer use past pest behaviour as an indicator of how things will work in the future, the spatial and temporal changes in pest populations and damage will inform our understanding of what influences pests at a large scale. So, while the specifics (intensity, frequency or locations of outbreaks) may change, the underlying processes will still impact the species and can be used to make informed projections of what may happen under different climate scenarios.
2	Douglas-fir beetle	Basic pest biology and life histories. (10)	This is a general competency that needs to be maintained across the country. As new invasive species are detected, we need expertise in basic insect biology and life histories to help develop response plans for the obscure species that become pests in new habitats. Better understanding of what mortality factors affect various species will help determine when treatments are required to crash a population versus allowing the natural enemies to collapse it for us.
	Douglas-fir beetle	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	Understanding the population dynamics of individual pests, including what usually causes populations to crash, will ensure we time our treatment programs in areas where populations are not going to collapse on their own.
3	Asian gypsy moth (8)	Detection or monitoring survey designs, and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	Data is needed from monitoring and detection programs that is placed in the context of population dynamics (calibration) and damage levels (treatment thresholds). Most agencies have a limited social licence to carry out eradication programs. Consequently, programs should only be implemented when a threshold for insect establishment (exotics) or unacceptable damage level (natives) is exceeded.
		Phytosanitary treatments: standards, methodologies and efficacy. (20)	The primary concern is that no agency currently has a mandate for looking at phytosanitary treatments. Historically, CFS has done some research, along with Forintek. Going forward, phytosanitary measures are being imposed without full knowledge of efficacy, and various international agencies are now questioning the validity of those measures, for which we do not have supporting data. This will not only impact our ability to export wood products to other countries, but also affect the risk that products imported into Canada could contain non-native species that were not controlled by the phytosanitary measures in place.
		Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	Understanding how various insects establish in their environments and how quickly they can spread through different habitat types is crucial information for implementing a response program. This information is also valuable for planning forest management activities that may either increase or decrease the ability of the species to survive in a stand or affect the spread of the species throughout the landscape.

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
4	Gypsy moth (European) (10)	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	Data is needed from monitoring and detection programs that is placed in the context of population dynamics (calibration) and damage levels (treatment thresholds). Most agencies have a limited social licence to carry out programs. Consequently, programs should only be implemented when a threshold for insect establishment (exotics) or unacceptable damage level (natives) is exceeded.
5	Armillaria root disease	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	For root disease, inoculum removal (stumping) is an effective control procedure. However, this treatment is not acceptable in some locations and on certain soil types. Other root disease control silvicultural treatments, such as thinning, understory vegetation and planted versus natural regeneration, should be explored to determine what influence these have on the root disease dynamics.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	Stem analysis of trees affected by root disease is needed. Using detailed stem analysis to study the effects on tree growth from root disease can provide more information on impacts to tree growth such as on height and basal area.
6	Sirex wood wasp	Semiochemical monitoring tools, including for trap designs, calibration and standardization. (4)	Effective management of forest pests is best accomplished when populations are still at relatively low levels. Without effective monitoring tools, our ability to detect low or rising populations is limited, and it is important to be able to correlate trap catches with population trends. In the case of non-native invasive species, we rely heavily on pheromone monitoring and effective trap designs to detect species at the time of introduction and not when they are at outbreak levels causing mortality.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	The pest risk analysis (PRA) will identify the risks associated with the introduction and establishment of a particular pest. This analysis is critical in informing response plans and in allocating resources to prevent the entry of high-risk pests. Knowing areas of highest risk or hazard will provide information on where to focus resources for the detection of a pest, or where to focus efforts during a suppression or eradication process.
7	Sudden oak death	Phytosanitary treatments: standards, methodologies and efficacy. (20)	The primary concern is that no agency currently has a mandate for looking at phytosanitary treatments. Historically, CFS has done some research, along with Forintek. Going forward, phytosanitary measures are being imposed without full knowledge of efficacy, and various international agencies are now questioning the validity of those measures, for which we do not have supporting data. This will not only impact our ability to export wood products to other countries, but also affect the risk that products imported into Canada could contain non-native species that were not controlled by the phytosanitary measures in place.

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
8	Mountain pine beetle (2)	Efficacy of response options: cultural, biological, chemical or regulatory. (9b)	Knowing the most effective treatment given a set of circumstances (e.g., pest, habitat type) allows programs to maximize their efficacy with limited resources. Research into new and improved products and pest control methods is needed as new pest introductions continue and there is increasing pressure to reduce the number of pesticides being used on the land base.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	Most provinces are challenged to determine where limited treatment dollars should be spent for forest health treatments. The ability to clearly articulate in monetary terms the gains associated with various forest health treatments will give us the information needed to develop business cases for larger programs and to rationalize our treatment programs in terms that are understood by politicians.
9	Climate change (including declines) (3)	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	Data is needed from monitoring and detection programs that is placed in the context of population dynamics (calibration) and to damage levels (treatment thresholds). Most agencies have a limited social licence to carry out eradication programs. Consequently, programs should only be implemented when a threshold for insect establishment (exotics) or unacceptable damage level (natives) is exceeded.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	As the climate continues to change, managing forest resources for non-timber values such as wildlife habitat and water conservation will likely surpass timber values over large areas. The ability to place a monetary value on these non-timber values will allow a more accurate accounting of the impacts of forest health agents on ecosystem services, not simply timber values.
10	Hard pine stem rusts	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	Stem analysis of trees affected by rust is needed. Using detailed stem analysis to study the effects on tree growth from pine stem rust(s) can provide more information on impacts to tree growth such as on height and basal area.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	Tree provenance has been observed as an influence on tree susceptibility to damage by rusts. Therefore, a tree breeding program should be considered.



ALBERTA

PRIORITY RESEARCH NEEDS – OVERVIEW

Research Topic	Provincial Ranking	National Ranking	Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			Mountain Pine Beetle (2)	Climate Change (includes declines) (3)	Asian Gypsy Moth (8)	Eastern Spruce Budworm (1)	Spruce Beetle (4)	White Pine Blister Rust	Abiotic (wind, hail, etc.)	Armillaria Root Disease	Douglas-fir Beetle	Western Balsam Bark Beetle
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	1	1	X	X		X	X		X			
Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	2	5	X	X		X	X		X	X		
Efficacy of response options: cultural, biological, chemical or regulatory.	3	9b	X									
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	4	4			X	X						
Introduction, establishment, spread, connectivity and pathways, and climate suitability models.	5	6	X		X							
Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values .	6	7	X	X		X	X	X	X	X		
Impact of pest management practices on non-timber forest values, including endangered wildlife.	7	18	X									
Assessment of cost/benefits of control, including for non-timber values.	8	9a	X			X	X			X		
Pest risk assessment or analysis, including hazard and risk rating.	9	2		X	X				X			
Remote sensing technologies for mapping pest or climate change damage/distribution.	10	14	X	X		X	X		X	X		

PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

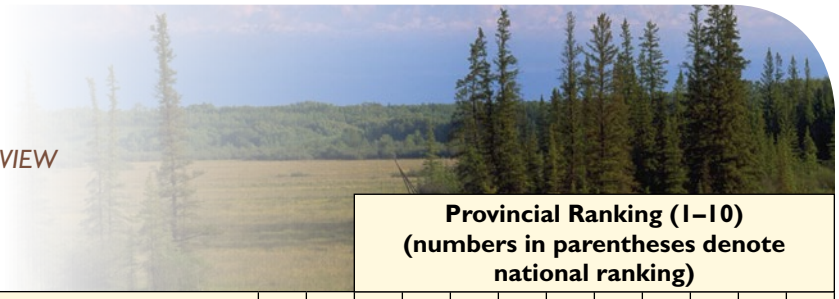
Priority	Priority Pest	Priority Research Topic	Research Need/Comments
1	Mountain pine beetle (2)	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	The changing climate and pest interactions will be the most important areas for our business in the future. We need to get ahead of the curve and anticipate some of the changing pest distributions and the resulting damage.
		Detection or monitoring survey designs, and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	With reduced staffing and budgets, the ability to detect forest health problems will be compromised in the future. Any information to increase our efficiency is of benefit.
		Efficacy of response options: cultural, biological, chemical or regulatory. (9b)	Controlling MPB is expensive, and without any good efficacy data, it is hard to justify and continue with a program.
		Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	It is critical to understand the threat of MPB to the rest of Canada.
		Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values. (7)	Non-timber values will be of higher importance than timber values in the future. We therefore need to understand the impact of MPB to caribou, watersheds, fire risk, etc.
		Impact of pest management practices on non-timber forest values, including endangered wildlife. (18)	Non-timber values will be of higher importance than timber values in the future. We therefore need to understand the impact of MPB to caribou, watersheds, fire risk, etc.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	Controlling MPB is expensive, and without any good efficacy data, it is hard to justify and continue with a program.
		Remote sensing technologies for mapping pest or climate change damage/distribution. (14)	With reduced staffing and budgets, the ability to detect forest health problems will be compromised in the future. Any information to increase our efficiency is of benefit.
2	Climate change (including declines) (3)	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	The changing climate and pest interactions will be the most important area for our business in the future. We need to get ahead of the curve and anticipate some of the changing pest distributions and the resulting damage.
	Climate change (including declines) (3)	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	With reduced staffing and budgets, the ability to detect forest health problems will be compromised in the future. Any information to increase our efficiency is of benefit.

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
3	Asian gypsy moth (8)	Semiochemical monitoring tools, including for trap designs, calibration and standardization. (1)	Type, number and distribution strategies will help us detect early introductions.
		Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	It is critical to understand our risk to introduction.
4	Eastern spruce budworm (1)	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	With reduced staffing and budgets, the ability to detect forest health problems will be compromised in the future. Any information to increase our efficiency is of benefit.
		Semiochemical monitoring tools, including for trap designs, calibration and standardization. (4)	This is a lower priority matter than for Asian gypsy moth.
		Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	The changing climate and pest interactions will be the most important area for our business in the future. We need to get ahead of the curve and anticipate some of the changing pest distributions and the resulting damage.
5	Spruce beetle (4)	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	The changing climate and pest interactions will be the most important area for our business in the future. We need to get ahead of the curve and anticipate some of the changing pest distributions and the resulting damage.
		Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	With reduced staffing and budgets, the ability to detect forest health problems will be compromised in the future. Any information to increase our efficiency is of benefit.

