PEST RISK ANALYSIS (PRA) TRAINING

Participant Manual

Standards and Trade Development Facility

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Agence canadienne d'inspection des aliments

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FOREWORD

Welcome to the IPPC introductory pest risk analysis (PRA) particpant manual. This manual has been designed to provide practical guidance to biological scientists, plant pest risk assessors, plant pest risk analysts and phytosanitary policy makers working in the field of international phytosanitary affairs who want a basic introduction to PRA.

The material in this manual explains the international context for PRA and outlines the pertinent international standards and resources available for pest risk assessment, pest risk management and pest risk communication.

Workshop materials that should accompany this manual include slides to be used to support oral presentations, practical exercises and a list of additional reading material. Instructors should be provided with a guide providing advice for delivery of this training package.

Participants will learn through the use of a variety of teaching methods ranging from formal presentations by experienced PRA workers, to small interactive group exercises and discussions in which all participants have the opportunity to play an active role.

The training course aims to:

- provide participants with the background knowledge to understand the purpose of PRA and how PRA fits into the IPPC,
- develop the skills required to conduct PRAs within the context of the IPPC,
- provide hands-on experience in conducting PRAs,
- provide examples of how PRA is performed in other countries, and
- develop self confidence amongst the course participants.

Upon completion of this course participants should be familiar with the structure and function of a PRA document and have conducted a number of trial PRAs as well as seen and discussed examples of many more. They should have the self confidence to complete PRAs and will know where to look for information to assist them and where to seek help when required.

1. THE INTERNATIONAL PLANT PROTECTION CONVENTION

The introduction and spread of plants and pests of plants from one geographical area to another is an issue of worldwide concern, and is addressed at the international level by several agreements. The principal agreement aimed at preventing the spread and introduction of pests of plants and plant products is the International Plant Protection Convention (IPPC). The IPPC is a multilateral treaty for international cooperation in plant protection. Its purpose is to secure common and effective action to prevent the spread and introduction of pests of plants and plant products, and to promote appropriate measures for their control (IPPC Article I.1). The Convention also aims to protect plant health while limiting interference with international trade. The IPPC applies to cultivated plants, natural flora and plant products, and includes both direct and indirect damage by pests (thus including plants as pests of plants (e.g., weeds)). In addition to plants and plant products, the IPPC also extends to storage places, packaging, conveyances, containers, soil and any other organism, object or material capable of harbouring or spreading pests of plants (Article I.4).

Pest

The IPPC defines a pest as: "...any species, strain or biotype of plant, animal or pathogenic agent, injurious to plants or plant products" (IPPC Article II.1).

Countries that have ratified the IPPC are referred to as contracting parties. Over 80% of the countries in the world are contracting parties to the IPPC. Contracting parties agree to cooperate with one another in their attempts to prevent the international spread of pests of plants. This includes exchanging information on pests of plants, providing technical and biological information necessary for pest risk analysis, and participation in any special campaigns for combating pests. Countries that have not ratified the IPPC (non-contracting parties) often also uphold the Convention, and are encouraged to do so (Article XVII).

Purpose of the IPPC

The purpose of the IPPC is to secure "...common and effective action to prevent the spread and introduction of pests of plants and plant products and to promote appropriate measures for their control."

One of the primary tools available to protect plant species of economic, environmental and aesthetic importance from pests that can spread into a new area is the application of phytosanitary measures.

From an import point of view, contracting parties may apply phytosanitary measures only where such measures are necessary to prevent the introduction and/or spread of quarantine pests or to limit the economic impact of regulated non-quarantine pests. Contracting parties shall apply phytosanitary measures in a transparent and non-discriminatory manner and they

Quarantine

The word quarantine has its roots in the Latin word for forty. It originally referred to the period of detention which was imposed on ships' passengers to allow latent cases of disease to develop before passengers were permitted to land. The earliest record of such restrictions for human disease goes back to the latter half of the 14th century. Subsequently, as governments became more concerned with the spread of pests destructive to agricultural and forest crops, new controls were gradually introduced under the name Plant Quarantine.

agree that phytosanitary restrictions will be used only where technically justified and not in lieu of barriers to protect an industry from competition.

From an export point of view, contracting parties shall make arrangements to ensure that their exports are not the source of new pests into their trading partners' territories and that their exports meet the import requirements of the importing country.

The IPPC is an international treaty, binding to contracting parties. Contracting parties have the right to use phytosanitary measures to regulate imports, but have an obligation to do so only where necessary and technically justified. Some other obligations of contracting parties include the following:

- establishing a National Plant Protection Organization (NPPO) (Article IV.1),
- publishing and transmitting their phytosanitary requirements, restrictions and prohibitions (Article VII.2b),
- conducting surveillance for pests (Article VII.2j),
- notifying trading partners of non-compliance with import requirements and emergency actions taken (Article VII.6), and
- exchanging information on pests of plants (including pest reporting) (Article VIII.1a).

The Commission on Phytosanitary Measures (CPM) is the governing body of the IPPC and it meets on an annual basis. The CPM has adopted a number of International Standards for Phytosanitary Measures (ISPMs) that provide guidance to countries and assist contracting parties in meeting the aims of the Convention. Some of the areas covered by ISPMs include: surveillance, pest risk analysis, establishment of pest free areas, export certification, phytosanitary certificates and pest reporting. Under the IPPC, ISPMs are considered guidance and their application is not mandatory; however, under the WTO-SPS Agreement, phytosanitary measures based on international standards do not need additional scientific or technical justification.

