Canadian Council of Forest Ministers

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NATIONAL FOREST PEST STRATEGY

Pest Risk Analysis Framework

User's Guide

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PEST RISK ANALYSIS FRAMEWORK

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Canadian Council of Forest Ministers
Forest Pest Working Group

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Executive Summary

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

Pest risk analysis is an internationally recognized process. It enhances our understanding of the nature of pest risks, uses evidence to characterize risk, identifies critical factors that determine risk, addresses gaps and uncertainties, and promotes collaboration on shared risks to ensure transparent and accountable public policy and decisions in natural resource management.

The Canadian Food Inspection Agency has long completed pest risk analyses (PRAs) to prevent the introduction and spread of plant pests of quarantine concern to Canada; mostly resulting from non-native pests. The NFPS PRA framework was developed to address the broader range of pests – alien, naturalized and native – and resource values at risk, as well as to promote a common approach to estimating such risks to Canadian forests. The framework is flexible, adaptable and transparent, thereby facilitating use across the country.

A PRA is triggered when a potential threat, such as a pest, a pathway or a change in policy, is identified. The analysis consists of risk assessment, risk response and risk communication.

- **Risk assessment** asks, How likely is it that the pest is going to occur? and, How bad will it be if it does?
- **Risk response** identifies mitigation options should the risk be deemed unacceptable.
- **Risk communication** encapsulates all phases.

A full PRA is needed only if the potential threat is deemed unacceptable according to objectives defined at the onset. The complexity of a PRA is defined by these objectives and the amount of information available for a pest.

Three elements underpin a PRA's strength: evidence, uncertainty and knowledge gaps. The type and nature of the evidence determines the level of uncertainty. And, in turn, defining the level of uncertainty leads to identification of knowledge gaps and research needs.

Evidence can be gathered either formally via workshops, or less formally via conference calls, email correspondence and similar methods. Regardless of the approach, including individuals with relevant backgrounds is key to the credibility of a PRA. Transparency is achieved by involving stakeholders, conducting public consultation where necessary, and ensuring ongoing communications.

This guide was developed to ensure that forest pest managers use a consistent approach to PRA across Canada. The overall purpose of a PRA is to identify the risk to specific values (whether they be forest products, wildlife habitat or watershed health) and to determine mitigation options, if required. While the approach presented here does not differ from existing provincial and territorial processes, it does help crystallize the process and make it more transparent, efficient and effective with ongoing practice. As such, a PRA should be viewed as an enhancement to existing processes, and an opportunity to improve collaboration and communication between practitioners and researchers.

Introduction

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

Pests include biotic factors such as insects, pathogens and invasive plants. Risk analysis itself is an internationally recognized process by which scientific information is used to develop and implement programs to reduce risk. Pest risk analysis has three main components: risk assessment, risk response and risk communication.

The PRA framework was developed by the NFPS Risk Analysis Technical Advisory Group to promote a common approach to estimating the risk of pest threats to a wide range of forest resource values as a result. The PRA differs from risk assessments completed by the Canadian Food Inspection Agency (CFIA) in that their focus is on preventing the introduction and spread of plant pests of quarantine concern to Canada, most of which result from non-native pests.

The PRA process enhances our understanding of the nature of pest risks, uses evidence to characterize risk, identifies critical factors that determine risk, addresses knowledge gaps and uncertainties, promotes collaboration on shared risks, and results in transparent and accountable public policy and decisions in natural resource management. The PRA framework is flexible, adaptable and transparent, facilitating use across the nation. It is also applicable to alien, naturalized and native pests of Canada's forests.

Several PRAs have been conducted across Canada, some under the auspices of the CCFM and some at a jurisdictional level. These were completed using the basic tenets of PRA and the NFPS framework, with no template for approach and format.

Feedback was sought from these users and incorporated into the development of this users' guide, as were lessons learned from the NFPS case studies (Nealis, 2009). As appropriate, these lessons learned are shown in the guide in blue text boxes. Other sources of information are listed in the sidebar here.

This guide draws on information from:

- the NFPS PRA workshop held in Halifax in March 2012;
- International Plant Protection Convention (IPPC) Pest Risk Analysis Training Participant Manual[1];
- IPPC PRA training slide decks; and
- examples from existing PRAs.

[1] Available at www.phytosanitary.info/information/ippc-pest-risk-analysis-training-course. Accessed October 28, 2014.

This guide aims to provide users with the information they need to complete a PRA using the NFPS framework. The guide is divided into three sections:

Section 1. Tools and resources, including links to completed PRAs, as well as pest data sources

Section 2. PRA overview of components and essential elements, types of PRAs, terminology and reporting

Section 3. Step-by-step guide to the NFPS PRA framework, including initiation (trigger), planning, risk assessment and risk response

Tools and Resources

PEST RISK ASSESSMENTS/ANALYSIS

NFPS-Specific

A number of NFPS case studies have been completed and are available from the CCFM website (www.ccfm.org/english/reports_articles.asp).

The original (2007) mountain pine beetle assessment is available from the Natural Resources Canada–Canadian Forest Service Publications web site (http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/28891.pdf).

Canadian Food Inspection Agency (CFIA)

Risk assessments completed by the CFIA differ from the NFPS PRA in that their focus is on preventing the introduction and spread of plant pests of quarantine concern to Canada, most of which are from non-native pests. Historically, the CFIA has only completed pest risk assessments, but recently it completed several risk management documents to complement the risk assessment. These materials are available at http://www.inspection.gc.ca/plants/plant-protection/directives/risk-management/eng/1304820847590/1304820997079.

The CFIA guidelines are the preferred method for PRAs, as presented in this users' guide (Appendix 1).

International

Many styles of PRA's exist internationally e.g. qualitative, quantitative, or blended; each designed to determine overall risk. While the equations and methods to determine risk differ somewhat, the main ingredients are essentially the same: likelihood of introduction and consequences of introduction. Appendix 2 provides a list of other internationally recognized PRA's, including papers comparing different styles and approaches.

The IPPC has also developed training material on PRA using its standards, terminology and examples. These materials are available at www.ippc.int/core-activities/capacity-development/training-material-pest-risk-analysis-based-ippc-standards.

Other PRAs

Yukon and Northwest Territories have each completed a PRA for mountain pine beetle (MPB). For access to these reports, contact territorial forest health personnel.

HISTORICAL PEST DATA

The National Forest Pest Strategy Information System (PSIS) contains historical pest incidence and damage records, based on provincial and territorial survey data, CFS Forest Insect and Disease

Survey data, and CFIA data. The PSIS is accessible online to members, and requires a user login through the National Forest Information System (https://ca.nfis.org/).

Pest Risk Analysis: Overview

Pest risk analysis uses an evidence-based approach to decision-making and, in doing so, provides a relevant and transparent framework for forest management. A PRA consists of gathering and assessing evidence and developing response options, as necessary (Figure 1). The input of the framework is dynamic and the output adaptable, but the framework remains stable.

A PRA is generally "triggered" by a forest pest threat of some kind, with risk being based on the likelihood and the consequences of occurrence (Figure 2). The analysis identifies not only pest risk but also associated uncertainties, thereby allowing for identification of knowledge gaps and research needs.

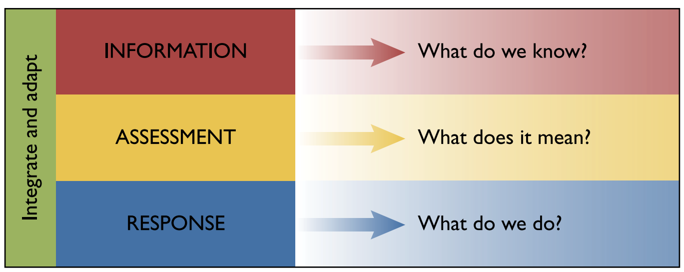

Figure 1. Pest risk analysis and adaptive management (Nealis, 2012).