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
7	Abiotic (wind, hail, etc.)	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	The changing climate and pest interactions will be the most important area for our business in the future. We need to get ahead of the curve and anticipate some of the changing pest distributions and the resulting damage.
		Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	With reduced staffing and budgets, the ability to detect forest health problems will be compromised in the future. Any information to increase our efficiency is of benefit.
8	Armillaria root disease	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	With reduced staffing and budgets, the ability to detect forest health problems will be compromised in the future. Any information to increase our efficiency is of benefit.

YUKON

PRIORITY RESEARCH NEEDS – OVERVIEW



Research Topic	Territorial Ranking	National Ranking	Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			Climate Change (includes declines) (3)	Mountain Pine Beetle (2)	Aspen Serpentine Leafminer	Spruce Beetle (4)	Western Balsam Bark Beetle	Northern Spruce Engraver	Pine Engraver Beetle	Tomentosus Root Rot	Spruce Needle Rust	Pine Needle Cast
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	1	1	X	X	X	X		X				
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	2	3		X	X	X						
Introduction, establishment, spread, connectivity and pathways, and climate suitability models.	3	6	X	X	X	X		X				
Expanding knowledge on the taxonomy of all pests of concern.	4	12	X	X	X	X	X	X	X	X	X	X
Efficacy of response options: cultural, biological, chemical or regulatory.	5	9b										
Pest risk assessment or analysis, including hazard and risk rating.	6	2	X	X	X	X	X	X	X	X	X	X
Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	7	8	X	X	X	X	X	X	X	X	X	X
Development of best practices guidelines for pest management.	8	13	X	X	X	X	X	X	X	X	X	X
Remote sensing technologies for mapping pest or climate change damage/distribution.	9	14	X	X	X	X	X	X	X	X	X	X
Aerial surveys and mapping technologies and technologies for ground survey data capture.	10	15	X	X	X	X	X	X	X	X	X	X

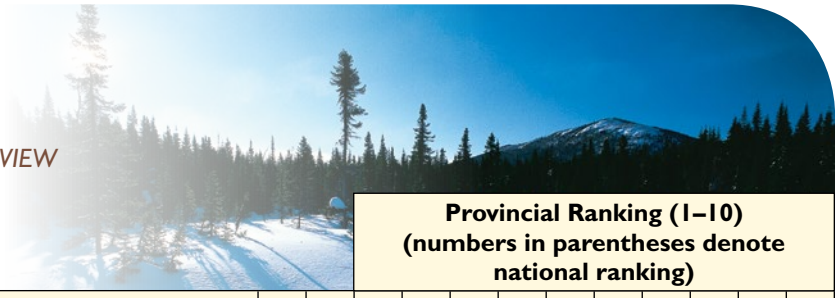
PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
2	Mountain pine beetle (2)	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	There's a need for better understanding of MPB behaviour and population dynamics in novel forests/naïve pine, including about the ability of low levels of surviving MPB overwintering progeny (below the snowline) to maintain endemic populations or support increasing populations.
		Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	We need better information about the spread, connectivity, pathways, climate suitability and potential for MPB establishment and spread in northern novel forests (Yukon).
3	Aspen serpentine leafminer	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	Why did the north (Yukon) rewrite the book on spruce beetle? There is a need to compare differences in behaviour in northern forests with known pest behaviour in other parts of their range.
4	Spruce beetle (4)	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	Why did the north (Yukon) rewrite the book on spruce beetle? There is a need to compare differences in behaviour in northern forests with known pest behaviour in other parts of their range.
6	Northern spruce engraver	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	There is a need to understand changes to secondary pest behaviour ,particularly in northern forest types.
Non-pest specific comments		Expanding knowledge on the taxonomy of all pests of concern. (12)	Small northern jurisdictions like the Yukon do not have capacity for handling the identification and taxonomy of insects, diseases and drought stress. How can we increase our baseline knowledge? We need this competency for new and emerging pests.
		Remote sensing technologies for mapping pest or climate change damage/distribution. (14)	Our interest is in large remote areas that are difficult to access. There is a need to increase the reliability of remote sensing.
		Efficacy of response options: cultural, biological, chemical or regulatory. (9b)	How suitable, feasible and acceptable are alternative management options? What can be done to improve public support of management responses?
		Development of best practices guidelines for pest management. (13)	Need for emphasis on non-timber values such as wildlife.

NORTHWEST TERRITORIES

PRIORITY RESEARCH NEEDS – OVERVIEW

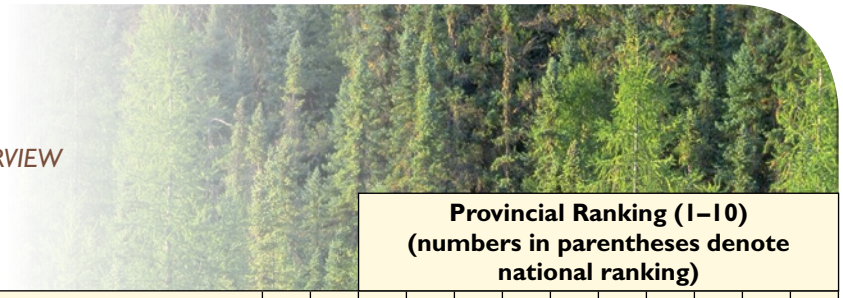


Research Topic	Territorial Ranking	National Ranking	Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			Mountain Pine Beetle (2)	Eastern Spruce Budworm (1)	Spruce Beetle (4)	Climate Change (includes declines) (3)	Larch Sawfly	Aspen Serpentine Leafminer	Forest Tent Caterpillar	Northern Spruce Engraver	Ambermarked Birch Leafminer	Large Aspen Tortrix
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	1	1	X									
Pest risk assessment or analysis, including hazard and risk rating.	2	2	X									
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	6	3	X									
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	4	4	X									
Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	3	5	X									
Introduction, establishment, spread, connectivity and pathways, and climate suitability models.	10	6	X									
Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values.	5	7	X									
Assessment of cost/benefits of control, including for non-timber values.	9	9a	X									
Development of best practices guidelines for pest management.	7	13	X									
Remote sensing technologies for mapping pest or climate change damage/distribution.	8	14	X									

PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
I	Mountain pine beetle (2)	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	Tools are needed to predict future scenarios relating to climate change predictions.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	We need to have a sound understanding of potential impacts and mitigation options.
		Detection or monitoring survey designs, and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	Similar to best practices, we need to understand what the best tools or options are for detection.
		Semiochemical monitoring tools, including for trap designs, calibration and standardization. (4)	We need to know what options are available and any new approaches.
		Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values.(7)	We need to understand what effects there would be on caribou, water and other ecosystem functions if MPB were to reach outbreak status in the Northwest Territories.
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	We need to understand MPB behaviour as the insect moves and establishes further north.
		Development of best practices guidelines for pest management. (13)	Best management practices as they relate to northern populations are needed.
		Remote sensing technologies for mapping pest or climate change damage/distribution. (14)	We need to know how to use remote sensing to detect and map MPB.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	We need to understand what the cost implications are of various control options.
		Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	We need to be able to predict potential spread and spread rates.



SASKATCHEWAN

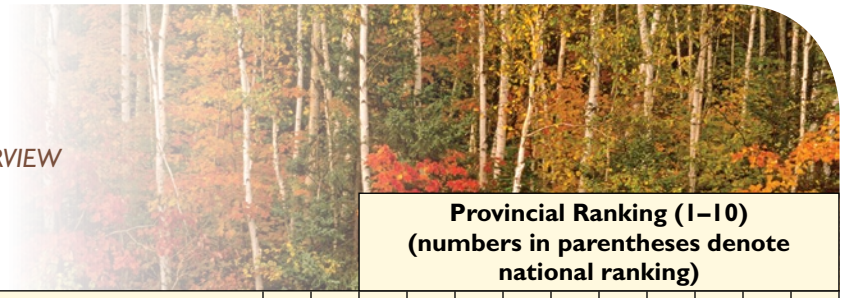
PRIORITY RESEARCH NEEDS – OVERVIEW

Research Topic	Provincial Ranking	National Ranking	Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			Mountain Pine Beetle (2)	Eastern Spruce Budworm (1)	Dutch Elm Disease	Abiotic (wind, hail, etc.)	Climate Change (includes declines) (3)	Jack Pine Budworm (7)	Pinewood Nematode	Large Aspen Tortrix	Armillaria Root Disease	Lodgepole Pine Dwarf Mistletoe
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	1	1	X			X	X	X	X			
Pest risk assessment or analysis, including hazard and risk rating.	2	2	X									
Introduction, establishment, spread, connectivity and pathways, and climate suitability models.	3	6	X						X			
Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	4	5	X									
Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	5	8	X	X	X							
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	6	4	X	X				X		X		
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	7	3	X	X								
Efficacy of response options: cultural, biological, chemical or regulatory.	8	9b	X	X							X	
Expanding knowledge on the taxonomy of all pests of concern.	9	12			X							
Assessment of cost/benefits of control, including for non-timber values.	10	9a	X	X			X					

PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
1	Mountain pine beetle (2)	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	Research is needed to understand the population drivers and mechanisms in naïve hosts (jack pine) in a novel environment (boreal) that influence spread dynamics (long and short distance), including a better understanding of mortality factors.
		Pest risk assessment or analysis, including hazard and risk rating.	Improvements on existing decision support systems used to guide field responses and to inform policy and procedures are needed. What are the conditions that might lead to the decision on how many trees in any given cluster triggers a response (fall and burn)?
		Semiochemical monitoring tools, including for trap designs, calibration and standardization.	Improved understanding of semiochemicals, including those used in tree baiting systems for early detection, and antiaggregants such as verbenone and green leaf volatiles.
		Assessment of cost/benefits of control, including for non-timber values.	Better understanding of efficacy of response action(s).
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides)	New tools that might be implemented in tree-level controls should be developed (e.g., mechanical devices such as tree monkey to de-bark tree).
		Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	Climate suitability modelling is needed.
2	Eastern spruce budworm (1)	Semiochemical monitoring tools, including for trap designs, calibration and standardization.	We need a better understanding and means of correlating ESBW moth trap catch with population predictions (for consideration in early intervention activities).
3	Dutch elm disease	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	Development of management tools to control the spread of this disease is needed. Also needed are effective products to replace banned chlorpyrifos for beetle population control.
6	Jack pine budworm (7)	Semiochemical monitoring tools, including for trap designs, calibration and standardization.	Trapping techniques should be included in decision support systems for JPBW.