Phytosanitary Measures

Phytosanitary Measures have been defined in International Standard for Phytosanitary Measures (ISPM) No. 5 (*Glossary of phytosanitary terms*, 2006) as "any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests".

As outlined in the Guide to the IPPC (provided to students in the pre-course material), the IPPC Secretariat coordinates the work programme for the global harmonisation of phytosanitary measures under the IPPC.

The IPPC Secretariat:

- implements the policies and activities of the CPM,
- oversees the IPPC standard setting work programme, including the development of ISPMs,
- publishes information related to the IPPC,
- facilitates information exchange between contracting parties to the IPPC,

- coordinates with the technical cooperation programmes of FAO to provide technical support on matters relating to the IPPC, particularly to least developed nations,
- facilitates dispute settlement, and
- liaises with other relevant international organizations.

1.1 NATIONAL PLANT PROTECTION ORGANIZATIONS

A National Plant Protection Organization (NPPO) is an official service established by a government to fulfil the functions specified in the IPPC. NPPOs implement the phytosanitary laws and/or regulations issued by their governments. Responsibilities of NPPOs under the IPPC (Article IV) include:

- issuance of phytosanitary certificates,
- surveillance and inspection,
- controlling pests (for example, administering treatments, preventing spread, disinfection or disinfestation),
- protecting endangered areas,
- conducting pest risk analyses,
- ensuring phytosanitary security of consignments from certification until export, and
- designation, maintenance and surveillance of pest free areas and areas of low pest prevalence.

To facilitate information exchange between the IPPC and contracting parties, each country has a designated official contact point, which is most often the NPPO. These contact points can be found on the IPPC web site: https://www.ippc.int/IPP/En/nppo.jsp

1.2 REGIONAL PLANT PROTECTION ORGANIZATIONS

Contracting parties also cooperate with each other within their regions through Regional Plant Protection Organizations (RPPOs). The functions of RPPOs include:

- participating in activities to achieve the objectives of the IPPC,
- disseminating information relating to the IPPC, and
- cooperating with the CPM and the IPPC secretariat in the development of international standards.

There are currently nine RPPOs, as follows:

- Asia and Pacific Plant Protection Commission (APPPC)—Southeast Asia, Indian subcontinent, Australia and New Zealand. Website: https://www.ippc.int/id/13497
- Comunidad Andina de Naciones (CAN) —Andean community. Website: www.comunidadandina.org
- Comité de Sanidad Vegetal del Cono Sur (COSAVE) —Southern cone of South America. Website: www.cosave.org

- Caribbean Plant Protection Commission (CPPC)—Caribbean Islands and Central America. Website: https://www.ippc.int/id/13470
- European and Mediterranean Plant Protection Organization (EPPO)—Europe and Mediterranean. Website : www.eppo.org
- Inter-African Phytosanitary Council (IAPSC)—Africa. Website: www.au-appo.org
- North American Plant Protection Organization (NAPPO)—North America. Website: www.nappo.org
- Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA) —Central America. Website: ns1.oirsa.org.sv
- Pacific Plant Protection Organization (PPPO)—Southwest Pacific Islands. Website: www.spc.int/pps

RPPOs each have their own independent statutes and conduct their own regional programmes. They may also create regional standards for their member countries. RPPOs cooperate with each other and with FAO and meet annually at the Technical Consultation, a meeting coordinated by the IPPC Secretariat. Lists of member countries of each RPPO and reports of these meeting can be found on the IPPC website: https://www.ippc.int

1.3 World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures

The World Trade Organization (WTO) is the international organization responsible for establishing rules of trade between nations. It is a legally binding agreement for WTO members. WTO agreements are the result of negotiations between WTO members and through these agreements members operate a non-discriminatory trading system that outlines their rights and obligations. Each member receives guarantees that its exports will be treated fairly and consistently in other member countries' markets and, likewise, each member country agrees to do the same for imports into its own country.

The WTO Agreement on the Application of Sanitary and Phytosanitary Measures (WTO-SPS Agreement) is an agreement on how governments can apply food safety and animal and plant health measures while facilitating trade.

With regard to plant health, the WTO-SPS Agreement allows countries to set their own standards to protect their economy or environment from damage due to the entry, establishment or spread of pests of plants. At the same time, it encourages them to use international standards, guidelines and recommendations, where they exist, when developing their sanitary and phytosanitary measures (Article 3 of the WTO-SPS Agreement).

Like the IPPC, the WTO-SPS Agreement states that measures must be science-based and not used for the purpose of trade protection. It requires that phytosanitary measures be based on an assessment of the risk to human, animal or plant health, taking into account risk assessment techniques developed by the relevant international organizations, and that they should be technically justified.

The WTO recognises the IPPC as the relevant international standard setting body for plant health. The WTO-SPS Agreement encourages its members to harmonise their sanitary and phytosanitary measures on the basis of international standards. In this way international standards for phytosanitary measures which are adopted by the CPM set out the basic internationally agreed elements for the establishment of harmonized plant health standards and phytosanitary measures. These phytosanitary measures can be set up at all levels of government: provincially, nationally, regionally and in some cases internationally.