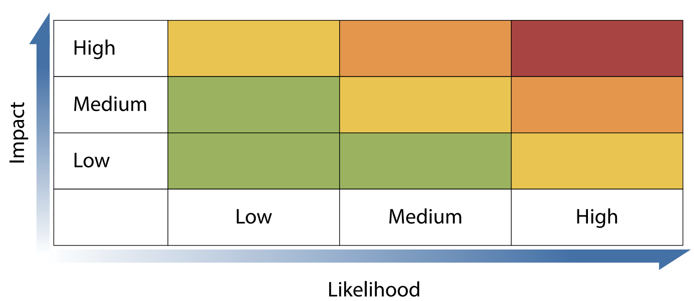

Figure 2. Pest risk matrix: likelihood and consequences of occurrence (International Plant Protection Convention, 2007a).

ELEMENTS OF A PRA

Pest risk analysis consists of three components: **risk assessment** (described on page 19); **risk response** (page 27); and **risk communication** (page 17).

Risk assessment evaluates the threat and potential impacts of a pest. Risk response identifies means to mitigate the risk. Both of these components involve collecting and summarizing evidence (anecdotal or research), and identifying associated uncertainties and research needs. Various steps occur within each component, as shown in Figure 3.

Risk communication encapsulates the entire process, ensuring transparency and accountability throughout the analysis.

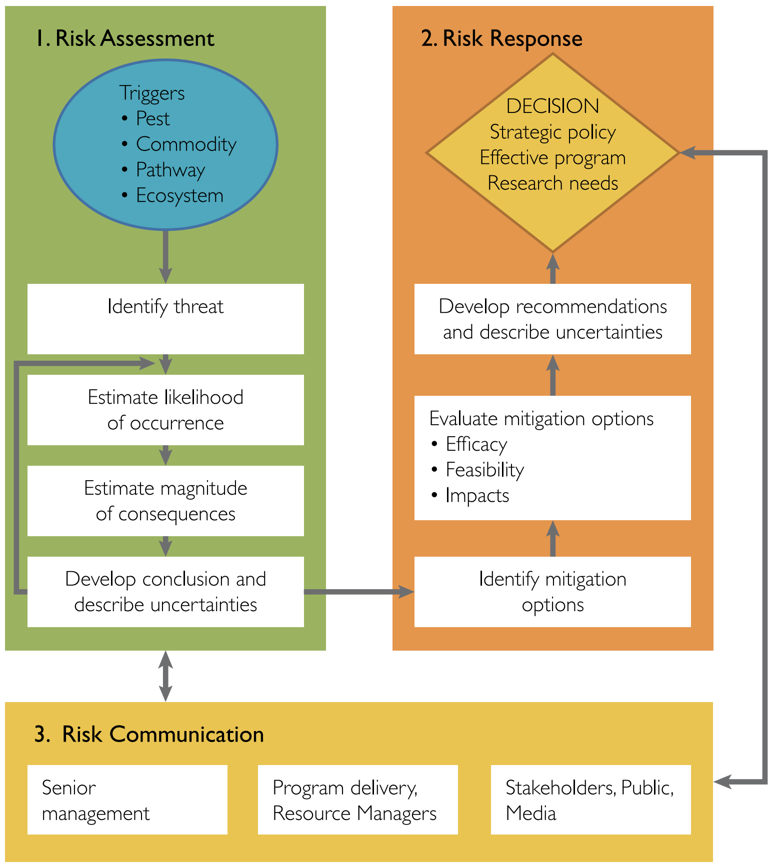

Figure 3. Elements of the National Forest Pest Strategy pest risk analysis framework.

EVIDENCE

Evaluation of evidence and associated uncertainties lies at the core of PRAs. A successful approach to distill evidence has been through the use of provocative or affirmative statements (see Step 4 on page 22). Such statements are made in reference to a particular aspect of a risk factor and help stimulate and document thoughts and discussion.

This approach helps those involved in an analysis summarize evidence under each of the factors considered in a PRA (e.g., probability of entry/damage, probability of establishment), and so facilitate derivation of overall risk. As well, this approach helps analysts identify knowledge gaps and uncertainties associated with each statement.

More than one statement can exist for each factor, but only one risk rating is assigned to a factor.

UNCERTAINTY

Uncertainty is inherent to any PRA because of missing, inaccurate or non-representative data. In the case of a native pest, for instance, we turn to historical data to identify trends and impacts, yet those may not be applicable in future. Similarly, the potential behaviour of invasive natives or alien pests in a novel environment is generally based on behaviour in their past habitat or country of origin. Uncertainty can also stem from pest risk assessor judgment, methodology, random or unexpected events, or the variable and complex nature of biological systems and human behaviour.

Thus, it is important to document uncertainty by defining terms (e.g., level of uncertainty), describing all plausible scenarios, and stating assumptions. This ensures transparency and can be valuable information when decisions are being made on the acceptability (or unacceptability) of the pest risk by decision-makers. Readers of PRAs should be informed of what is known for certain and what assumptions are being made.

Identification of the assumptions and uncertainties ensures a comprehensive and objective view of the pest risk.

UNCERTAINTY RATINGS

A variety of uncertainty ratings exists internationally, but the three – low, medium, high – shown in Table 1 are recommended.

Table 1. Uncertainty ratings for use in National Forest Pest Strategy pest risk analysis

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

Predefined uncertainty ratings are preferred over subjective evaluation.

IDENTIFICATION OF KNOWLEDGE GAPS AND RESEARCH NEEDS

Identifying and documenting uncertainty enables analysts to identify knowledge gaps and prioritize research needs, possibly in the form of a research plan.

The objective of a research plan is to reduce the level of uncertainty identified in the PRA; and, although it is not essential to the PRA, such a plan can reduce uncertainty in future iterations. A research plan identifies: priorities; means to promote research needs; potential research partners; funding sources; partnerships; and collaboration opportunities.

Research priorities can be identified based on the consequences of not having sufficient information (Appendix 3). For instance, a knowledge gap can have a high level of uncertainty but with few consequences; another one can have low uncertainty and high consequences and so may be considered a higher priority.

Other required actions may include collecting more data, validating existing data with observations, developing decision support tools, and conducting statistical analysis. This feature is what makes a PRA dynamic: when new research is available, the risk assessment or risk response can be updated. This increases the accuracy of the risk assessment predictions, improves efficacy and feasibility, reduces impacts, and reduces costs associated with management actions recommended as part of the risk response.

TYPES OF PRAs

A PRA can be qualitative, quantitative or a combination of both. However, in dealing with forest pests –and particularly in dealing with new or novel situations – there may be many unknowns. Hence, a qualitative approach may be the only option where quantifiable data are not available.

QUALITATIVE

A qualitative risk assessment is one that describes risk in words rather than numbers. This is commonly used for pest risk assessments and is recommended for the NFPS PRA framework.

Nevertheless, qualitative methods have some challenges. Most notable is how to maintain consistency between assessments and between assessors. To address that problem, the CFIA's pest risk assessment guidelines have been chosen as the preferred method for analyses conducted using the NFPS PRA framework (Appendix 1).

To date, the PRAs conducted under the auspices of the CCFM have been purely qualitative in nature. Collective knowledge and wisdom about pest behaviour and impacts in native habitat – informed by expert opinion and review and complemented possibly by anecdotal evidence in new habitat – have been used to describe and assess potential risk.

Use of predefined pest risk rating guidelines to attain an overall risk rating is preferable to a subjective evaluation of risk factors.

QUANTITATIVE

A quantitative PRA generally involves the use of data for modelling purposes. As in qualitative assessments, this requires expert knowledge of pest biology and of predicted behaviour and impacts in the area of interest.

While a quantitative pest risk assessment addresses some of the challenges posed by a qualitative approach – for example, allowing for more consistent interpretation, reliably translated and communicated – it also presents its own challenges. Often quantifiable data are lacking or incomplete, particularly in naïve habitats; and selection of variables (and the assignment of values to those variables) can present the assessor with challenges.

COMBINATION

A semi-quantitative pest risk assessment combines elements of both quantitative and qualitative assessments, adding precision using quantitative methods (where these are applicable), and incorporating qualitative methods for those parts of the assessment where data are not available or the same degree of precision is not required.

TERMS USED IN A PRA

The list below defines terms commonly used in a PRA.

Note: These terms are aimed at invasive pests. Terms such as **hazard, susceptibility** and **vulnerability** are more applicable to native pests, and have therefore been left off this list (given the variation in the definitions of terms across jurisdictions and pests). If native pests are being assessed, it is recommended that local terminology be substituted and used as appropriate (e.g., **host abundance** in some jurisdictions equates to hazard).