MANITOBA

PRIORITY RESEARCH NEEDS – OVERVIEW

Research Topic	Provincial Ranking	National Ranking	Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			Eastern Spruce Budworm (1)	Jack Pine Budworm (7)	Emerald Ash Borer (5)	Mountain Pine Beetle (2)	Climate Change (includes declines) (3)	Abiotic (wind, hail, etc.)	Eastern Larch Beetle	Lodgepole Pine Dwarf Mistletoe	Gypsy Moth (European) (10)	Dutch Elm Disease
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	1	1					X		X			
Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values.	2	7				X		X	X			
Pest risk assessment or analysis, including hazard and risk rating.	3	2							X			
Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	4	8										X
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	5	3								X		
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	6	4			X							
Introduction, establishment, spread, connectivity and pathways, and climate suitability models.	7	6			X	X						
Assessment of cost/benefits of control, including for non-timber values.	8	9a		X								
Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	9	5			X							X
Development of best practices guidelines for pest management.	10	13	X								X	

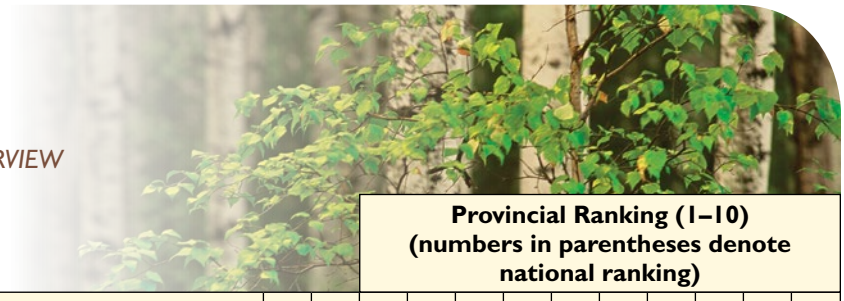
PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
1	Eastern spruce budworm (1)	Development of best practices guidelines for pest management. (13)	Most provinces conduct monitoring surveys for spruce budworm, but they have all found a method that provides reliable information for their jurisdictions. It would be interesting to look at why each jurisdiction has different monitoring practices.
2	Jack pine budworm (7)	Assessment of cost/benefits of control, including for non-timber values. (9a)	We need a better understanding of the cost/benefit of controlling this pest for non-timber values.
3	Emerald ash borer (5)	Semiochemical monitoring tools, including for trap designs, calibration and standardization. (4)	Detecting low populations may be critical to management for EAB within urban communities. More information is required to develop the best options for communities when monitoring for this invasive pest at low population levels.
		Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	We know the risk for movement of the pest into Manitoba is high, but we need to look closer at the main pathways and climate suitability for options to prevent or delay entry.
		Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	We need better options for detecting low population levels, as finding an infestation early might provide better management options. These tools need to be cost-effective to be allowed for implementation.
4	Mountain pine beetle (2)	Introduction, establishment, spread, connectivity and pathways, and climate suitability models.(6)	We need to have a better understanding of the impact that this insect will have on the boreal jack pine forest.
		Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values.(7)	More information is needed about the impact this pest will have on jack pine forests, including looking at the loss of habitat for some endangered species in Manitoba (such as Woodland Caribou).
5	Climate change (including declines) (3)	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	We need to look at the effects of climate change on pests in Canada. Some pests appear to have changed, both in their historical range and population levels. More information is required to identify the reasons for these changes and assist with predicting future populations.
6	Abiotic (wind, hail, etc)	Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values. (7)	As climatic extremes seem to be occurring more frequently, these new cycles may have implications that are not currently taken into consideration.
7	Eastern larch beetle	Pest risk assessment or analysis, including hazard and risk rating. (2)	This pest is at a historically high population level in Manitoba. We therefore need to look at the risk to the province's larch forests.

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
7	Eastern larch beetle	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	This pest has reached historically high populations level in Manitoba. We therefore need more information to determine whether this represents a change in pest behaviour or it is a trend that has occurred before which was not recorded.
		Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values. (7)	More information is needed to look at the regeneration of larch after an eastern larch beetle outbreak.
8	Lodgepole pine dwarf mistletoe	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	More information is required to determine whether there are any parasites and predators that could be used to keep this plant in check.
9	Gypsy moth (European) (1)	Development of best practices guidelines for pest management. (13)	What are the best practices currently being applied in North America to keep this invasive in check?
10	Dutch elm disease	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (14)	We need improved response options for this disease, including the ability to identify brood trees (high-risk trees) and remove them as part of a rapid response program. More research on elm resistance to this disease is also needed.
		Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	We need the ability to detect brood trees to allow for these trees to be targeted for rapid removal.

PRIORITY RESEARCH NEEDS – OVERVIEW



Research Topic	Provincial Ranking	National Ranking	Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			Emerald Ash Borer (5)	Mountain Pine Beetle (2)	Eastern Spruce Budworm (1)	Jack Pine Budworm (7)	Climate Change (includes declines) (3)	Asian Longhorn Beetle	Asian Gypsy Moth (8)	Beech Bark Disease	Sudden Oak Death	Ash Dieback (*Chalara fraxinea*)
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	1	4	X			X		X	X			
Introduction, establishment, spread, connectivity and pathway, and climate suitability models.	2	6	X	X	X	X	X	X	X	X	X	
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	3	3	X	X	X	X	X				X	
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	4	1	X	X	X	X	X			X		X
Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values.	5	7	X	X	X	X				X		X
Assessment of cost/benefits of control, including for non-timber values.	6	9a	X	X	X	X		X	X	X	X	
Basic pest biology and life histories.	7	10	X	X	X	X		X	X	X	X	
Pest risk assessment or analysis, including hazard and risk rating.	8	2	X	X	X	X		X	X	X	X	X
Application technologies (e.g., flake formulation, other).	9	16	X	X	X	X						
Remote sensing technologies for mapping pest or climate change damage/distribution.	10	14	X	X	X	X						X

PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

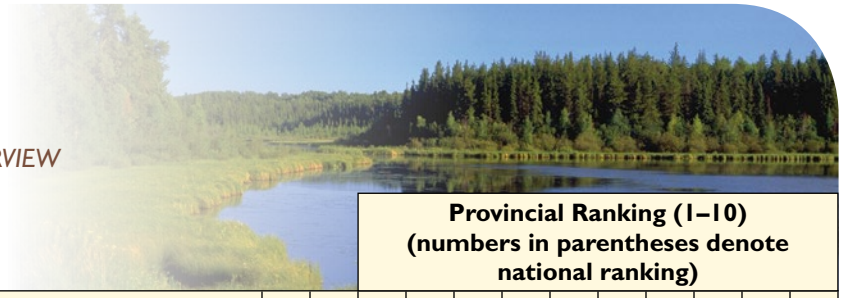
Priority	Priority Pest	Priority Research Topic	Research Need/Comments
1	Emerald ash borer (5)	Semiochemical monitoring tools, including for trap designs, calibration and standardization. (4)	Tools are needed to detect this insect and estimate its population densities. In particular, research is needed to elucidate the ash-specific chemicals used by this insect to find ash trees.
		Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	As part of the risk analysis for this insect, we need to obtain better information about the insect's introduction and spread in order to predict arrival times and impacts.
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	We need detailed information on the population dynamics and biology of this pest and its associated control factors, to model its spread and impacts and the efficacy of control options, as part of modelling climate change and developing management strategies for this insect.
		Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	Information on the influence of climate on population dynamics, impacts and rates of spread, etc., is needed for modelling spread, forecasting impacts and doing cost benefit analysis.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	As part of risk analysis, cost/benefit assessments need to be conducted in order to plan risk response and communicate pest management decisions.
		Basic pest biology and life histories. (10)	We need more information, as the insect moves on to the Canadian Shield, for pest risk analysis purposes.
		Application technologies (e.g., flake formulation, other). (16)	There is need to explore application technologies such as the use of pheromone for mating disruption, use of endophytic fungi, use of basal bark sprays of insecticides, and the inundative release of native parasitoids.
		Remote sensing technologies for mapping pest or climate change damage/distribution. (14)	We need to know how to use remote sensing technologies for doing an ash inventory, detecting early tree response, and mapping impacts.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	We need to address the risk to uninfested parts of Ontario and the rest of Canada.
2	Mountain pine beetle (2)	Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	As part of the risk analysis for this insect, we need to obtain better information about the insect's introduction and spread in order to predict arrival times and impacts.
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	We need detailed information on the population dynamics and biology of this pest and its associated control factors, to model its spread and impacts and the efficacy of control options, as part of modelling climate change and developing management strategies for this insect.

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
2	Mountain pine beetle (2)	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	Information on the influence of climate on population dynamics, impacts and rates of spread, etc. is needed for modelling spread, forecasting impacts and doing cost benefit analysis.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	As part of risk analysis, cost/benefit assessments need to be conducted in order to plan risk response and communicate pest management decisions.
		Basic pest biology and life histories. (10)	We need to learn more as the insect moves eastward into novel habitat and naïve trees.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	We need to assess the risk to jack pine and other pines east of Alberta.
		Application technologies (e.g., flake formulation, other). (16)	More research is needed into the use of pheromone for mating disruption and use of endophytic fungi.
		Remote sensing technologies for mapping pest or climate change damage/distribution. (14)	We need more information on the use of remote sensing technology to detect fading trees (e.g., early changes in chlorophyll production).
3	Eastern spruce budworm (1)	Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	Data and models are needed to predict changes in ESBW population dynamics, range and impacts under changing climates.
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	We need detailed information on the population dynamics and biology of this pest and its associated control factors, to model its spread and impacts and the efficacy of control options, as part of modelling climate change and developing management strategies for this insect.
		Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	Information on the influence of climate on population dynamics, impacts and changes in distribution, etc. is needed for designing monitoring programs, forecasting impacts and developing management options.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	As part of risk analysis, cost/benefit assessments need to be conducted in order to plan risk response and communicate pest management decisions.
		Basic pest biology and life histories. (10)	Data are needed to better understand population dynamics and plan management programs.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	A pest risk analysis (PRA) is needed for planning responses to the next outbreak.
		Application technologies (e.g., flake formulation, other). (16)	Explore technology for mating disruption.
		Remote sensing technologies for mapping pest or climate change damage/distribution. (14)	Use of remote sensing for mapping in remote northern areas.