1.4 PRIMARY PHYTOSANITARY PRINCIPLES

ISPM No. 1: (*Phytosanitary principles for the protection of plants and the application of phytosanitary measures in international trade*, 2006) describes twenty eight principles, eleven of which are basic principles and seventeen operational principles. The eleven basic principles are fundamental to all aspects of IPPC-related activities undertaken by a member country. They are:

- Sovereignty—countries have the sovereign authority to utilise phytosanitary measures to regulate the entry of plants and plant products or other regulated articles, for the purpose of preventing the introduction and/or spread of quarantine pests into their country.
- Necessity—phytosanitary measures may only be applied where such measures are necessary to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests.
- Managed risk—phytosanitary measures should be based on a policy of managed risk, recognizing that risk of the spread and introduction of pests always exists when importing plants, plant products and other regulated articles.
- Minimal impact—phytosanitary measures should be consistent with the pest risk involved and should represent the least restrictive measures available to address that risk. They should result in the minimum impediment to international movement of people, commodities and conveyances.
- Transparency—countries should publish and disseminate phytosanitary requirements, restrictions, and prohibitions promptly and the rationale for such measures should be made available upon request.
- Harmonisation—phytosanitary measures should be based, wherever possible, on international standards, guidelines and recommendations developed within the framework of the IPPC.
- Non-discrimination—phytosanitary measures should be applied without discrimination between countries of the same phytosanitary status. For a particular quarantine pest, phytosanitary measures should be no more stringent when applied to imported goods than measures applied to the same pest within the territory of the importing country.
- Technical justification—phytosanitary measures should be technically justified based on an appropriate pest risk analysis or, where applicable, another comparable examination and evaluation of available scientific information.
- Cooperation—countries should cooperate to prevent the spread and introduction of pests of plants and plant products, and to promote measures for their official control.
- Equivalence—importing countries should recognise alternative phytosanitary measures proposed by exporting countries as equivalent when those measures are demonstrated to achieve the appropriate level of protection determined by the importing country.

- Modification—modifications of phytosanitary measures should be determined on the basis of a new or updated pest risk analysis or relevant scientific information. Countries should not arbitrarily modify phytosanitary measures.

In addition to the eleven basic principles, ISPM No. 1 (2006) also describes the seventeen operational principles, which either relate to the establishment, implementation and monitoring of phytosanitary measures or to the administration of a phytosanitary system.

1.5 INTERNATIONAL STANDARDS FOR PHYTOSANITARY MEASURES

International Standards for Phytosanitary Measures (ISPMs) are intended to harmonise phytosanitary measures used in international trade. They provide guidance to member countries to assist them in implementing national phytosanitary programs that fulfill the requirements of the IPPC and contribute to harmonisation between contracting parties. Although WTO member countries are required to base their phytosanitary measures on international standards where they exist, national phytosanitary measures do not necessarily violate the WTO-SPS Agreement if they differ from international standards. The application of phytosanitary measures that result in higher standards must be technically justified.

1.5.1 HOW ISPMS ARE SET

Contracting parties cooperate and provide input into the development of ISPMs which are adopted by the Commission on Phytosanitary Measures (CPM).

Topics for ISPMs may be proposed by NPPOs, RPPOs, the IPPC Secretariat and the WTO-SPS Committee. The CPM approves the IPPC standard setting work programme and decides on priorities for ISPM development. The Standards Committee, the body responsible for overseeing the standard setting process, then develops a specification for each draft ISPM, which outlines what the ISPM should address. A first draft is written by an expert working group or technical panel and is then submitted to the Standards Committee. The Standards Committee reviews and modifies the draft as necessary and then it is submitted to NPPOs and RPPOs for consultation.

In this consultation phase, NPPOs and RPPOs review draft ISPMs and submit their comments to the IPPC Secretariat through the NPPO contact point. These comments are considered by the Standards Committee and any changes deemed necessary are made to the draft ISPM. Once the draft ISPM is satisfactory to the Standards Committee, it is then submitted to the CPM. The CPM either returns the draft ISPM to the Standards Committee for further revision, or revises it as necessary and adopts it. The IPPC Secretariat publishes and distributes the ISPM following its adoption by the CPM.

More detail on this process is available in the IPPC Procedural Manual, available on the web at: https://www.ippc.int/id/159891

1.5.2 ISPMS SPECIFICALLY RELATED TO PEST RISK ANALYSIS

The ISPMs that are most relevant to pest risk analysis (PRA) are:

- ISPM No. 2 (*Framework for pest risk analysis*, 2007)—This standard describes the overall process of PRA for pests of plants.
- ISPM No. 3 (*Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms*, 2005)—This standard provides guidelines for risk management related to the export, shipment, import and

release of biological control agents and other beneficial organisms, and contains a section on PRA for these types of organisms.

- ISPM No. 11 (*Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms*, 2004)—This standard describes the factors to consider when conducting a PRA to determine if a pest is a quarantine pest. The emphasis in ISPM No. 11 is on the pest risk assessment and risk management components of PRA, although the full PRA process is covered.
- ISPM No. 21 (*Pest risk analysis for regulated non-quarantine pests*)—This standard provides guidelines for conducting PRA on regulated non-quarantine pests.