Terms	Description
Consequences of occurrence	The magnitude of the impact of something in terms of the values put at risk (e.g., economic, environmental, social).
Entry	Movement of a pest into an area where it is not yet present, or is present but not widely distributed and being officially controlled.
Establishment	The perpetuation, for the foreseeable future, of a pest within an area after entry or occurrence. Establishment requires the interaction of the pest, its hosts and its environment (biotic and abiotic).
Likelihood of occurrence	The combined relative probability of pest entry, expansion, and establishment and spread.
Occurrence	The entry of a pest that results in its establishment.
Pathway	Any means that allows the entry or spread of a pest.
Pest categorization or pre-assessment	A quick assessment of risk to determine if a pest (generally an invasive alien species) has the characteristics of a quarantine pest or those of a regulated non- quarantine pest. The assessment is based on readily available information to determine if a full PRA is needed. It considers pest, host, management or regulatory status, potential for establishment and spread, and economic impacts.
Pest risk analysis area	The geographic boundaries of the area being evaluated for risk.
Risk	A situation involving exposure to danger. It is a combination of the likelihood of occurrence (probability of entry, establishment and spread) and the consequences of occurrence (economic, environmental and social).
Risk characterization	Characterizing risk based on occurrence, establishment potential and spread, and impacts – in essence, a combination of likelihood and consequences of occurrence.
Spread	Expansion of the geographical distribution of a pest within a pest risk analysis area.
Trigger	A forest pest threat of some kind that may elicit a response.

Step-by-Step Guide to the NFPS PRA Framework

A PRA is initiated with the recognition of a threat – the trigger: a pest, a pathway or a change in policy. It often concludes with development of a research plan (although such a plan is optional).

Appendix 4 provides a checklist of all factors to consider in a PRA.

INITIATION (TRIGGER)

The first phase of a PRA, following recognition of a potential threat (trigger), is a quick evaluation of whether or not that threat is of significance to your agency.

Figure 4 expands on some of the preliminary steps to be considered once a threat (trigger) has been recognized and before beginning a PRA.

Not all components will be necessary, and it is up to the project team (or whoever the lead is) to decide which ones are. The decision will likely depend on the nature of the PRA. For instance, stakeholder and public consultation or a communication strategy may not be required for a PRA being done for a native pest in a seed orchard, but would likely be required for a PRA being done for an invasive native in managed forests.

If the threat is deemed significant, then a PRA is initiated.

TRIGGER EXAMPLES

Looming **spruce budworm** outbreak in eastern Quebec (Porter, 2012)

Rapid change in **mountain pine beetle population** status and newly gained information (Nealis and Cooke, 2014)

New **brown spruce longhorn beetle** (BSLB) trap findings beyond the containment area and the need to re-evaluate Nova Scotia's BSLB risk management in light of successes, failures and new science. Also, suggestions that the CFIA might reduce its BSLB surveillance and regulatory efforts in the near future (CCFM, 2014).

The potential long-distance spread of **emerald ash borer** (EAB) into northern Ontario and Manitoba by people moving infested materials from infested parts of Ontario, Quebec and the U.S. Also concern over the potential impacts that EAB could have on the ash population in un-infested areas of Canada (Hodge et al., 2015)

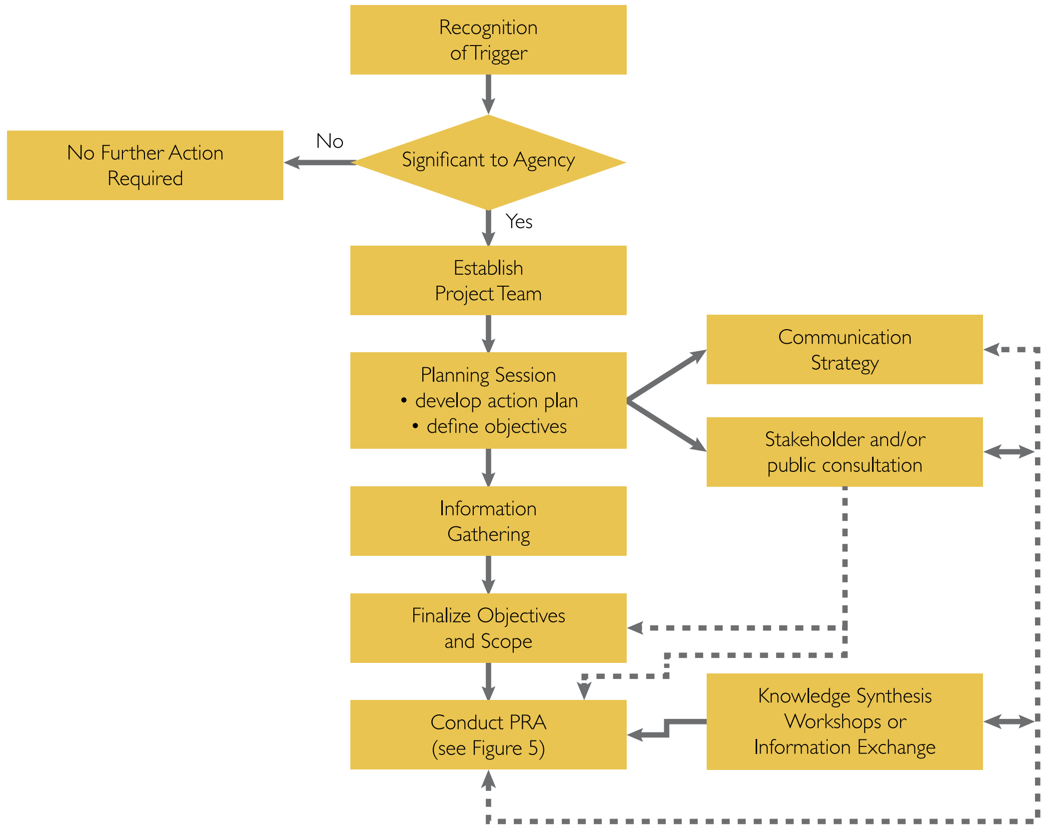

Figure 4. Events leading to completion of a pest risk analysis (PRA). Dashed lines indicate optional components depending on the nature of the PRA.

PLANNING A PRA

Completion of a PRA requires central coordination by one or more lead agencies or individuals.

If the anticipated scope and objectives of the PRA warrant it, you may elect to identify a project team, which may include forest pest managers, subject matter experts and stakeholders. The role of the project team is to: draft objectives for the PRA; identify stakeholders, subject matter experts, information sources, and information exchange formats (e.g., knowledge synthesis workshops); set plan timeframes; establish roles and responsibilities, if necessary; and discuss the need for a risk communication plan or strategy. The task is, essentially, to develop an action plan that can be achieved through a planning session, the first stage of a PRA.

SETTING OBJECTIVES

Setting the objectives of a PRA is critical in that it helps to establish the anticipated boundaries and depth of the analysis, and to identify portions of the process that need not be completed.

The objectives of the risk analysis must be transparent and stated at the outset. They can be in the form of a statement of desired outcomes of the PRA, or in the form of questions that need to be answered. Clearly defined objectives at the outset will help the project team focus on relevant issues. It will also assist with the identification of potential stakeholders, government agencies and subject material experts. Resource availability and the time required to conduct the PRA must also be carefully considered when setting objectives.

Objectives may need to be refined in response to timing constraints or the outcome of public or stakeholder consultation.

Small focused groups can be an effective way of planning the objectives and design of the risk analysis (Nealis, 2009). This could include other government departments that may be affected, as well as communications departments.

Categorizing objectives into the elements of risk assessment (e.g., entry potential, spread potential, establishment potential) can help focus and condense objectives.

OBJECTIVE EXAMPLES

Spruce budworm in Quebec

- To complete a literature review and synthesis of research knowledge.
- To identify: potential impacts by various stand types, potential intervention options, potential preventative measures, and priority populations to harvest or treat.
- To evaluate Spruce budworm decision support system protection planning system (SBWDSS PROPS) as a decision-making tool.
- To explore the potential for developing scenario analyses as a tool.