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
4	Jack pine budworm (7)	Application technologies (e.g., flake formulation, other). (16)	Explore technology for mating disruption.
		Semiochemical monitoring tools, including for trap designs, calibration and standardization. (4)	Inconsistent pheromone trap captures need to be resolved to identify the best trap for this insect, optimum placement in the in or below the canopy.
		Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	Data and models are needed to predict changes in JPBW population dynamics, range, and impacts under changing climates.
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	We need detailed information on the population dynamics and biology of this pest and its associated control factors, to model its spread and impacts and the efficacy of control options, as part of modelling climate change and developing management strategies for this insect.
		Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	Influence of climate on population dynamics, impacts, and changes in distribution, etc. are needed for designing monitoring programs, forecasting impacts and developing management options.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	As part of risk analysis, cost/benefit assessments need to be conducted in order to plan risk response and communicate pest management decisions.
		Basic pest biology and life histories. (10)	Data are needed to better understand population dynamics and plan management programs.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	A pest risk analysis (PRA) is needed for planning responses to the next outbreak.
		Remote sensing technologies for mapping pest or climate change damage/distribution. (14)	We need to know how to use remote sensing technologies for mapping in remote northern areas.
6	Asian longhorn beetle	Pest risk assessment or analysis, including hazard and risk rating. (2)	A pest risk analysis (PRA) for Ontario and Canada is needed in advance of the next find, but based on lessons learned from Toronto infestation.
		Semiochemical monitoring tools, including for trap designs, calibration and standardization. (4)	While progress has been made in the U.S. on a baited trap, it is not yet operational or reliable. An effective trap could be used to survey for this insect in urban and rural areas.
			We need to be able to survey for this insect and, if possible, separate the Asian gypsy moth from European gypsy moth.
		Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	As part of the risk analysis for this insect, we need better information about the insect's introduction and spread in order to predict arrival times and impacts.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	As part of risk analysis, cost/benefit assessments need to be conducted in order to plan risk response and communicate pest management decisions.
		Basic pest biology and life histories. (10)	We need to understand how the insect will behave outside the Toronto area.

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
7	Asian gypsy moth (8)	Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	As part of the risk analysis for this insect, we need better information about its introduction and spread in order to predict arrival times and impacts.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	As part of risk analysis, cost/benefit assessments need to be conducted in order to plan risk response and communicate pest management decisions.
		Basic pest biology and life histories. (10)	We need to understand how the insect will behave in various parts of Canada.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	A pest risk analysis (PRA) for Ontario and Canada is needed in advance of the next find, based on the latest understanding of the pathways and the insect's biology.
8	Beech bark disease	Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	As part of the risk analysis for this disease and the associated scale insect, we need better information about its introduction and spread in order to predict arrival times and impacts.
		Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	We need to quantify the losses due to this disease, and predict the status of the host species after the wave of BBD moves through.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	We need to evaluate non-timber impacts of losing a mast species.
		Basic pest biology and life histories. (10)	We need to understand rate of spread (time from scale infestation to pathogen infection to disease manifestation).
		Pest risk assessment or analysis, including hazard and risk rating. (2)	A pest risk analysis (PRA) is needed to outline a risk response and risk communications strategy for this disease as it spreads across the range of beech.
9	Sudden oak death	Introduction, establishment, spread, connectivity and pathway, and climate suitability models. (6)	As part of the risk analysis for this disease, we need better information about the insect's introduction and spread in order to predict arrival times and impacts.
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	As part of the risk analysis for this disease, we need information on what drives the abundance of the disease and the conditions under which the pathogen manifests as a disease.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	We need to evaluate whether management actions are warranted should the disease arrive via horticulture stock and be found in the forests.
		Basic pest biology and life histories. (10)	We need to understand the risk posed by the pathogen to various parts of Canada based on climate and hosts.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	We need an updated pest risk analysis (PRA) based on data from the U.S. on lack of spread from coastal areas, and role of streams in dispersal.

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
10	Ash dieback	Spatial and temporal analysis of pest to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	We need to quantify the losses due to this disease, and predict the status of the host species after decline.
		Remote sensing technologies for mapping pest or climate change damage/distribution. (14)	We need to know how to use remote sensing to map ash distribution and assess decline.



QUÉBEC

PRIORITY RESEARCH NEEDS – OVERVIEW

Research Topic	Provincial Ranking	National Ranking	Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			Eastern Spruce Budworm (1)	White Pine Blister Rust	Eastern Hemlock Looper (9)	Emerald Ash Borer (5)	Climate Change (includes declines) (3)	Jack Pine Budworm (7)	Armillaria Root Disease	Beech Bark Disease	Pine Sawflies	Butternut Canker
Pest risk assessment or analysis, including hazard and risk rating.	1	2	X		X	X		X		X		
Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values.	2	7	X	X	X	X			X	X		X
Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	3	5	X	X	X	X		X		X		X
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	4	3	X		X	X						
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	5	1	X	X						X		X
Impact of pest management practices on non-timber forest values, including endangered wildlife.	6	18	X									
Remote sensing technologies for mapping pest or climate change damage/distribution.	7	14	X		X		X	X			X	
Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	8	8	X	X	X	X		X	X	X	X	X
Efficacy of response options: cultural, biological, chemical or regulatory.	9	9b	X	X	X							
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	10	4	X		X	X		X				

PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
1	Eastern spruce budworm (1)	Pest risk assessment or analysis, including hazard and risk rating. (2)	A pest risk analysis (PRA) is needed for ESBW infestation in managed stands (pertaining to thinnings, plantations, etc.).
		Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values. (7)	We need to understand the impacts (positive and negative) of SBW outbreaks (different scenarios, different management practices, different stand types).
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	We need to understand the evolution of parasitoid, predator and disease populations from their level during the endemic phase of a cycle to the level we see in declining ESBW populations.
		Impact of pest management practices on non-timber forest values, including endangered wildlife. (18)	A cost/benefit analysis is needed of pest management practices on non-market values during an ESBW outbreak.
		Remote sensing technologies for mapping pest or climate change damage/distribution. (14)	Detection of major pests and damage evaluation (e.g., of cumulative defoliation, mortality) needs to be improved.
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	We need improved and new biological formulations (all defoliators).
		Efficacy of response options: cultural, biological, chemical or regulatory. (9b)	We need to better understand efficacy of silviculture treatments to reduce stand vulnerability.
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	We need to better understand the mechanisms involved in switching between endemic and epidemic phases in the ESBW cycle (parasitoids, predators, diseases).
2	White pine blister rust	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	There is a need for a response tool in forest nurseries, and for development of biocontrol tools (e.g., antagonistic fungus) to reduce populations.
		Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values. (7)	The impact (losses and mortality) caused by the fungus needs to be quantified in plantations over time.
		Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	Development is needed of a more efficient (faster) and less costly alternative to current DNA identification techniques.

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
3	Eastern hemlock looper (9)	Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values. (7)	We need a better understanding of the impacts (positive and negative) of an outbreak.
		Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	We need improved predictive surveys of populations and damage, integrating parasitism.
4	Emerald ash borer (5)	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	Development of approaches to reduce the delay between EAB arrival and detection in an area.
		Semiochemical monitoring tools, including for trap designs, calibration and standardization. (4)	Development of approaches to reduce the delay between EAB arrival and detection in an area.
8	Beech bark disease	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	Development of biocontrol tools to reduce insect vector populations.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	A pest risk analysis (PRA) is needed to enable us to better quantify the impacts of the disease and develop potential mitigation methods.
10	Butternut canker	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	We need to find and develop resistant trees.

NEW BRUNSWICK

PRIORITY RESEARCH NEEDS – OVERVIEW

			Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			1	2	All similar (3-6)				7	8	9	10
Research Topic	**Provincial Ranking**	**National Ranking**	**Eastern Spruce Budworm (1)**	**Spruce Beetle (4)**	**Emerald Ash Borer (5)**	**Asian Longhorn Beetle**	**Asian Gypsy Moth (8)**	**Brown Spruce Longhorn Beetle (6)**	**Climate Change (includes declines) (3)**	**Mountain Pine Beetle (2)**	**Sirococcus Shoot Blight**	**Eastern Hemlock Looper (9)**
Pest risk assessment or analysis, including hazard and risk rating.	1	2	X	X	X	X	X		X			
Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	2	8	X	X	X	X	X					X
Application technologies (e.g., flake formulation, other).	3	16	X	X								X
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	4	3	X		X	X	X		X			
Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values.	5	7	X	X	X	X	X	X	X	X	X	X
Interactions between disturbance factors, including FIAS.	6	17							X			
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	7	1								X		
Introduction, establishment, spread, connectivity and pathways, and climate suitability models.	8	6			X	X	X	X		X		
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	9	4			X	X						
Remote sensing technologies for mapping pest or climate change damage/distribution.	10	14	X	X					X			X

PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

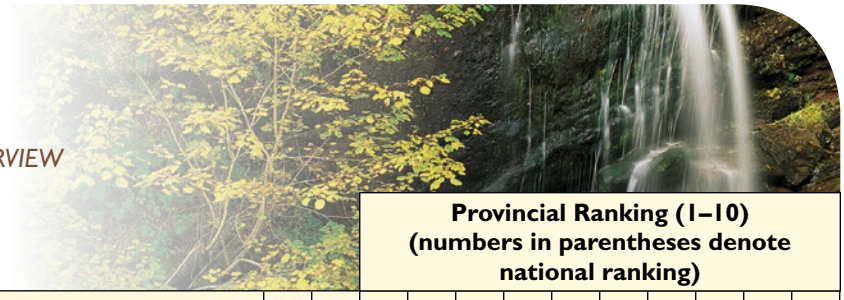
Priority	Priority Pest	Priority Research Topic	Research Need/Comments
1	Eastern spruce budworm (1)	Pest risk assessment or analysis, including hazard and risk rating. (2)	The analysis of benefits associated with pest management of ESBW should be expanded to include not only timber but also ecosystem services and long-range reduction in fire hazard. Does this alter how we would prioritize areas for protection?
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	There is evidence that existing tools for foliage protection are not as efficacious as historical products (e.g., fenitrothion, aminocarb, etc). Therefore, we need to maximize the efficacy of existing response tools for ESBW, as well as develop new options given the small number of registered products.
		Application technologies (e.g., flake formulation, other) (16)	This topic ties into the response tool topic. Tools are only effective if they can be operationally delivered successfully to the target.
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	Given the interest in pursuing early intervention strategies, we need to enhance our understanding of what factors initiate SBW outbreaks to determine whether early intervention will even work. This is a priority for accelerated research given the imminent outbreak in New Brunswick. The opportunity will not present itself again for many decades. We would rank this as the number one science and technology priority at present.
		Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values. (7)	We need better information on the impact of ESBW on young, intensively managed stands during the increasing phase of outbreak.
		Remote sensing technologies for mapping pest or climate change damage/distribution. (14)	There is a need to develop ways to process imagery so that the extent of ESBW infestation/mortality can be identified in a timely and cost-effective manner and used as input into pest mitigation strategies. The goal should be to have satellite imagery replace the need for traditional aerial mapping.
2	Spruce beetle (4)	Pest risk assessment or analysis, including hazard and risk rating. (2)	Given that we will likely be unable to protect all areas against ESBW, the risk of a future widespread spruce beetle epidemic is high. What are the potential impacts on New Brunswick forests from spruce beetle given different ESBW outbreak/ protection scenarios? Results of this analysis could have implications for how ESBW is managed.
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	Given that we will likely be unable to protect all areas against ESBW, the risk of a future widespread spruce beetle epidemic is high. We therefore need to explore alternative techniques to salvage harvesting for managing SB across large areas.
3	Emerald ash borer (5)	Pest risk assessment or analysis, including hazard and risk rating. (2)	We need to better understand what the overall impact of EAB will be on New Brunswick forests (including municipal). Will there be extensive ecological impacts (e.g., on water quality)? Are there actions that we should be taking now to help mitigate future impacts?

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
5	Asian longhorn beetle	Pest risk assessment or analysis, including hazard and risk rating. (2)	What are the potential consequences of ALHB arriving in New Brunswick? What impact could it have on the sugar maple industry in Eastern Canada? Are there actions that we should be taking now to help mitigate future impacts?
6	Asian gypsy moth	Pest risk assessment or analysis, including hazard and risk rating. (2)	Will this pest pose a greater threat to New Brunswick forests than the European gypsy moth?
7	Climate change (including declines) (3)	Pest risk assessment or analysis, including hazard and risk rating. (2)	What are the implications of climate change for pest management in New Brunswick? Is there a probable scenario of how our list of major forest pests will change in the next 25, 50 and 100 years? What lessons or direction can this provide to current forest management strategies/regimes?
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	We need to gain a better understanding of how climate change will alter the spatial distribution of pest outbreaks and how the severity/duration of pest outbreaks change under varying future climate scenarios. This information is needed to enable us to forecast potential impacts of climate change and design appropriate adaptation/mitigation strategies. This work is also needed to support robust pest risk analysis of climate change impacts.
		Remote sensing technologies for mapping pest or climate change damage/distribution. (14)	We need to improve our ability to detect deterioration in indicators of forest health (branch dieback, moisture stress, decrease in vigour, etc.) as a way to measure impacts of climate change.

Additional comments about emerald ash borer and research topic = Introduction, establishment, spread, connectivity and pathways, and climate suitability models:

> "We do not really see this as an S and T priority given that not much research is needed to identify the pathways for movement and establishment as they appear to be already well known. However, we want to indicate our belief that there is a need to collect more data on the pathways to help improve risk analysis and make effective management strategies. Much of this data could be collected through existing field operations (e.g., conducting firewood surveys by Park attendants) or data mining existing datasets (e.g., shipping databases). This same reasoning applies to the other invasives as well (ALHB, AGM, BSLB)."

PRIORITY RESEARCH NEEDS – OVERVIEW



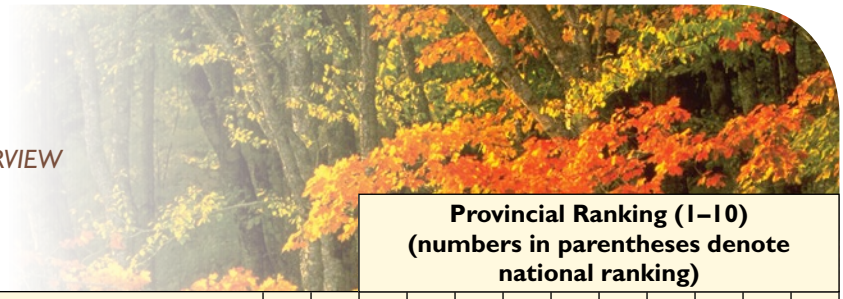
Research Topic	Provincial Ranking	National Ranking	Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			Balsam Fir Sawfly	Brown Spruce Longhorn Beetle (6)	Beech Flea Weevil	Eastern Spruce Budworm (1)	Spruce Beetle (4)	Whitemarked Tussock Moth	Balsam Woolly Adelgid	Eastern Blackheaded Budworm	Emerald Ash Borer (5)	Asian Gypsy Moth (8)
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	1	4	X		X		X	X		X	X	X
Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	2	5	X	X	X	X	X	X	X	X	X	X
Aerial surveys and mapping technologies and technologies for ground survey data capture.	3	15	X	X	X	X	X	X	X	X	X	X
Pest risk assessment or analysis, including hazard and risk rating.	4	2	X		X		X	X	X	X	X	X
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	5	3	X	X	X	X	X	X	X	X		
Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	6	8	X	X		X		X	X	X		
Efficacy of response options: cultural, biological, chemical or regulatory.	7	9b	X	X	X	X		X	X	X	X	X
Develop or enhance existing decision support system (e.g., Windows-based; multi-insect; customizable; training modules/ tutorials/workshops).	8	19	X			X		X		X		
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	9	1	X			X	X	X	X	X		
Development of best practices guidelines for pest management.	10	13	X	X	X	X	X	X	X	X	X	X

PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
1	Balsam fir sawfly	Semiochemical monitoring tools, including for trap designs, calibration and standardization. (4)	Development of a pheromone for detecting BFS is needed, and trap catches need to be related to subsequent life stages and damage.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	Development of a hazard rating system is needed.
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	What are the processes driving population dynamics?
		Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	
2	Brown spruce longhorn beetle (6)	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	What is the relationship between trap catch and damage levels?
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	What are the regulatory factors for BSLB (e.g., predators, competition, etc.)?
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	Feasible response options for slowing the spread of BSLB are needed.
		Efficacy of response options: cultural, biological, chemical or regulatory. (9b)	The efficacy and impacts of response options need to be better understood.
3	Beech flea weevil	Semiochemical monitoring tools, including for trap designs, calibration and standardization. (4)	Development of a pheromone for detecting this insect is needed (new insect introduced to Nova Scotia).
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	This is an introduced insect, so understanding its population dynamics in Nova Scotia compared to those in its native habitat is critical to the proper management of this pest.

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
4	Eastern spruce budworm (1)	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	More research is needed into new biocontrol options.
		Efficacy of response options: cultural, biological, chemical or regulatory. (9b)	The efficacy and impacts of response options need to be better understood.
		Develop or enhance existing decision support system (e.g., Windows-based; multi-insect; customizable; training modules/ tutorials/workshops). (19)	
		Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses. (1)	
5	Spruce beetle (4)	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	We need a means of measuring the SB population and relating that to populations and damage (i.e., thresholds for response).
		Pest risk assessment or analysis, including hazard and risk rating. (2)	Development of a hazard rating system is needed.
7	Balsam woolly adelgid	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys. (5)	We need a predictive survey that Christmas tree growers could use.
		Pest risk assessment or analysis, including hazard and risk rating. (2)	The effect of stand management and site characteristics on damage and population densities of this insect need to be better understood, and a hazard rating system should be developed.
8	Eastern blackheaded budworm	Semiochemical monitoring tools, including for trap designs, calibration and standardization. (4)	Development of a pheromone for detecting BHBW is needed, and the ability to relate trap catches to subsequent life stages and damage of the insect.
9	Emerald ash borer (5)	Pest risk assessment or analysis, including hazard and risk rating. (2)	Development of a hazard rating system is needed.



PRINCE EDWARD ISLAND

PRIORITY RESEARCH NEEDS – OVERVIEW

Research Topic	Provincial Ranking	National Ranking	Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			Gypsy Moth (European) (10)	Japanese Beetle	Eastern Spruce Budworm (1)	Brown Spruce Longhorn Beetle (6)	Emerald Ash Borer (5)	Beech Bark Disease	Balsam Woolly Adelgid	Mountain Pine Beetle (2)	Asian Longhorn Beetle	Sudden Oak Death
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	1	3	X	X	X						X	
Expanding knowledge on the taxonomy of all pests of concern.	2	12										
Pest risk assessment or analysis, including hazard and risk rating.	3	2	X	X		X					X	X
Development of best practices guidelines for pest management.	4	13		X		X			X			
Basic pest biology and life histories.	5	11										
Develop or enhance existing decision support system (e.g., Windows-based; multi-insect; customizable; training modules/ tutorials/workshops).	6	19										
Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	7	8	X	X	X	X	X	X	X	X	X	X
Assessment of cost/benefits of control, including for non-timber values.	8	9			X							
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	9	4										
Aerial surveys and mapping technologies and technologies for ground survey data capture.	10	15										

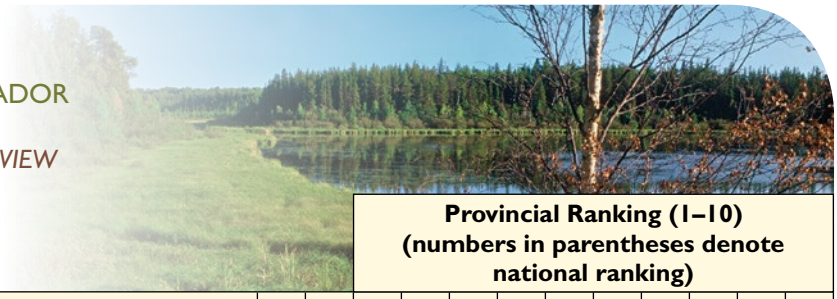
PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
1	Gypsy moth (European) (10)	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	
		Pest risk assessment or analysis, including hazard and risk rating. (2)	
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	
2	Japanese beetle	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	
		Pest risk assessment or analysis, including hazard and risk rating. (2)	
		Development of best practices guidelines for pest management. (13)	
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	
3	Eastern spruce budworm (1)	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	
		Assessment of cost/benefits of control, including for non-timber values.	