1.5.3 Other ISPMs Applicable to PRA

All ISPMs relate to PRA in some way. Some of the more relevant ones are:

- ISPM No. 1 (*Phytosanitary principles for the protection of plants and the application of phytosanitary measures in international trade*, 2006)—This standard describes the principles of plant quarantine as related to international trade.
- ISPM No. 5 (*Glossary of phytosanitary terms*, 2007)—This standard is a glossary of terms and definitions applicable to phytosanitary systems worldwide. It provides an internationally agreed-upon vocabulary associated with the IPPC and ISPMs.
- ISPM No. 5, Supplement No. 1: (*Guidelines on the interpretation and application of the concept of official control for regulated pests*)—This supplement describes the concept of official control of regulated pests and its application.
- ISPM No. 5, Supplement No. 2 (*Guidelines on the understanding of potential economic importance and related terms including reference to environmental considerations*)—This supplement provides background and other relevant information to clarify potential economic importance and related terms so that their application is consistent with the IPPC.
- ISPM No. 6 (*Guidelines for surveillance*)—This standard describes the components of survey and monitoring systems for the purpose of pest detection and the supply of information for use in PRAs, the establishment of pest free areas and, where appropriate, the preparation of pest lists.
- ISPM No. 8 (*Determination of pest status in an area*)—This standard describes the content of a pest record, and the use of pest records and other information in the determination of pest status in an area.
- ISPM No. 14 (*The use of integrated measures in a systems approach for pest risk management*)—This standard describes how a systems approach to pest risk management can meet phytosanitary import requirements.
- ISPM No. 17 (*Pest reporting*)—This standard describes the responsibilities of, and requirements for, contracting parties in reporting the occurrence, outbreak and spread of pests in areas for which they are responsible. It also provides guidance on reporting successful eradication of pests and establishment of pest free areas.
- ISPM No. 19 (*Guidelines on lists of regulated pests*)—This standard describes the procedure to prepare, maintain, and make available lists of regulated pests.

- ISPM No. 24 (*Guidelines for the determination and recognition of equivalence of phytosanitary measures*)—This standard describes the principles and requirements that apply for the determination and recognition of equivalence of phytosanitary measures. It also describes a procedure determining equivalence in international trade.

Appendix 1 provides a complete listing of all ISPMs.

1.5.4 NATIONAL APPLICATION OF ISPMS

Although ISPMs are internationally agreed to and adopted, they are meant to be guidelines and their use is not mandatory within the framework of the IPPC. In addition, their interpretation and application on a national level varies from country to country. This variation is illustrated by the many different national systems and procedures that exist for carrying out PRA. Countries often take slightly different approaches to implementing the standards while still staying true to their intent. ISPMs are designed to be a framework and countries use that framework as a basis for their own national systems that may arrange the guidelines into a protocol or similar system, often adding additional elements to meet their needs.

Throughout this manual, examples and case studies from different countries illustrate the range of ways that the IPPC standards and principles are applied around the world. One example of a different approach to interpretation and application of the PRA standards is included as Appendix 2.

2. PEST RISK ANALYSIS – AN OVERVIEW

Pest risk analysis (PRA) is a science-based process that provides the rationale for determining appropriate phytosanitary measures for a specified PRA area. It is a process that evaluates technical, scientific and economic evidence to determine whether an organism is a potential pest of plants and, if so, how it should be managed. Under the IPPC, the term plant pest refers to all organisms harmful to plants or plant products including other plants, bacteria, fungi, insects and other animals, mites, molluscs, nematodes, and viruses. Pests can be either regulated or not, and the IPPC recognizes and defines two categories of regulated pests of plants: quarantine pests and regulated, non-quarantine pests. PRA assists with determining whether a pest fits either of these two categories and the strength of phytosanitary measures, if any, that should be taken in response to it.

Pest Risk Analysis (PRA)

Pest risk analysis is a process consisting of three stages (1) initiation of the PRA through identification of a pest or pathway, or review or revision of an existing phytosanitary policy, (2) pest risk assessment, and (3) pest risk management. Risk communication is an integral component that occurs throughout each step.

If it is determined that the organism is a potential quarantine pest of plants, the probability of introduction and spread and the magnitude of potential consequences is evaluated using scientific, technical and economic evidence. If the pest risk is deemed unacceptable, the analysis may continue by suggesting management options that will reduce the pest risk to an acceptable level. These pest risk management options may be used to establish phytosanitary regulations.

A PRA may also consider the pest risks posed by the introduction of organisms associated with a particular pathway, such as a traded commodity. In most cases the commodity itself does not pose a pest risk but it might carry organisms that are pests of plants.

Quarantine Pest

A quarantine pest is defined by the IPPC as “a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled” (IPPC, 1997). In other words, it is any organism that is injurious or potentially injurious, directly or indirectly, to plants or plant products or by-products of plants and includes bacteria, fungi, insects, mites, molluscs, nematodes, other plants and viruses, not present in a specified area at risk or, if present, being controlled by an NPPO.

Regulated Non-Quarantine Pest (RNQP)

A regulated non-quarantine pest (RNQP) is defined by the IPPC as “a non-quarantine pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated within the territory of the importing contracting party” (IPPC, 1997). RNQPs are usually widely distributed in the country where they are regulated.