Brown spruce longhorn beetle (BSLB) in Nova Scotia

- To estimate the rate and direction of BSLB spread and establishment.
- To identify the values at risk to BSLB colonization.
- To characterize the risk of BSLB using evidence.
- To identify uncertainties and information needs.
- To develop conclusions and describe factors that could, over the short and long terms, influence the volume of vulnerable host material in Nova Scotia.
- To describe mitigation options.
- To identify future research needs.

IDENTIFYING STAKEHOLDERS, EXPERTS AND INFORMATION SOURCES

Stakeholders should be identified and their input sought at the outset of a PRA to ensure their concerns are considered and/or included in the objectives. The formats for seeking their input will depend on several factors, such as the number of stakeholders and time available. Public consultation should be conducted as required (though note that it may be more pertinent to the risk response portion of a risk analysis than to the risk assessment part). Including these groups leads to a transparent and inclusive process that can help reduce potential issues in the future.

DEVELOPING A RISK COMMUNICATION PLAN

Regardless of the nature of a PRA, risk communication on some level is a critical component. Nealis (2015) describes risk communication as an interactive dialogue with stakeholders to provide open and consultative decisions that are effective and clear.

Although stakeholder consultation typically centres on pest managers communicating their plan, in risk analysis, this consultation is a two-way process. Stakeholders may be the best source of information that is relevant to assessment but not available from professionals. Community-based estimates of risk tolerance can also be obtained. It is during this public input that sources of conflict resulting from different values, perceptions, and interests will emerge.

The purpose of risk communication is to promote awareness among all participants about the issues under consideration and the various steps taken in a PRA. It should also improve participants' understanding of the risks. As well, a communications plan should foster trust and confidence among all parties involved through the transparency, credibility and consistency of information exchanged and decisions made to deal with pest risks.

Jurisdictional communication policies will likely influence both the content and distribution of communication materials.

For additional information on risk communication principles and potential barriers, see Appendix 5.

- **The decision-making process must be transparent, and all results clearly shared. Multiple methods of communication should be used to reach a large audience.**

- **Before a risk analysis is undertaken, a communications plan and timetable – at least in principle – must be available (Nealis, 2009).**

- **Risk communication is vital for engaging stakeholders, implementing policy effectively with full compliance, and avoiding inconsistent messages. Communication must take place throughout the risk analysis process, not just in the beginning to solicit information and concerns and at the end to post decisions (Nealis, 2009).**

RISK COMMUNICATION STRATEGY

Developing a communication strategy is the best approach to taking advantage of multiple tools and a variety of forms and opportunities to communicate effectively. How comprehensiveness such a strategy is should be determined by the seriousness of the pest.

The strategy should identify who the potential partners and contributors are and who the affected and interested parties are. The latter should be informed about the plans and asked if they have conducted an analysis on the same subject in the past.

GATHERING INFORMATION

Identifying and collecting all the information and information sources relevant to the objectives of the PRA sets the stage for actual analysis. These sources include previous PRAs (see list on page 9), historical pest data (see page 9), peer-reviewed articles, in-house reports and fact sheets.

CONDUCTING A PRA

Because a PRA is evidence-based, collection and review of relevant materials is crucial. Information-gathering collates existing published materials, but unpublished materials (e.g., the current state-of-knowledge and anecdotal observations) are not as easily collected. The latter should therefore be collected through workshops, email correspondence and conference calls. This form of knowledge synthesis is necessary for both risk assessment and risk response (Figure 5).

Information exchange can occur through presentations and discussions with researchers, people concerned about the pest, and possibly other stakeholders. Discussions should have clear objectives so that they remain focused. Provocative or affirmative statements can be formulated to help distill evidence and identify knowledge gaps and uncertainties associated with each statement.

Following discussions, the project lead should summarize the information and send it to participants for review.

Affirmative statements in a risk assessment should align with each of the factors considered in the assessment – that is, probability of entry/damage, probability of establishment, probability of spread, and potential economic and environmental consequences. This makes it easier to assign a risk (in keeping with CFIA guidelines) to each of these factors, and ultimately to define the overall risk.

More than one statement can exist per factor, but only one risk rating should be assigned to a factor. Once all of the affirmative statements have been assessed and assigned an uncertainty and risk rating, the overall risk can be determined (Appendix 1).

- Making materials available in advance engages participants and clarifies the objective of the discussion (Nealis, 2009).
- Face-to-face meetings are the best means to acquire current knowledge, establish key contacts, and gather stakeholder feedback.
- Provision of travel funds helps ensure participation by outside agencies in face-to-face meetings.

CARRYING OUT A PEST RISK ASSESSMENT

Nealis (2015) describes pest risk assessment as the process of identifying a hazard and estimating the risk associated with it by analyzing scientific and socioeconomic evidence to characterize, evaluate and summarize the risk in a way that addresses the needs of decision-makers. The significance of the threat will depend on the severity of cumulative impacts, the temporal and spatial extent of those impacts, and whether or not the impacts are reversible.

A pest risk assessment sets out to answer two questions: How likely is it that the pest is going to occur? and, How bad will the situation be if the pest does occur? The assessment achieves this by determining: whether the organism is a threat, based on tolerance thresholds; what the potential is for the organism's occurrence, establishment and spread; and what the potential impact is on values of concern.

The steps involved in a risk assessment are described below and shown in Figure 5.

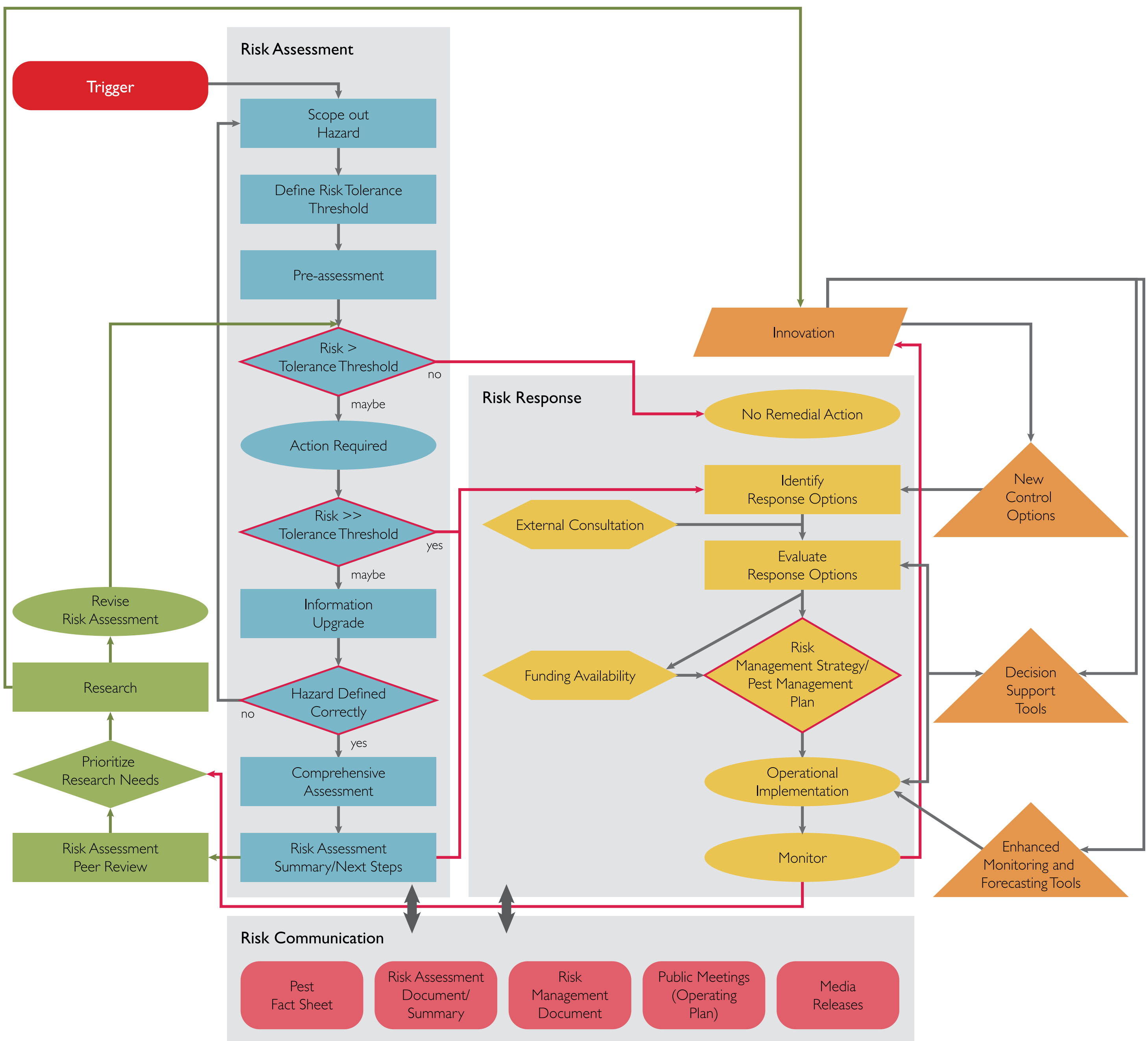

Figure 5. Detailed National Forest Pest Strategy pest risk analysis (PRA) framework.