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
4	Brown spruce longhorn beetle (6)	Pest risk assessment or analysis, including hazard and risk rating. (2)	
		Development of best practices guidelines for pest management. (13)	
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	
5	Emerald ash borer (5)	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	
6	Beech bark disease	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	
7	Balsam woolly adelgid	Development of best practices guidelines for pest management. (13)	
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	
8	Mountain pine beetle (2)	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
9	Asian longhorn beetle	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	
		Pest risk assessment or analysis, including hazard and risk rating. (2)	
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	
10	Sudden oak death	Pest risk assessment or analysis, including hazard and risk rating. (2)	
		Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides). (8)	



NEWFOUNDLAND AND LABRADOR

PRIORITY RESEARCH NEEDS – OVERVIEW

Research Topic	Provincial Ranking	National Ranking	Provincial Ranking (1–10) (numbers in parentheses denote national ranking)									
			Eastern Hemlock Looper (9)	Eastern Spruce Budworm (1)	Balsam Fir Sawfly	Balsam Woolly Adelgid	Spruce Beetle (4)	Brown Spruce Longhorn Beetle (6)	Eastern Blackheaded Budworm	European Scleroderris Canker	Whitemarked Tussock Moth	Yellow-headed spruce Sawfly
Basic pest biology and life histories.	1	11										
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	2	3		X								
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	3	1	X	X								
Introduction, establishment, spread, connectivity and pathways, and climate suitability models.	4	6						X		X		
Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values.	5	7	X	X	X							
Assessment of cost/benefits of control, including for non-timber values.	6	9a	X	X	X							
Interactions between disturbance factors, including forest invasive alien species.	7	17				X						
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	8	4			X							
Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	9	5	X	X	X							
Aerial surveys and mapping technologies and technologies for ground survey data capture.	10	15	X	X	X		X					

PEST-SPECIFIC RESEARCH NEEDS OR COMMENTS

(numbers in parentheses denote national ranking)

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
1	Eastern hemlock looper (9)	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	How will climate change affect the distribution and severity of damage from HL in Newfoundland and Labrador?
		Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values.	There is particular interest in being able to assess non-timber values using existing decision support system (DSS) tools.
2	Eastern spruce budworm (1)	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	How will climate change affect the distribution and severity of damage from ESBW in Newfoundland and Labrador (ongoing outbreak in Labrador).
		Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases. (3)	Interested in early detection of ESBW populations on island (Newfoundland and Labrador). Trap catches are increasing on the west coast (from immigrants or other triggers)?
		Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber.	Particularly interested in being able to assess non-timber values using existing DSS tools.
		Assessment of cost/benefits of control, including for non-timber values. (9a)	Particularly interested in being able to assess non-timber values using existing DSS tools.
3	Balsam fir sawfly	Semiochemical monitoring tools, including for trap designs, calibration and standardization.	A pheromone trapping system for this pest should be developed to allow for early detection of rising BFS populations.
4	Balsam woolly adelgid	Interactions between disturbance factors, including FIAS.	Should impacts used in existing DSS tools for SBW and HL be adjusted to include interaction with damage by balsam woolly adelgid?
8	European sclerroderis canker	Introduction, establishment, spread, connectivity and pathways, and climate suitability models. (6)	What factors are responsible for spread and establishment of this disease in Newfoundland and Labrador? Do climatic conditions play more of a role here?

Priority	Priority Pest	Priority Research Topic	Research Need/Comments
Non pest-specific comments		Detection or monitoring survey designs, and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	These are being done independently by many jurisdictions for major pests. Would there be advantages to standardized approaches?
		Aerial surveys and mapping technologies and technologies for ground survey data capture.	These are being done independently by many jurisdictions for various surveys. Would there be advantages to standardized approaches?
			Unfortunately, different jurisdictions have different capacities to incorporate new technologies for digital capture of information.

CANADIAN FOOD INSPECTION AGENCY

PRIORITY RESEARCH NEEDS – OVERVIEW

Research Topic	National Ranking	CFIA Ranking (1–5) (numbers in parentheses denote national ranking)				
		Asian Gypsy Moth (8)	Emerald Ash Borer (5)	Brown Spruce Longhorn Beetle (6)	Asian Longhorn Beetle	Sudden Aak Death
Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	1	X		X		
Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	3	X				X
Semiochemical monitoring tools, including for trap designs, calibration and standardization.	4		X	X	X	
Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	5	X	X	X	X	
Introduction, establishment, spread, connectivity and pathways, and climate suitability models.	6	X				
Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber values .	7	X		X		
Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	8	X		X	X	
Assessment of cost/benefits of control, including for non-timber values.	9a			X		X
Development of best practices guidelines for pest management.	12		X	X		X
Aerial surveys and mapping technologies and technologies for ground survey data capture.	14		X			
Interactions between disturbance factors, including forest invasive alien species.	16	X				
Phytosanitary treatments: standards, methodologies and efficacy.	19	X				

Discussion

This report provides a snapshot of the forest health research needs of provincial, territorial and federal agencies responsible for forest pest management in Canada.

From the 21 research topics ranked as a priority, four distinguish themselves from the rest, with 11 out of 12 provinces and territories selecting them as a top 10 research topic. These topics focus on climate change influences on pest behaviour (spatial and temporal analysis), pest population trends and pest impacts, pest risk analysis, pest population dynamics and processes, and semiochemical monitoring tools. The broad range of research topics identified is indicative not only of the diversity of Canadian forests, but also of the need for maintaining core capacities and competencies at facilities providing forest pest research across Canada.

Seven out of the top 11 research topics pertain to risk assessment, and only 4 pertain to risk response. This may reflect increasing uncertainties associated with changes, or anticipation of potential changes in pest behaviour and distribution due to climate change and the increased likelihood of the entry of invasive pests.

From an initial list of 112 pests, 48 were ranked as being a top 10 priority by one or more jurisdictions. Once again this large number of pests represents the vast diversity of Canadian forests and pests, some of which are regionally significant and not represented at a national level. These include several pathogens and less widespread defoliators and forest invasive alien species. Only 18% of the priority pests were pathogens, most of which were ranked as lower priority. However, as the potential for these pest disparities was recognized at the onset, the survey was designed to ensure that both national and jurisdictional concerns were captured and differentiated - and hence the distinction between national and jurisdictional priorities in this report.

The high-priority pests at the national level are:

- Eastern spruce budworm, the most prevalent defoliator of Canadian forests;
- Mountain pine beetle, a native turned "invasive";
- Spruce beetle, a Canada-wide killing bark beetle; and
- Emerald ash borer, a forest invasive alien species.

As well as pests, the topic of climate change and abiotic disturbances ranked relatively high in the priorities (third). This demonstrates their importance to the forest pest management community.

Of note is that the usual pests of major national concern – such as jack pine budworm, root diseases and dwarf mistletoes – have been displaced by this eclectic mix, so much so that there are no native pathogens on the top 10 list. This may be in part due to the chronic nature of many pathogens. While their impact on forested ecosystems has not decreased, nor has our knowledge of those pests substantially increased, their relative importance has been overshadowed by the "pests of the day." Given that forest pathogens and diseases are recognized as being major contributing factors to forest health, research would result in a better understanding of the factors affecting the development of diseases in forest ecosystems.

- **Eastern spruce budworm research needs** include traditional topics such as spray and treatment efficacies, population processes, improvements on population predictions using semiochemical tools, stand treatments to reduce vulnerability, and stand impacts. However, there is a growing need for information about changes in pest behaviour and distribution due to climate change, early intervention tools, impacts on non-timber values, and new biocontrol options.
- **Research needs for mountain pine beetle** are, for the most part, dominated by the desire to have a better understanding of anticipated behaviour, response tools, and impacts (including non-timber) in novel forests. More research is required into: pathways, spread and establishment potential, and climate suitability; the applicability of traditional tools to novel habitats; potential hosts; efficacy of existing response tools; and development of new response tools.
- **Climate change research needs** are predictably those concerning changes in pest behaviour and distribution (including for pests currently considered secondary pests): how these changes will affect

management strategies, when management strategies should be modified, and what the potential impacts are on timber and non-timber values. While some people might argue that climate change is a catch-all category for a number of forest health factors (both biotic and abiotic), the inclusion of this category – and final ranking as third – highlights the importance of this issue to forest pest managers.

- **Spruce beetle research needs** apply mostly to eastern Canada and include the desire to have a better understanding of the interaction between spruce beetle and the imminent eastern spruce budworm outbreak. Research is needed into potential impacts, potential changes to management strategies, and alternative techniques to salvage harvesting. Other research needs include developing better tools to predict population levels and damage, improving our understanding of thresholds for response, and examining spruce beetle behavioural differences in northern forests (Yukon) and other parts of its range.
- **Research needs for emerald ash borer** include gaining a better understanding of the influence of climate change on the insect's spread and behaviour, population dynamics and pathways, developing improved monitoring tools to reduce delay between arrival and detection, assessing the impacts on timber and non-timber values, devising preventative strategies, developing semiochemical tools, and conducting cost/benefit analyses.

Research needs for the priority pests that ranked lower on the list (e.g., eastern hemlock looper, European gypsy moth, brown spruce longhorn beetle, jack pine budworm, Asian gypsy moth) vary between species. For invasive pests, the emphasis is on learning more about introduction, spread and establishment, early detection tools, regulatory factors, strategies to slow the spread, and potential impacts. For native pests, the research focus is on better understanding of: changes in pest behaviour; distribution and potential impacts due to climate change; population dynamics; trapping techniques; efficacy of response options; and timber and non-timber impacts, and how to integrate those into decision support systems.

Conclusions and Recommendations

This survey was directed at identifying priority research needs of provincial, territorial and federal agencies responsible for forest pest management in Canada. It will likely be updated every 3 to 5 years.