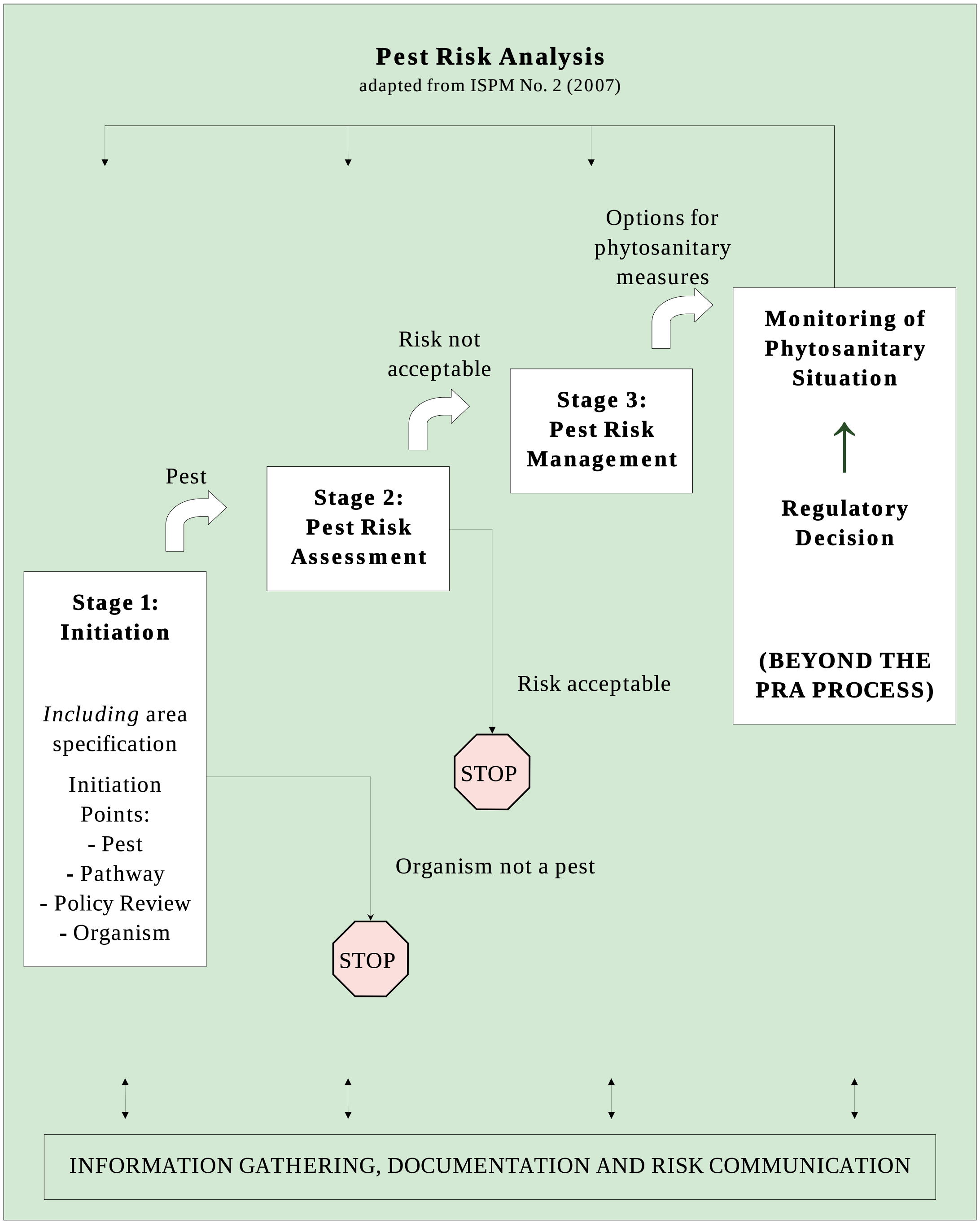
In some cases the commodity itself may pose a pest risk. When deliberately introduced and established in its intended habitats in new areas, organisms imported as commodities (such as plants for planting, beneficial organisms and living modified organisms (LMOs)) might pose a risk by spreading to unintended habitats and causing injury to plants. Such pest risks are also analysed using the PRA process. It should be noted that in the case of LMOs, ISPM No. 11 (2004) Annex 3 (*Determining the potential for a LMO to be a pest*) should be applied prior to conducting a full PRA.

The PRA process may be used for recognized pests of plants, organisms not previously recognized as pests of plants (such as plants, biological control agents or other beneficial organisms and LMOs), pathways and review of phytosanitary policy.

Focus of a PRA

A PRA may be based on:

- a particular commodity,
- a category of commodities,
- a particular organism or disease, or group of organisms or diseases that share common epidemiological characteristics, or
- one or more forms of conveyance.


Pest Risk Analysis
adapted from ISPM No. 2 (2007)
Options for phytosanitary measures
Monitoring of Phytosanitary Situation
Regulatory Decision
(BEYOND THE PRA PROCESS)
Risk not acceptable
Stage 3: Pest Risk Management
Pest
Stage 2: Pest Risk Assessment
Stage 1: Initiation
Including area specification
Initiation Points:
- Pest
- Pathway
- Policy Review
- Organism
Risk acceptable
STOP
Organism not a pest
STOP
INFORMATION GATHERING, DOCUMENTATION AND RISK COMMUNICATION

2.1 RISK

Risk is considered to be a product of likelihood and impact, i.e. how likely something is to happen and how much of an effect it would have if it did. Stage 2 of the PRA, pest risk assessment, therefore, assesses these two elements. Pest risk is assessed by combining estimates of the probability or likelihood of an event occurring (the pest's entry, establishment and spread) and the consequences or magnitude of the impact if it does occur (the economic, environmental and social impacts that would potentially be attributable to the pest).

Pest risk

Pest Risk = (Probability of introduction) x (Magnitude of impact)

Probability of introduction

Probability of introduction = (Probability of entry) x (Probability of establishment) x (Probability of spread)

Magnitude of impact

Magnitude of impact = (Economic impacts) + (Environmental impacts) + (Social impacts)

Therefore, if an event is likely to occur but will have no impact, there is no risk. Similarly, if there is no likelihood of an event occurring there is no risk.

2.1.1 PROBABILITY

Probability is the likelihood that an event will occur. This may be expressed quantitatively, such as "1 chance in 1oo (0.01)", or qualitatively, such as "very likely" or "impossible". There are also semi-quantitative measurements of probability that incorporate aspects of both the quantitative and qualitative methods.

Qualitative vs. Quantitative

Qualitative measure: In throwing two dice, the probability of rolling a combined score of 2 is low while the probability of rolling a combined score of 6 or more is high.