STEP 1. SCOPE OUT HAZARD

The area of concern, the resource assets at risk, and the stakeholders within the affected area should all be identified at the start of the analysis as part of the scope-setting step. It is important that the scope align with the PRA objectives to ensure that both resources and time are available for completion of the analysis.

The area to which the assessment pertains must be identified with clear geographic boundaries. The area should be large enough to enable the objectives to be met, but not so large that it prevents meaningful conclusions being drawn. The area of concern can, for example, be based on administrative boundaries, ecosystem or host distribution.

- **The scope of a risk analysis should be clearly defined at the beginning of a PRA.**
- **A narrow scope for a risk analysis may be preferable, but the reasons and boundaries for that should be explicit. That said, a comprehensive account may be useful outside the original scope, enabling an extension of the scope to address new needs (Nealis, 2009).**

STEP 2. DEFINE RISK TOLERANCE THRESHOLD

Risk tolerance is generally defined by the organization undertaking the PRA, but can be influenced by stakeholders and the adaptive management capacity of the risk.

Tolerance threshold influences the timing and selection of response options. If the risk is much greater than tolerance thresholds and is imminent, then consideration and implementation of response actions may be warranted before completion of a full PRA.

The tolerance threshold should also inform the pre-assessment and determination of whether or not a full assessment is required. For example, before 2006, Alberta had zero tolerance to mountain pine beetle (MPB) and implemented aggressive control actions. However, Alberta's response had to adapt over time with the realization that zero tolerance was no longer realistic given resource availability and population status.

STEP 3. CONDUCT A PRE-ASSESSMENT

The assessor has the option of conducting a pre-assessment to determine whether a full risk assessment is necessary. A pre-assessment typically has all the elements of a full risk assessment but in less detail.

A pre-assessment generally applies to invasive alien species or "surprise" natives species. It is essentially a quick estimate of the likelihood of occurrence and associated impacts – an exercise that does not require a full-fledged knowledge synthesis but instead relies on rapid collation and interpretation of readily available information to estimate risk.

If the risk exceeds tolerance thresholds, then a full PRA would be required. Or, if the risk is high and imminent, then the assessor may choose to recommend response actions before completing a full PRA. If the risk is low, then the PRA can end with a recommendation for no remedial action.

> Even quick risk assessments can provide immediate information for planning both policy and research.

STEP 4. CONDUCT A COMPREHENSIVE PEST RISK ASSESSMENT

In this step, central to risk assessment, the likelihood and consequences of pest occurrence are to be estimated. The evidence must be presented and the associated uncertainties and information gaps identified.

Pest risk assessments previously completed under the CCFM have used affirmative statements for this purpose. An example is shown in the box below, along with substantiating evidence, the level of uncertainty determined (Table 1), and information needs.

AFFIRMATIVE STATEMENT EXAMPLE

Affirmative Statement

Artificial (i.e., human assisted) movement has contributed to the spread of the BSLB.

Evidence

Brown spruce longhorn beetle flight behaviour was studied in the lab using flight mills. Most beetles made many short flights or did not fly at all. Some flew more than 10 kilometres in 24 hours. However, the mean lifetime distance flown by adults was only 2–3 kilometres (Sweeney, Silk, Pureswaran, Flaherty, Wu, Price, Gutowski, & Mayo, 2009; Jon Sweeney-NRCAn, personal communication, September 5, 2013). In field studies, flights averaged about 25 metres (BSLB Science Sub-committee, 2010) and the longest flight recorded was 800 metres (Jon Sweeney-NRCAn, personal communication, September 5, 2013). Given this slow rate of spread, any BSLB detections more than 80 kilometres from Point Pleasant Park (i.e., outliers) are likely the result of artificial movement rather than natural spread.

Uncertainty

- Low uncertainty on the flying abilities of BSLB and likelihood for BSLB to exhibit rapid dispersal.
- Moderate uncertainty with a natural spread rate of 3–4 kilometres per year because this estimation is dependent on the detection of BSLB.
- Low uncertainty on the BSLB outliers being a result of artificial movement.

Information Needs

- The risk of BSLB being spread by artificial movement of spruce roundwood and firewood.

Likelihood of occurrence – Likelihood of occurrence is most applicable to invasive alien species and invasive native species, but from a native pest perspective could be viewed as changes in range due to climate change or likelihood of damage. The likelihood of occurrence is calculated based on the probability of entry and the establishment potential (where the probability of entry for a native pest could be the probability of range expansion or damage).

Likelihood of occurrence considers the status and movement of the pest, potential pathways, life stage of the pest, and existing management efforts (including regulatory controls currently in place to reduce the likelihood of occurrence). Pest ability to transfer to hosts and climate suitability can also be considered, but only in the context of the pest surviving initial entry.

When identifying pathways, it is important to consider natural spread as a mechanism for entry or occurrence, as well as human-assisted pathways. The probability of a pest being on a pathway depends on: the volume and frequency of its movement along the pathway; seasonal timing; and pest management or phytosanitary measures currently being applied. The probability of a pest surviving transport should consider the pest's length of time in transport and the robustness of its life stage during transport or storage. The probability of a pest transferring to a suitable host or habitat depends on the timing of transport, distribution of pathway in time and space, dispersal mechanisms (including vectors), and proximity of suitable hosts or habitat.

Probability of entry – Probability of entry is based on the pest's current status and distribution, including its population levels outside the PRA area, its interception history, predictive sampling results for it, its movement, its potential pathways, and management efforts currently in place to reduce the likelihood of entry.

For instance, the probability of MPB entry into Yukon is currently higher than into Saskatchewan because of the absence of management efforts in northern British Columbia compared with the efforts underway along the Alberta/Saskatchewan border.

Negligible (0)	The probability of entry is extremely low given the combination of factors including the distribution of the pest and susceptible hosts, interception history, predictive sampling results, management practices applied, or unsuitable climate.
Low (1)	The probability of entry is low but clearly possible given the expected combination of factors necessary for occurrence described above.
Medium (2)	The probability of entry is likely given the combination of factors necessary for occurrence described above.
High (3)	The probability of entry is very likely or certain given the combination of factors necessary for occurrence described above.

Source: Canadian Food Inspection Agency

Establishment potential – Evaluating the probability of establishment involves comparing information about a pest's biology and conditions in its current area of distribution with the conditions present in the PRA area. Establishment – meaning the perpetuation for the foreseeable future of a pest within an area after entry – depends on the interactions of pest, host and environment (Figure 6).

Assessing establishment potential involves three tasks:

- First, the following information on the three establishment elements (Figure 6) should be collected:

» Biological information about the pest – its life cycle, hosts, alternate hosts and vectors, reproductive and adaptive capacity, environmental conditions
» Information about the PRA area – environmental conditions (such as climate, soil types and vegetation), vectors, natural enemies
» Information about hosts in the PRA area – what hosts are present, how abundant they are, how they are distributed, whether they are managed or not

Figure 6. Elements required for pest establishment.