- Lessons learned from the previous survey provided guidance on the design of this survey, as well as serving as a great resource and starting point for identification of forest research topics. Rather than relying on supporting criteria for evaluation of survey responses (as had been proposed for the 2008/2009 survey), the Delphi method benefited from the knowledge and expert opinions of jurisdictional specialists. In this way, the Delphi method proved to be a worthy tool for this exercise, and is recommended for future surveys of a similar nature.
- Climate change influence on pest behaviour and distribution was identified as a common research theme for most pests. A key characteristic of research needs for **invasive species** is the desire for a better understanding of the likelihood of introduction and the consequences of introduction, and for better detection and monitoring tools; while key characteristic of research needs for **native species** is the desire for publicly acceptable biocontrol tools, improved detection tools, quantification of impacts on non-timber resources, and improved management strategies.
- The large variety of research topics identified and selected by jurisdictions requires a diverse set of expertise. Addressing the research needs and priorities presented in this report involves the maintenance of core capacities and competencies by research agencies in those areas.
- The responses highlight and prioritize current forest pest management issues, including those for forest invasive alien species. While the ranking system used sought equitable representation, both from a jurisdictional perspective and forest disturbance perspective, future surveys may want to consider stratifying and collecting responses by pest type – forest insects, forest diseases, or forest invasive

alien species – or by short-term and long-term needs. Without some form of stratification, future surveys to identify science and technology research priorities may well have a similar mix of eclectic pests because of climate change, increased international trade and traffic, and fewer resources to monitor pests. In essence, the ability to practise proactive forest pest management, as envisioned by the National Forest Pest Strategy, may be compromised or threatened if research and management efforts remain focused strictly on responding reactively to new introductions or to uncertainties around native pests.

- Mechanisms to promote the research needs and priorities presented in this report, and to ensure their integration into research programs, are still being explored. In the meantime, this document will help guide research and funding proposals to public and private organizations, research institutions or funding agencies across Canada.

Appendix 1.

National and Jurisdictional Science and Technology Forest Pest Research Needs and Priorities – Priority Research Topics and Pests Survey Methodology and Results, March 2013.

SURVEY PARTICIPANTS

Participants for the survey – 12 in all – were provincial and territorial forest health specialists, and a CFIA manager. Given that the majority of jurisdictions do not have Provincial Pathologists per se, one response per jurisdiction was solicited to capture both entomology and pathology concerns (i.e., collective priorities at a jurisdictional level). This ensured that each response had a similar influence on the survey.

Participants were asked to consult with other forest health specialists within their organization to ensure the responses represented the organization as a whole. The CFIA did not contribute to the survey process, but instead submitted its research needs at the end of the survey, once the priority research topics had been defined by the provinces and territories. The CFS was not included in the survey as it has its own internal research priority-setting mechanism, and is viewed as an agency that could *provide* forest pest research rather than *requiring* forest pest research support.

PRIORITY RESEARCH TOPICS SURVEY METHODOLOGY

The initial pool of priority research topics (28 in total) was derived from analysis of the 2008/2009 survey results, which were reviewed and modified by the project team. Each research topic was categorized according to the three components of pest risk analysis: risk assessment (12), risk response (14), and risk communication (2).

A modified *ranking-type Delphi survey* (based on a widely adapted process outlined by Schmidt [1997][1] and Okoli and Pawlowski [2004][2]) was used to determine research topic priorities. Following numerous Delphi survey rounds, the final top 10 national rankings were based on a combination of weighting of the rankings and number of provinces and territories that voted for a particular topic.

OVERVIEW OF THE DELPHI METHOD

The Delphi method was chosen as the preferred survey tool for identifying priority research topics. Skulmoski, Harman and Krahn (2007)[3] provided the following summary of the Delphi method.

> "The Delphi method is an iterative process to collect and distill the anonymous judgments of experts using a series of data collection and analysis techniques interspersed with feedback. The questionnaires are designed to focus on problems, opportunities, solutions, or forecasts. Each subsequent questionnaire is developed based on the results of the previous questionnaire. The process stops when the research question is answered: for example, when consensus is reached, theoretical saturation is achieved, or when sufficient information has been exchanged.
>
> It is a method for structuring a group communication process to facilitate group problem solving and to structure models. The method can be applied to problems that do not lend themselves to precise analytical techniques but rather could benefit from the subjective judgments of individuals on a collective basis and to focus their collective human intelligence on the problem at hand. Key features include the following:
>
> 1. Anonymity of Delphi participants: allows the participants to freely express their opinions without undue social pressures to conform from others in the group. Decisions are evaluated on their merit, rather than who has proposed the idea.

[1] Schmidt, R.C. 1997. Managing Delphi surveys using nonparametric statistical techniques. *Decision Sciences* 28(3): 763–774.

[2] Okoli, C. and S. Pawlowski. 2004. The Delphi method as a research tool: an example, design considerations and applications. *Information and Management* 42(1): 15–29.

[3] Skulmoski, G.J., F.T. Harman and J. Krahn. 2007. The Delphi method for graduate research. *Journal of Information Technology Education*, Volume 6.

2. Iteration: allows the participants to refine their views in light of the progress of the group's work from round to round.
3. Controlled feedback: informs the participants of the other participant's perspectives, and provides the opportunity for Delphi participants to clarify or change their views.
4. Statistical aggregation of group response: allows for a quantitative analysis and interpretation of data."

Delphi surveys are generally composed of several steps: list building, list paring, and list ranking (iterative rounds) (Figure A1.1). The facilitator is responsible for summarizing and distributing results for subsequent survey rounds, and the identity of participants' responses is known only to the facilitator.

RANKING-TYPE DELPHI SURVEY

In addition to the typical iterative rounds of a Delphi survey, the ranking-type survey employs some simple nonparametric statistical techniques to ensure that consensus has been reached or, at the very least, some measure of consensus is possible.

"Modified" refers to the fact that existing lists are used as a starting point rather than having a typical Delphi brainstorming session for developing these lists. In this case, the initial research topics list was developed by the Science and Technology project team based on a review and summary of the 2008/2009 science and technology survey responses. The survey process accommodates review and additions of the initial lists by survey participants at the onset. Because this is a ranking-type exercise, identification of all potential research topics is necessary.

The steps outlined below are shown in Figure A1.1. The survey facilitator was responsible for all steps of the survey, including summarizing the iterative rounds.

PRIORITY PESTS SURVEY METHODOLOGY

The baseline pest list was the one developed in 2012 for the CCFM national forest pest monitoring report[4]. This list represents contributions from all

[4] Canadian Council of Forest Ministers. 2012. Forest pest monitoring in Canada: current situation, compatibilities, gaps, and proposed enhanced monitoring program. Ottawa. 42 p.

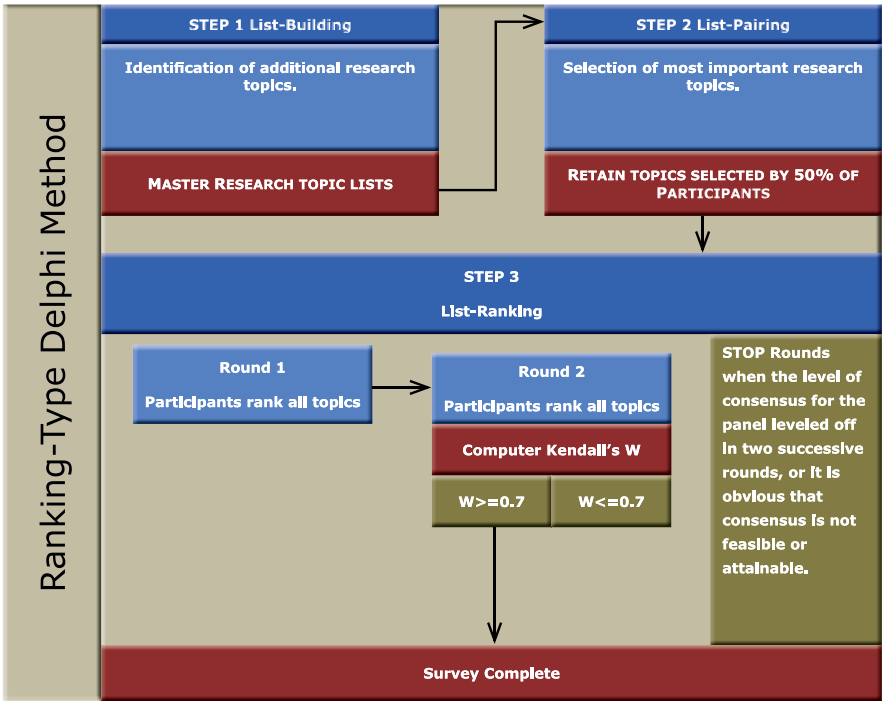


Figure A1.1. Steps involved in a ranking-type Delphi survey.

jurisdictions. A non-iterative method was used for this survey because the likelihood of persuading participants to vote for a pest that is not in their jurisdiction, or to change the ranking of a pest, is likely very low. Participants were asked to review the list, add any missing pests, and rank their top 10. National pest priorities were based on a weighting of these rankings, and priorities were classified according to a combination of natural breaks in the weighted sums and number of jurisdictions that selected the pest.

PRIORITY RESEARCH NEEDS

Once the priority research topics and priority pests requiring further research were identified, each jurisdiction was asked to align its priority research topics with its priority pests. Based on this alignment, participants were then asked to provide more pest-specific research needs where necessary, or to comment on why they considered a particular research topic and pest combination to be a priority.

RESULTS

PRIORITY RESEARCH TOPICS

Step 1 – List Building

A research topics list derived from the 2008/2009 science and technology survey was circulated to participants. Participants were asked to review the list, modify it if necessary, and add any missing items.

- No additional topics were added and none were modified. Twenty-eight topics in total (Table A1. 1).

Step 2 – List Paring

Step 1 results were distributed and participants were asked to identify research topics that were important.

- Each topic was selected by at least 50% of participants; therefore no research topics were eliminated.
- The CFIA opted out of additional steps because of the potential skewing of national results, given the agency's mandate.

Step 3 – List Ranking (Iterative Rounds)

Round 1

The research topic priority list (Step 2 results) was sent out to participants, who were asked to rank the top 10 topics and provide comments explaining or justifying their rankings.

Other tasks in this round:

- Computed percentage of respondents placing each item in the top half of their list.
- Consolidated and summarized comments/ research topic.
- Eliminated any topics which were not selected.

- Three topics were eliminated (they had no votes).
- Three topics were consolidated based on comments from participants.
- Twenty-one topics remained (Table A1.1).