Quantitative measure: The probability of rolling a combined score of 2 is 0.02778 (1/36) while the probability of rolling a combined score of 6 or more is 0.7222 (26/36).

When described numerically, the probability of an event appears quantitative and is typically expressed on a scale from 0 to 1; a rare event has a probability close to 0, a very common event has a probability close to 1. Describing an event in this way requires practical observations or prior knowledge of the event. However, assessment of pest risk need not necessarily be quantitative, especially when practical observations or specific prior knowledge are lacking. In such circumstances it is necessary to make judgements about the likelihood and /or magnitude of events. Such judgements need to be based on reasoned assessment using the information available.

When assessing the probability of an event, the precision or accuracy of how it is reported should take into account the quantity and quality of the information used in making the assessment. The level of precision or accuracy required will depend upon the needs of the NPPO. In the context of the IPPC, the terms "probability" and "likelihood" have very similar meanings and are often used interchangeably. Uncertainties about the likelihood of an event should be considered. Section 4.5 discusses uncertainty in more detail.

2.1.2 IMPACTS

Impacts may be economic, environmental or social, and they may be direct or indirect. They may be measurable and hence quantitative, or they may be described in a qualitative manner, or a combination of both. Whereas probability is a reflection of the likelihood of an event (how likely?) as discussed above, impacts are a question of magnitude (how severe?).

When assessing the magnitude of the impact, the PRA should consider both the direct consequences of the pest introduction and spread plus the magnitude of the impacts associated with the mitigation measure taken against the pest.

The definition of the term “economic impacts” in ISPM No. 5 (2006) indicates that it also includes environmental and social impacts. Accounting for environmental concerns in economic terms can be done using monetary or non-monetary values and should take into account the fact that market impacts are not the sole indicator of pest consequences. Countries have the right to adopt phytosanitary measures with respect to pests for which the damage caused to plants, plant products or ecosystems within an area cannot be easily quantified. ISPM No. 5 (2006), Supplement No. 2 (*Guidelines on the understanding of potential economic importance and related terms including reference to environmental considerations)* provides guidance on this issue.

2.2 PURPOSE OF PEST RISK ANALYSIS

PRA can be regarded as a process to answer the following questions:

- Is the organism a pest?
- What is the likelihood of introduction, establishment and spread?
- How much economic (including environmental and social) damage (unacceptable impacts) does it cause?
- What can be done to mitigate unacceptable impacts?

A PRA asks: What could happen? How likely is it to happen? What would the consequences be? Do we want to do anything about it? If so, what can be done about it?

Consequently any phytosanitary measures implemented by a country to mitigate against a particular pest should be technically justified by the PRA.

2.3 PEST-INITIATED VS. PATHWAY-INITIATED PRAS

There are two widely adopted approaches to conducting a PRA, one focused on a pathway, the other focused on a particular pest associated with one or more pathways. A commodity PRA is one type of pathway PRA. In the case of a pathway PRA, it is necessary to conduct PRAs on those pests associated with the pathway that are identified as potential quarantine pests. In the case of a pest PRA, consideration needs to be given to all possible pathways or commodities with which the pest may be associated.

Types of PRA

1) A PRA being undertaken by a country following a request to import wheat (*Triticum/Triticale*) seed is a pathway PRA.

2) A PRA being undertaken by a country to ensure that the country is adequately safeguarded against a newly identified pest is a pest PRA.

The pathway PRA may identify potential pests of wheat, and will also assess wheat as a potential weed or invasive plant. A potential pest of wheat seed, such as *Urocystis agropyri* (Preuss) Schröt which causes Flag smut of wheat, may be identified and then a PRA conducted on it in the context of the wheat seed pathway. The pest PRA would consider relevant potential entry pathways for the newly identified pest.

2.4 COMMUNICATION

Risk communication is important throughout each stage of PRA, as outlined in ISPM No. 2 (*Framework for pest risk analysis,* 2007). It is the interactive process of exchanging information among regulators and analysts, and between regulators and stakeholders, in recognition that pest risk analysis is a complex process that requires many different types of information from many different sources. Risk communication provides an opportunity for regulators to obtain new information that helps them to better understand the nature, severity or acceptability of risks to those affected or involved. The risk communication process is meant to facilitate both development of the PRA and understanding of its results. Risk communication gives all stakeholders an opportunity to provide input to the decision-making process. When risk communication is successful, risk management decisions are more completely understood and accepted by stakeholders.

Communication may take place in many forms. Public meetings, formal presentations, and review and comment periods for written material are all useful means of facilitating risk communication. Having an effective communication strategy in place throughout all stages of the PRA process contributes to well-informed decisions by decision makers and informed action on the part of stakeholders. It can also ensure that the interests of all affected stakeholders are considered.

ISPM No. 2 (2007) states that risk communication is meant to reconcile the views of scientists, stakeholders, politicians etc. in order to:

- achieve a common understanding of the pest risks,
- develop credible pest risk management options,
- develop credible and consistent regulations and policies to deal with pest risks, and
- promote awareness of the phytosanitary issues under consideration.

Risk communication may take place before, during and after each stage of the PRA process. Before commencing a PRA, it may be useful to communicate with potential partners or contributors to the PRA, and to stakeholders who may be affected by its outcomes. At this early stage, consultations with experts, industry groups, and other stakeholders may help to more clearly define the issue.