- Second, the information collected about the hosts in the areas where the pest is already present should be compared with the information about the PRA area. Similarities or differences that would significantly impact the probability of the pest's establishment after entry into the PRA area should be noted. The suitability of the environment, or climatic suitability, of the PRA area is one of the most important factors in determining the potential distribution of a pest. Information about the climate and environmental conditions in the known distribution areas of the pest can often be extrapolated to predict the pest's potential distribution in the PRA area.

- Third, the probability of establishment should be assessed: how likely the pest is to become established in the PRA area after entry. This is different from determining the seriousness of the impacts or estimating how rapidly the pest would become established over the PRA area. The questions here are: Is there a threshold population required for establishment? and Will practices currently being used in the PRA for other pests on similar hosts control this pest?

The better your knowledge and understanding of the pest's biology, the conditions under which it occurs in its current distribution, and the conditions in the PRA area, the better able you will be to assess its establishment potential.

Negligible (0)	The pest has no potential to survive and become established in the PRA area.
Low (1)	The pest has potential to survive and become established in approximately one third or less of the range of economic or environmentally significant range of its host in the PRA area.
Medium (2)	The pest has potential to survive and become established in approximately one third to two third of the range of economic or environmentally significant range of its host in the PRA area.
High (3)	The pest has the potential to survive and become established throughout most or all of the range of economic or environmentally significant range of its host in the PRA area.

Source: Canadian Food Inspection Agency

Spread potential – Natural spread potential is estimated based on: host abundance and connectivity; dispersal potential; presence and abundance of vectors and alternate hosts; population persistence (i.e., suitability of the environment for natural spread); presence of natural barriers; levels of natural enemies; and biological aspects of the pest, including reproductive capacity. Information about all of these factors helps to determine how the pest spreads, and how fast and how far it could spread in the PRA area. Human-assisted spread should also be considered.

These types of assessments are qualitative and should make use of existing data and expert opinion to describe the predicted means, rate and magnitude of spread. Spread can be described in relative terms (such as "faster than," "further than" or "less effectively than") or in descriptive terms (such as "rapid," "widespread" or "localized").

Predictive spread models are also sometimes used to add more precision to the assessment of spread potential. These models may be quantitative or qualitative, and often substitute expert opinion or assumptions for hard data when the latter are not available. Predictive spread models often provide a visual image of spread over time, which is a useful communication and planning tool.

Negligible (0)	The pest has no potential for spread in the PRA area.
Low (1)	The pest has potential for spread within the area of introduction or historical distribution area e.g. some reproductive potential and/or some mobility of propagule, in the PRA.
Medium (2)	The pest has potential for spread beyond the area of introduction or historical distribution area e.g. high reproductive potential or highly mobile propagules.
High (3)	The pest has potential for rapid spread to all of the PRA area e.g. high reproductive potential and highly mobile propagules.

Source: Canadian Food Inspection Agency

Likelihood of occurrence and spread rating – The likelihood of occurrence is determined by multiplying the individual scores of the probability of entry, establishment and spread potential. Each of the factors is necessary for risk to exist. The resultant score determines the likelihood of occurrence. See Appendix 1 (CFIA Rating Guidelines: Determination of Pest Risk) for guidance in determining ratings based on resultant scores.

For the purposes of transparency, the numerical score and risk rating for each of the three factors should be included in the risk assessment.

Consequences of occurrence – Consequences of occurrence is determined based on the potential socioeconomic and environmental impacts that the pest could have in the PRA area.

Assessments about the impacts of the pest can be conducted using qualitative judgment, qualitative description and expert judgment, or – with more time and resources – models and spreadsheets. Impact assessments can be challenging because of the lack of sufficient data to generate information on potential economic and environmental losses.

A good first step is to determine the pest impacts in areas where the pest already occurs, the significance of the damage, the frequency of occurrence, and whether the pest's presence is related to biotic or abiotic events.

Socioeconomic impacts – Social impacts to be considered include: loss of employment; increased risk to human health and safety from increased wildfire risk; loss of tourism; reduction in or loss of traditional plants for cultural purposes; loss of green space, including parks for recreational activities; reduced property enjoyment or recreational activity resulting from nuisance species; negative impacts on human health and personal well-being (e.g., from biting insects, frass, webbing, species overabundance); public expectations of native species composition or favoured organisms (e.g., provincial tree, attractive species, beneficial insects, symbolic species); need to redirect limited financial and human resources to pest management and away from other social needs (e.g., municipal recreational programs, education, health); and loss of species of cultural or heritage value.

Economic impacts include direct and indirect effects and market and non-market impacts. Market impacts have a monetary value. The direct effect of a pest on timber products could lead to reduced yield or extra control and management costs. Economic impacts to be considered include: cost of control programs (including wildfire fighting expenditures); changing harvesting schedules and times; need for site sanitation and removal of habitat refugia; indirect costs associated with impacts of regulatory controls; costs associated with fuel reduction programs; reduced home and property values; and increased air conditioning costs (loss of shade trees).

Socioeconomic consequences are expressed over time, and there may be a lag between a pest's establishment and the expression of consequences of that. Furthermore, the consequences can change as the distribution of pest occurrences varies over time. For example, a pest may originate at a single point and spread slowly; or it may be introduced at multiple points and spread rapidly. Thus, determining the potential socioeconomic consequences of a pest requires analyzing its rate of spread and the expected manner of spread.

Negligible (0)	There is no social or economic impact on value.
Low (1)	The pest has minor social or economic impacts.
Medium (2)	The pest has moderate social or economic impact.
High (3)	The pest has a severe social or economic impact on value(s).

Source: Canadian Food Inspection Agency

Environmental impacts – Environmental impacts can include:

- direct effects, such as loss of keystone species (species that are of fundamental importance to the integrity of the ecosystem), loss of threatened or endangered species, reduction of range or viability of keystone species or endangered species, and damage to watersheds and water bodies; and
- indirect effects, such as increased wildfire risk and changes in habitat composition or abundance, soil structure, water table, and ecosystem structure and function.

Negligible (0)	There is no potential to degrade the environment or otherwise alter ecosystems by affecting species composition.
Low (1)	There is limited potential impact on the environment, slightly reducing host longevity, competitiveness, as well as recreation or aesthetic impacts.
Medium (2)	There is potential to cause moderate impact on the environment with obvious change in the ecological balance, affecting several attributes of the ecosystem, as well as moderate recreation or aesthetic impacts.
High (3)	There is potential to cause major damage to the environment with significant losses to plant ecosystem structure and functions and subsequent physical environmental degradation.

STEP 5. SUMMARIZE THE RISK ASSESSMENT AND NEXT STEPS

In this concluding step of the risk assessment, the overall risk should be summarized using the procedure outlined in Appendix 1. This includes describing in brief the strengths (e.g., evidence) and weakness (e.g., uncertainties) of the assessment. Research needs should also be identified based on the uncertainties, and research priorities set based on the consequences of not knowing (Appendix 5). A research plan may be developed as well (optional).

Once the risk has been determined, it is up to the assessor to decide whether it is acceptable. It could be so low that the costs of lowering it further are greater than the impacts of the pest itself. Or, if the risk is no greater than that already being posed in the PRA area by the pest being assessed, or the pest can be managed through practices that are already in place, then there would be no reason to impose mitigation measures (because they will provide no added protection).

Deciding that the pest risk is acceptable can be a complex exercise, requiring the balancing of costs and benefits in the context of the economic, environmental and social impacts in the PRA area.

Deciding that the pest risk is unacceptable is perhaps more straightforward: if the pest incursion is expected to result in significant economic, environmental or social consequences, then the risk is likely unacceptable.

Critical review of risk assessments by practitioners has high value in directing next steps and engaging stakeholders. Gaps identified by initial assessments may be quickly filled once their importance is put into operational context as a need to formulate a response (Nealis, 2009).

CONDUCTING A RISK RESPONSE

Determining the best response to the assessed risk requires the project team to identify options for response, evaluate those options and select the ones that seem to be the most appropriate to manage the risk (Nealis, 2015).

The extent to which an action is appropriate will depend on its efficacy and feasibility, and on consideration of whether the action introduces new risks or exacerbates existing ones. Decisions leading to control will likely require a pest management plan and provision for quality control and review in relation to statutory policies. In the risk response step, research needs should also be identified and prioritized, as determined by the risk assessment and risk response uncertainties.