Round 2

Each jurisdiction's survey results were sent out with the consolidated and summarized comments from all participants, the number of times each topic had been ranked in the top 5, and the jurisdiction's previous ranking. Participants were asked to review comments and rank all topics from 1 to 21 (for the purposes of calculating consensus).

Other tasks in this round:

- Calculated consensus, using a coefficient of concordance (Kendall's W).
- Identified national research topics priority list based on a combination of weighting and number of times a topic was ranked in the top 10 (only those topics ranked as 1 to 10 were used) (Table A1.2).

- Consensus on national priorities was fair to moderate with a Kendall W statistic of 0.43. Ideally, iterative rounds continue until the W statistic is ≥0.7. However, based on the provincial/ territorial ranking changes from Round 1 to Round 2, it is doubtful that additional rounds would have made much difference.
- The top 5 research topics identified in Round 2 were the same as Round 1, but in a slightly different order.
- Only 1 topic changed in the top 6–10 from Round 1 to Round 2, again with a slightly different order.

PRIORITY PESTS

Step 1 – List Building

Participants were asked to review the baseline pest list, and to add any additional pests if necessary.

- Only 1 pest was added to the initial list, for a total of 112 potential priority pests.

Step 2 – Pest Ranking

The revised pest list was sent out to participants, who were asked to rank their top 10 priority pests requiring further research.

- Forty-eight pests were ranked as top 10 priority pests requiring further research (Table A1.3).
  - The majority were insect pests, including native and invasive (Figure A1. 2).
- National top 10 priority pests were based on a weighting of the rankings (Table A1.3).

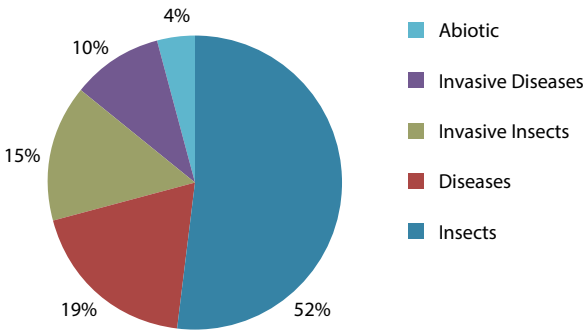


Figure A1.2. Summary of jurisdictional priority pests, by type.

Table A1.1. Summary of Step 3: ranking of priority research topics – Round 1.

Topic No.	Risk Theme [a]	Research Topic	Removed	Merged	No. of Votes Top 5 Ranking
1	RA	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	No	Absorbed topic No. 4	3
2	RA	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	No	No	6
3	RA	Interactions between disturbance factors, including FIAS.	No	No	0
4	RA	Climate change influence on host and/or pest distribution and population dynamics.	No	Merged with topic No. 1	5
5	RA	Introduction, establishment, spread, connectivity and pathways, and climate suitability models.	No	No	4
6	RA	Basic pest biology and life histories.	No	No	2
7	RA	Ecosystem-, stand- or tree-level impacts and losses, including non-timber values.	No	No	3
8	RA	Impact of pest management practices on non-timber forest values, including endangered wildlife.	No	No	1
9	RA	Environmental impacts assessment of pest control products.	Yes	n/a	n/a
10	RA	Assessment of cost/benefits of control, including for non-timber values.	No	No	0
11	RA	Value of pest management to carbon sequestration.	Yes	n/a	n/a
12	RA	Pest risk assessment or analysis, including hazard and risk rating.	No	No	6
13	RR	Develop or enhance existing decision support system	No	No	2
14	RR	Semiochemical monitoring tools, including for trap designs, calibration and standardization.	No	No	5
15	RR	Detection or monitoring survey designs, techniques and tools. This includes for calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	No	Absorbed topic No. 21	6
16	RR	Molecular diagnostic kits.	Yes	n/a	n/a
17	RR	Aerial surveys and mapping technologies and technologies for ground survey data capture.	No	No	2
18	RR	Remote sensing technologies for mapping pest or climate change damage/distribution.	No	No	1
19	RR	Expanding knowledge on the taxonomy of all pests of concern.	No	No	2
20	RR	Efficacy of response options: cultural, biological, chemical or regulatory.	No	No	2
21	RR	Response thresholds.	No	Merged with topic No. 15	0

Topic No.	Risk Theme [a]	Research Topic	Removed	Merged	No. of Votes Top 5 Ranking
22	RR	Response tools and options.	No	Absorbed topic No. 23	3
23	RR	Improved or new biocontrol and chemical formulations, including baculoviruses, narrow spectrum insecticides, and fungicides.	No	Merged with topic No. 22	2
24	RR	Application technologies (e.g., flake formulation, other).	No	No	1
25	RR	Phytosanitary treatments: standards, methodologies and efficacy.	No	No	2
26	RR	Tree genetic resource strategies in response to climate change and invasive species.	No	No	0
27	RC	Public attitudes: pest outbreaks and control, climate change and related events.	Yes	n/a	n/a
28	RC	Development of best practices guidelines for pest management.	No	No	2

[a] RA = risk assessment, RR = risk response, RC = risk communication

Table A1.2. Summary of Step 3, ranking of research topic priorities – Round 2, final list.

				Round 2		
Topic No	**Risk Theme**	**Research Topic**	**Round 1 Ranking**	**Weighted Sum**	**No. of Top 10 Votes**	**Final Ranking**
1	Risk Assessment	Spatial and temporal analysis of pest data to: detect changes in pest behaviour and distribution due to climate change; analyze regional or national population trends; or assist with quantifying losses.	1	80	11	1
12	Risk Assessment	Pest risk assessment or analysis, including hazard and risk rating.	2	77	11	2
2	Risk Assessment	Pest population dynamics and processes, including the biology and ecology of parasites, predators and diseases.	4	75	11	3
14	Risk Response	Semiochemical monitoring tools, including those for trap designs, calibration and standardization.	3	61	11	4
15	Risk Response	Detection or monitoring survey designs, techniques or tools. This includes calibration (e.g., triggers and response thresholds) and standardization of predictive surveys.	5	53	8	5
5	Risk Assessment	Introduction, establishment, spread, connectivity and pathway, and climate suitability models.	7	51	9	6
7	Risk Assessment	Ecosystem-, stand- or tree-level impacts and losses, including on and of non-timber.	8	47	7	7
22	Risk Response	Response tools and options, including improved or new biocontrol and chemical formulations (baculoviruses, narrow spectrum insecticides, and fungicides).	6	38	7	8
10	Risk Assessment	Assessment of cost/benefits of control, including for non-timber values.	14	24	8	9a
20	Risk Response	Efficacy of response options: cultural, biological, chemical or regulatory.	9	24	6	9b
6	Risk Assessment	Basic pest biology and life histories.	16	30	4	10
19	Risk Response	Expanding knowledge on the taxonomy of all pests of concern.	12	18	3	11
28	Risk Communication	Development of best practices guidelines for pest management.	10	16	5	12
18	Risk Response	Remote sensing technologies for mapping pest or climate change damage/distribution.	15	12	6	13
17	Risk Response	Aerial surveys and mapping technologies and technologies for ground survey data capture.	13	11	4	14
24	Risk Response	Application technologies (e.g., flake formulation, other).	18	10	2	15
3	Risk Assessment	Interactions between disturbance factors, including forest invasive alien species.	20	9	2	16

				Round 2		
Topic No	**Risk Theme**	**Research Topic**	**Round 1 Ranking**	**Weighted Sum**	**No. of Top 10 Votes**	**Final Ranking**
8	Risk Assessment	Impact of pest management practices on non-timber forest values, including endangered wildlife.	19	9	2	17
13	Risk Response	Develop or enhance existing decision support system (e.g., Windows-based; multi-insect; customizable; training modules/tutorials/workshops).	11	8	2	18
25	Risk Response	Phytosanitary treatments: standards, methodologies and efficacy.	17	7	1	19
26	Risk Response	Tree genetic resource strategies in response to climate change and invasive species.	21	0	0	20

Table A1.3. Priority pests requiring further research, and final ranking of the top 10 pests.

Disturbance	No. of Votes	Weighted Sum	Percent Who Selected as Top 5	Ranking
Eastern spruce budworm	10	87	100	1
Mountain pine beetle	9	64	67	2
Climate change (includes declines)	9	56	78	3
Spruce beetle	6	42	100	4
Emerald ash borer	6	41	83	5
Brown spruce longhorn beetle	4	28	100	6
Jack pine budworm	4	26	75	7
Asian gypsy moth	5	26	40	8
Eastern hemlock looper	3	19	67	9
Gypsy moth (European)	3	19	67	10
Balsam fir sawfly	2	18	100	
Abiotic (wind, hail, etc.)	3	16	33	
Balsam woolly adelgid	3	15	33	
Armillaria root disease	4	15	25	
White pine blister rust	2	14	50	
Aspen serpentine leafminer	2	13	50	
Asian longhorn beetle	3	13	33	
Douglas-fir beetle	2	11	50	
Beech bark disease	3	11	0	
Western spruce budworm	1	10	100	
Dutch elm disease	2	9	50	
Japanese beetle	1	9	100	
Northern spruce engraver	2	8	0	
Beech flea weevil	1	8	100	
Eastern blackheaded budworm	2	7	0	
Western balsam bark beetle	2	7	50	
Whitemarked tussock moth	2	7	0	
Sudden oak death	3	7	0	
Larch sawfly	1	6	100	
Sirex wood wasp	1	5	0	
Lodgepole pine dwarf mistletoe	2	4	0	
Large aspen tortrix	2	4	0	
Eastern larch beetle	1	4	0	
Pine engraver beetle	1	4	0	
Forest tent caterpillar	1	4	0	
Pinewood nematode	1	4	0	
European scleroderris canker	1	3	0	
Tomentosus root rot	1	3	0	

Disturbance	No. of Votes	Weighted Sum	Percent Who Selected as Top 5	Ranking
Spruce needle rust	1	2	0	
Pine sawflies	1	2	0	
Ambermarked birch leafminer	1	2	0	
Sirococcus shoot blight	1	2	0	
Ash dieback	1	1	0	
Comandra blister rust	1	1	0	
Pine needle cast	1	1	0	
Yellow-headed spruce sawfly	1	1	0	
Butternut canker	1	1	0	

PRIORITY RESEARCH NEEDS

These results are presented in the main body of the report.