During the pest risk assessment stage of the PRA, risk communication may take the form of consultations with experts in various scientific fields, including economics, pest management, and predictive modelling. Experts and other stakeholders may contribute to a stronger, more defensible pest risk assessment, and they may benefit from the exercise by acquiring a better understanding of the PRA process.

During the pest risk management stage consultation with other stakeholders and partners may address issues related to potential mitigation measures such as their effectiveness in achieving the desired level of protection, their feasibility and likely impacts on the affected industry groups, their acceptability to the importing country's NPPO or industry groups, and willingness and ability of partner agencies to support the proposed measures. Consultations at this stage will contribute to a better understanding of the positive and negative outcomes of the proposed mitigation measures and other mitigation measures that had not previously been identified may come to light.

Identification of contacts for pest risk communication at various stages during development of the PRA is critical. It may be useful to develop and maintain lists of contacts for different types of issues or different stages of the PRA.

Groups that may be appropriate contacts at one or more stages in the PRA process include:

- industry representatives, importers and exporters;
- grower organizations or individual growers;
- other national and sub-national government agencies;
- non-government groups;
- academics and research organizations;
- cultural groups; and
- other NPPOs and RPPOs.

Throughout the course of communicating with partners and stakeholders on the matter of pest risk, it is important to explain the PRA process, the situation at hand, and the purpose of the consultation. Effective communication is not a one-way flow of information from the decision-maker to the stakeholders, but is a process of dialogue between the two, allowing the stakeholder to participate in the decision-making process. By involving stakeholders, an NPPO can develop trust and encourage acceptance among its partners and stakeholders.

Expert Judgement

Expert opinions can provide useful information for interpreting existing data on pests, and forecasting future events such as pest establishment, pest impacts or effects of proposed mitigation measures. Expert judgements may, therefore, contribute to virtually all stages of a PRA, including identification of the pests likely to be associated with a pathway, potential for entry, establishment and spread, potential economic or environmental impacts, identification of control measures and potential impacts of such measures. When conducting quantitative pest risk assessments in particular, it may be necessary to use expert judgement to assign values to the probability of events if scientific data is absent or incomplete. Finally, expert judgement may be helpful in reducing uncertainty, or compensating for it, in a PRA, and in building stakeholder confidence during various stages of risk communication.

An expert is a person with specific knowledge or skills in a particular subject area. Many kinds of experts may contribute to a PRA, including pest specialists, agronomists, ecologists, economists, treatment specialists, industry specialists, etc. Experts may come from within an NPPO, or they may come from other governmental organizations, research centres, universities or other non-governmental groups. The selection of appropriate experts is an important process. Factors to take into account when selecting experts include their scientific expertise as demonstrated by research and publications, their availability and willingness to participate, their experience in performing judgements of this type, and their impartiality.

When seeking input from experts, it is necessary to ensure that they have an understanding of the PRA process and of what is required of them so that they can be prepared and can contribute fully. In using expert judgement, it is important to solicit opinions from a variety of experts representing different points of view, though effort should also be taken to account for any biases that might exist.

Expert judgement may be solicited in a number of different ways. Experts may be asked to review or contribute to all, or parts, of a PRA at different stages in its development; they may be asked to provide their opinions individually, in writing, or in person, or as a group, such as in face-to-face workshops in which all experts are assembled to discuss answers to specific questions. Some basic principles for using expert judgement within a PRA include the following:

- select experts from a variety of sources,
- use more than one expert,
- educate experts about the PRA process and its uses in establishing phytosanitary measures, and
- account for biases that may influence experts' opinions.

2.5 INFORMATION GATHERING

An essential activity necessary to complete all stages of a PRA is the gathering of information. The quality and completeness of the information gathered relating to the PRA will dictate how well the analyst is able to properly assess the risk and therefore make appropriate management decisions or recommendations.

It is generally presumed that more information is better than less, although the level of detail necessary for any individual PRA may vary and may depend upon the complexity of the issue, the urgency of the situation, the needs of the NPPO and other factors. The risk analyst will need to judge if all of the information needed to make an informed decision has been gathered, or indeed is available. If not, information that is lacking should be recorded in the PRA.

Gathering relevant information can often be very time consuming. It may be helpful to prepare a fact sheet containing relevant information for each pest or commodity being assessed. A complete and up-to-date pest fact sheet can be a valuable resource for both the current PRA and future PRAs on other pathways, and for other uses, including risk communication and implementation of phytosanitary measures when, and if, they are necessary. See Appendix 3 for an example of a pest fact sheet.

2.5.1 SOURCES OF INFORMATION

It is important to ensure that the information used to support the PRA is both reliable and relevant. The information should be verifiable and retrievable at a later date. Information sources should be properly cited in the PRA.

Information on the distribution or abundance of a pest in another country may be obtained from that country's NPPO. It is an obligation under the IPPC to provide official information regarding pest status. ISPM No. 8 (*Determination of pest status in an area*) provides guidance in this matter.