STEP 1. IDENTIFY RISK RESPONSE OPTIONS

Following knowledge synthesis and information exchange – of research findings and anecdotal observations – all possible risk response options should be identified.

In arriving at options, all pathways of the pest should be taken into account. For instance, in the case of emerald ash borer, both natural spread and firewood movement should be considered in terms of mitigation options. Depending on the pest, the points at which mitigation options might be applied should also be looked at, based on the most likely pathways of entry and expansion.

STEP 2. EVALUATE RISK RESPONSE OPTIONS

Each risk response option should be evaluated in terms of its: effectiveness in achieving the desired outcome; efficiency in achieving the expected results; expected costs and cost effectiveness; feasibility and practicality, potential adverse consequences to human health, economic values and ecosystem health; and effects on overall risk. Stakeholder and public consultation should also be considered in this evaluation.

For each option, assumptions and uncertainties should be taken into account.

Where predicted damage levels do not necessitate action, or where conventional or operational response options do not exist, have low efficacy, are cost prohibitive or are not palatable to the public, then a research plan should be considered based on knowledge gaps. Valid response options can include those outside of conventional control options, such as using enhanced, consistent monitoring and identifying, promoting and garnering support for research needs.

STEP 3. SELECT RISK RESPONSE OPTIONS

After evaluation of the options, those measures or groups of measures that will bring the risk down to an acceptable level should be selected. Selection of the appropriate response measure should be based on consideration of the costs and benefits of treatment, and of the public appetite for response.

STEP 4. PROVIDE CONCLUSIONS AND RECOMMENDATIONS

The PRA should be concluded with a summary of the overall risk (drawn from the risk assessment and risk response steps) and recommendations that will help guide development of policy, a pest management plan, and a research plan. Each recommendation should include a level of uncertainty that is based on the predicted costs, benefits, effectiveness, efficiency and feasibility of the mitigation action it contains.

The guiding principle for pest risk management should be to achieve the required degree of protection that can be justified and is feasible within the limits of available options and resources.

REPORTING ON THE PRA

A potential reporting template is shown in the sidebar below. It can be modified to accommodate jurisdictional reporting or communication requirements.

EXECUTIVE SUMMARY (OPTIONAL)

Introduction – Describe the history and current status of the pest (including phytosanitary or management measures to date), any previous PRAs conducted for the pest, brief description of the pest's known impacts, and the rationale for this PRA.

Pest Risk Analysis Overview – Describe the NFPS pest risk analysis framework, elements and components. Briefly describe the approach used in the assessment (e.g., affirmative statements, evidence, uncertainties and information gaps). Link to an appendix that provides full descriptions of uncertainty and pest rating guidelines, if any, used in the assessment.

Trigger – Describe the potential threat that triggered the PRA. (See page 15 of the guide.)

Objectives – List the objectives set for the PRA. (See page 16 of the guide.)

Risk Communication – Describe the importance of risk communication and any workshops and outcomes associated with the PRA. (See page 18 and Appendix 5 of the guide.)

Quick Pest Facts (or similar) – Briefly describe the pest's biology and epidemiology in its native habitat and highlight any uncertainties as they pertain to the geographic scope of the PRA.

Pest Risk Assessment Summary – Provide the overall risk rating for the pest, and concluding remarks, including areas with greatest uncertainty and considerations for future research priorities.

Pest Risk Response – Report the identified options for response and the appropriate actions to take to manage risk, if risk deemed unacceptable. (See page 27 of the guide.)

Risk Response Conclusions and Recommendations – If a risk response section has not been included, present management considerations and list the research priorities identified.

References

Appendices – Use as necessary to provide uncertainty ratings, pest rating guidelines, communication materials, and any other information referred to in the body of the document.

References

Canadian Council of Forest Ministers (CFIA), Forest Pest Working Group. 2015. Pest risk analysis: Risk assessment of the threat of brown spruce longhorn beetle to Nova Scotia forests. Compiled by Department of Natural Resources Forest Protection, Shubenacadie, NS. Ottawa, ON. 87 p.

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Porter, K. 2012. Looming spruce budworm outbreak in Quebec. PowerPoint presentation. National Forest Pest Strategy Risk Analysis Framework: Technology Transfer Workshop, Halifax, NS, March 21–22, 2012.

Presidential/Congressional Commission on Risk Assessment and Risk Management. 1997. Risk management in regulatory decision-making. Final Report, Volume 2.

APPENDIX 1. *CFIA Rating Guidelines for Determining Pest Risk*

Predefined ratings of high, medium, low and negligible are assigned to the overall risk for the two key risk assessment elements: probability (occurrence, establishment, spread) and impacts (economic, environmental, social). The overall risk is based on a combination of these ratings.

The PRA template used by the Canadian Food Inspection Agency (CFIA) is based on standards No. 2 and No. 11 of the International Plant Protection Convention (IPPC) and has been modified and refined over many years. This approach facilitates a nationally consistent, transparent and accountable approach to defining pest risk from invasive alien species.

PROBABILITY OF INTRODUCTION AND SPREAD

The individual ratings given to the probability of entry, probability of establishment and probability of spread are factored into a re-rating to determine the probability of introduction and spread of the pest.

A product score is reached by multiplying the individual numerical scores. Depending on the resulting score, the likelihood of introduction will be rated as negligible (0), low (1–3) medium (4–12) or high (>12), in accordance with the following guide:

Resultant Score	Likelihood of Occurrence and Spread Rating
0	Negligible
1–3	Low
4–12	Medium
18 or 27	High

Note that the underlying assumption behind this approach is that entry, establishment and spread all need to occur for there to be risk – that is, if one of these factors is rated as 0 or negligible, the likelihood of occurrence and spread rating is 0.

Both the numerical rating, derived by multiplying the individual ratings for entry, establishment and spread, and the description rating (negligible, low, medium or high) are provided in the pest risk assessment so that the reader can see which factors contribute most or least to the overall rating.

Probability of introduction and spread = probability of entry × probability of establishment × probability of spread.

	Numerical Score	Risk Rating
A. Probability of entry		
B. Probability of establishment		
C. Probability of spread		
D. Overall probability of introduction and spread (A*B*C)		

CONCLUSION OF THE PEST RISK ASSESSMENT

Overall risk is a product of probability and consequence, so the summary of pest risk is presented as ratings for each of these two elements, and the level of uncertainty associated with each is indicated.

	Risk Rating	Uncertainty Level
Overall probability of introduction and spread (D from previous table)		
Potential socioeconomic consequences		
Potential environmental consequences		
Overall risk		

APPENDIX 2. *International PRA Guides*

COUNTRY

Australia
www.planthealthaustralia.com.au/wp-content/uploads/2013/07/Pest-risk-assessment-for-IBPs-July-2013.pdf

New Zealand
https://mpi.govt.nz/document-vault/2031

European and Mediterranean Plant Protection Organization
www.eppo.int/QUARANTINE/Pest_Risk_Analysis/PRA_intro.htm

United States
www.aphis.usda.gov/import_export/plants/plant_imports/process/downloads/PRAGuidelines-ImportedFruitVegCommodities.pdf

COMPARATIVE DOCUMENTS

EFSA Panel on Plant Health (PLH); Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA. *EFSA Journal* 2010; 8(2):1495. [66 pp.]. doi:10.2093/j.efsa.2010.1495. Available online: www.efsa.europa.eu/en/efsajournal/pub/1495.htm

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APPENDIX 3. *Prioritizing Research Needs: Example*

Prioritization of uncertainties identified in a PRA by category, consequences of not knowing, and ways to reduce uncertainty.[1]

Priority	Category	Uncertainty	Consequences of Not Knowing	Ways to Reduce Uncertainty
1	Biology and Epidemiology	i. There is moderate uncertainty regarding increased brood productivity in naïve pine as it is based on limited observations and could be associated with local factors affecting host defense. ii. There is a moderate degree of uncertainty as to the population growth or persistence potential associated with successful overwintering progeny below the snowline in novel forests due to increased brood production in naïve pine. iii. There is moderate uncertainty as to the proportion of the northern expanding population which is univoltine and that which is semivoltine. iv. There is high degree of uncertainty with the interpretation of MPB limiting factors in historic habit to those of novel forests. v. There is low to moderate uncertainty regarding the incidence of secondary insects and their potential role in endemic populations in naïve pine forests in Yukon. vi. There is moderate uncertainty regarding future climatic conditions and limiting factors to MPB survival and persistence in novel habitats.	High –Management strategies and tactics will not be calibrated to new population processes and dynamics. This includes monitoring tools and thresholds used to interpret MPB populations i.e. polygon:spot ratios, green:red ratios, overwinter surveys, and proportion of infested trees to remove in order to maintain or reduce population levels. Misinterpretation of population success and associated risk will lead to inadequate or inefficient deployment of resources, and ineffective management efforts.	Continued monitoring and research into population processes and dynamics in novel forests to help calibrate revised population-based management frameworks currently being developed by UBC. Revise RA once UBC has completed models.
2	Monitoring	There is moderate uncertainty on causal agent of the three spot infestations near Yukon border.	Moderate – If the spots are MPB, and they are accurately quantified, they are likely not large enough to lead to explosive population levels and expansion next year.	Confirm and potentially remove 2012 attacked trees, or monitor for growth and expansion.
2	Climate and Susceptibility	There is a moderate degree of uncertainty regarding stand susceptibility parameters and applicability to Yukon forests.	Moderate – Misrepresentation of stand susceptibility will result in misguided deployment of management tactics and compromise ability to suppress or eliminate MPB populations.	Determination of tree and stand characteristics associated with MPB in once established and validation/modifications to existing susceptibility rating system.

[1] Hodge, J.C. 2012. Mountain pine beetle pest risk analysis for Yukon lodgepole pine forests. Contract report submitted to Yukon Government Energy, Mines and Resources, Forest Management Branch, Whitehorse, Yukon. 84 p.

APPENDIX 4. Checklist and Description of Factors to Consider in a Pest Risk Analysis

Phase/Step	Description	Done?
Initiation		
Initiation/Trigger	Conduct a quick evaluation to determine whether the perceived threat is of significance to your agency.	
Planning	Define a project team, possibly including stakeholders. Conduct a planning session and formulate an action plan that includes draft objectives, type of communications required, format of information- and knowledge-gathering phases, and timelines.	
Risk Assessment		
Step 1. Scope out hazard	Identify your area of concern, resource assets at risk, and stakeholders within the area.	
Step 2. Define the risk tolerance threshold	Determine the threshold based on whether the risk is imminent and unacceptable, and whether control actions might be required before a full PRA were completed.	
Step 3. Conduct a pre-assessment	Make a quick estimate of the pest's likelihood of occurrence and of the consequences of its occurrence, to determine whether a full PRA is warranted.	
Step 4. Conduct a comprehensive pest risk assessment		
Probability of entry	Determine the current status and distribution of the pest and the mitigation actions in place to prevent entry.	
Establishment potential	Determine whether the conditions in the pest's historic or native habitat are similar to those in the area of concern. As well, consider: the distribution of the host in the area of concern; the pest's biology; and the environment. Assess whether current practices in place to manage other pests in the area of concern would also control potential establishment by the pest in question.	
Spread potential	Find out how the pest spreads, and how far and how fast; and determine host abundance and connectivity, pest dispersal potential, presence and abundance of vectors or an alternate host, climate favourability, natural barriers and enemies, and reproductive capacity.	
Socioeconomic impacts	Identify and quantify all relevant social and economic impacts in the PRA area.	
Environmental impacts	Identify and quantify all relevant environmental impacts in the pest risk analysis area.	
Step 5. Summarize the risk assessment and next steps	Determine the overall risk and acceptability using the CFIA method (in Appendix 1), and summarize research needs and develop research plan as necessary (optional).	

Phase/Step	Description	Done?
Risk Response and Conclusion		
Step 1. Identify risk response options	Identify both traditional and emerging response options.	
Step 2. Evaluate risk response options	Consider cost effectiveness, efficacy, feasibility and practicality, adverse consequences to other factors including human health, and expected costs. Identify uncertainties.	
Step 3. Select risk response options	No response is also an option if cost prohibitive or not efficacious. Identify and promote research needs accordingly.	
Step 4. Provide conclusions and recommendations	Summarize the overall risk by considering both risk assessment and risk response and make recommendations which will guide policy and development of a pest management plan and research plan.	

APPENDIX 5. *Risk Communication Principles and Potential Barriers*

Adapted from FAO (1998) and IPPC (2007)

- Knowing your audience is a basic principle of any kind of communication. Messages directed to people of different backgrounds or levels of knowledge need to be delivered in a way that reaches each distinct audience. Therefore, effective communication requires a good understanding of who you are talking to – and the best way to do that is to maintain an open channel of communication with them.
- Scientists must be involved in a PRA as they can provide critical input in gathering and interpreting information and data. At the same time, they must be able to clearly explain what they know and what they don't know, and to explain the uncertainties related to the risk assessment process.
- Successful risk communication requires expertise that managers and technical experts may or may not have. That's why people with expertise in risk communication should be involved as early as possible to help shape and target communication efforts.
- Information coming from credible sources is the best way to influence people's perceptions of a risk. Sources recognized for their expertise, trustworthiness, fairness and lack of bias are recommended.
- Government agencies have a fundamental responsibility in risk communication, particularly when risk management decisions involve regulatory or voluntary controls. But all parties involved in the risk communication process have joint responsibilities for the outcome of the communication even though their individual roles may differ. It is important to keep this in mind and engage others.
- Transparency in risk analysis consists of having the process open and available for scrutiny by affected and interested parties. An open, two-way flow of information between risk assessors, managers and affected and interested parties is key to achieving transparency.
- Risk communication should start early enough and throughout the PRA process. Many controversies become focused on the question, "why didn't you tell us sooner" rather than on the risk itself. Starting communication efforts early and continuously may avoid that.
- Most of the communication will take place during the pest risk analysis. During the pest management stage, communicating issues related to effectiveness and likely impacts of risk response measures on the affected groups contributes to a better understanding of the positive and negative outcomes of the proposed mitigation measures. Other measures that had not previously been identified may also come to light.

POTENTIAL BARRIERS

Barriers can be specific to the pest risk analysis process or even to the specific issue under consideration. Other barriers will apply to all contexts. Process barriers include the following:

1. Restricted access to vital information feeding in a pest risk analysis may be an important challenge. Information and data may be unavailable, inexistent or inaccessible which will have a significant impact on uncertainties at different steps of the PRA, such as in the risk characterization and the evaluation of mitigation options.
2. A lack of participation in the PRA process by those parties having a significant interest in the outcome, can be also be an important barrier. Broad participation in the process will improve communication by offering opportunities to identify and address the concerns of interested

parties when decisions are made. Those who were involved in the decision-making process are less likely to challenge the outcomes, especially if their concerns have been addressed.

Other barriers that apply in all contexts include the following:

1. Individuals perceive risks or values very differently. People may disagree with risk assessors and managers regarding the relative magnitude or priority of risk. It is thus important to gain an understanding of how interested parties perceive the risk (e.g. through meetings, focus groups, surveys and other methods).
2. Receptivity also differs from an individual or a group to another. For instance, many individuals believe they are less at risk than others and perceive that risk messages are directed to others. Risk taking behaviours may also be perceived as normal or desirable within particular groups, and risk messages may then be discounted as inappropriate.
3. Over-reliance on precise scientific terminology may even obscure the meaning of facts for non-experts and limit the effectiveness of communication. If messages are not kept relatively simple, they may be misunderstood. Communicators should then try to minimize the differences between them and their audience by using a language that is clear and comprehensible to other parties.
4. Finally, the media play an important role in risk communication because they can heavily influence public perception about risks. However, they have their own agendas, they can decide what is newsworthy and they can instigate concern or draw attention to neglected or underappreciated risks. Therefore, risk communicators need training in media skills in order to avoid issues. One thing to keep in mind is that honesty and accuracy are essential in a relationship with the media.

As pest issues evolve, new information will likely be obtained during or after the risk analysis process. Appropriate communications ensure that people have the necessary information to complete a risk analysis adequately.