In addition to the information provided by the exporting country's NPPO (which can include official pest lists and pest reports) other sources of scientific information may include:

- published scientific literature, such as reference books and journals
- previous PRAs (national or international) and/or PRAs from similar pests or pathways
- official files, published and unpublished reports and other correspondence from plant health and quarantine authorities, information from RPPOs
- pest or commodity databases (e.g. CAB International Crop Protection Compendium, and CAB International Forestry Compendium), and other abstract compilation services
- climate data, maps, and models
- crop production data from the PRA area
- pest and disease interception databases from quarantine authorities
- data on control or mitigation measures
- pest records and pest reports
- the internet and online information sources and list servers
- reference collections of plants, insect pests and plant pathogens of agricultural importance
- trade data
- expert judgement (consultation with botanists, entomologists, nematologists, pathologists, plant health and quarantine officers and other experts)
- national IPPC contact points
- environmental impact assessments

2.5.1.1 PEST RECORDS

ISPM No. 8 describes pest records as essential components of the information required to establish the status of a pest in an area. They document the presence or absence of a pest, time and location of observations, damage observed, host(s) where appropriate, as well as references and other relevant information. ISPM No. 8 lists the following as basic information required in a pest record:

- current and previous scientific name of the organism including, as appropriate, subspecific terms (strain, biotype, etc.)
- life stage or state
- taxonomic group
- identification method
- year and month (if known) recorded
- locality
- scientific name of host, as appropriate
- host damage, as appropriate
- circumstances of collection, as appropriate
- prevalence
- bibliographic references, if any

Pest records are derived from many sources of information and thus have varying levels of reliability. ISPM No. 8 describes methods to verify the reliability of pest records.

2.5.1.2 PEST REPORTS

The information from pest records is used to prepare a pest report, the purpose of which is to communicate immediate or potential threats arising from the occurrence, outbreak or spread of a quarantine pest in either the country in which it is detected, or neighbouring countries or trading partners. This is often done by an RPPO.

2.6 TRANSPARENCY IN PRA

The PRA process is meant to be a transparent one; therefore, it needs to be well documented so that the available information that was used, the sources of that information, the uncertainties regarding data or conclusions, and the rationale used to arrive at a conclusion are clearly demonstrated. It is also important to note the date on which the information was gathered in case any subsequent data collected is such that modification of the final PRA conclusion or the resulting phytosanitary import requirements is required.

Transparency helps to ensure:

- inclusion of those involved or affected
- consistency, fairness and rationality in the decision-making process
- ease of understanding by all interested parties
- gaps in information are identified
- assumptions are documented

- uncertainties are dealt with appropriately
- reasons for the conclusions and recommendations are understood by all
- stakeholders are provided with clear rationale for the imposition of measures

One of the goals of the WTO-SPS Agreement is to increase the transparency of phytosanitary measures to protect consumers and trading partners from protectionism through unnecessary technical requirements.

2.7 DOCUMENTATION OF THE PRA

Complete and careful documentation for each PRA is necessary in order to implement an effective and efficient review process for the PRA. Documentation provides a valuable record of the process and is a useful tool for handling future PRA issues. A well-documented PRA is more easily communicated or up-dated when necessary and may also serve as a useful resource for future PRAs on related subjects.

ISPM No. 11 (2004) outlines the main elements to be documented in a PRA as:

- scope and purpose of the PRA
- pest, pest list, pathways, PRA area, endangered area
- sources of information
- categorised pest list
- conclusions of pest risk assessment including probability and consequences
- pest risk management options identified and selected

Other items that could be included in documentation include a list of stakeholders and their comments or contributions, risk management procedures currently in place, composition of the risk management team, terms of reference and objectives of the risk management team, and the communication plan.

ISPMs No. 2 (2007), No. 11 (2004) and No. 21 are guidelines which may serve as a format for PRAs, however, an NPPO may opt to develop its own standard format or structure for the PRAs it conducts, provided the procedures followed remain consistent with the IPPC principles and guidelines. This approach has several advantages in that it increases the efficiency of the PRA process, ensures consistency between PRAs and between risk analysts, and facilitates training or risk communication activities related to the subject matter of the PRA. It also expedites transparency by ensuring all considerations are documented during the course of development of the PRA. Any standard PRA format should have the flexibility to accommodate inherent differences between pests or trade situations which may arise and must be addressed appropriately.

See Appendix 2 for an example of a PRA format.

2.8 STAGES OF PRA

PRA for quarantine pests follows a process that is defined by three stages:

- Stage 1: Initiation—This stage involves identifying the reason for the PRA and identifying the pest(s) and pathway(s) that may be considered for PRA in relation to the PRA area.

- Stage 2: Pest risk assessment—In this stage, the information on the pest or pest group identified in Stage 1 is gathered and evaluated. The results are used to decide whether risk management is required. Also, the endangered area within the PRA area is identified.
- Stage 3: Pest risk management—This stage determines appropriate management options to reduce the risks identified in Stage 2.

The PRA can stop during or after any one of these stages, depending on the conclusions reached. Reasons to end the process can include the following:

- concerns about the risk no longer exist
- all associated risks are considered acceptable
- existing controls are deemed to be sufficient
- the activity generating the risk ceases
- the risk is not manageable

3. STAGE 1: INITIATION

The PRA process begins with the initiation stage. The aim of this stage is to identify the pests, organisms and pathways that the PRA will focus on and which should be considered for an in-depth evaluation, or pest risk assessment (Stage 2).

The result of the initiation stage should be a list of potential quarantine pests for further consideration. In the case of a pest PRA this is usually just one taxon, usually a species. In the case of a pathway PRA, there may be a long list of organisms potentially associated with that pathway. If no potential quarantine pests are identified as likely to follow a particular pathway, the PRA may stop at this point and the reasons should be recorded.

Pest Lists

Individual pests of plants can be associated with one or more plant species in the country of origin and may be associated with particular plant parts or growth stages. It is necessary to take these factors into account in order to get an accurate reflection of the pests that may be associated with a particular pathway or commodity and to limit the list of pests to be considered in the PRA to those of actual concern. Considering the pests of every part of a plant will generate a much longer list of pests than a list of pests generated when considering pests potentially associated with the specific plant part that is the commodity, such as seeds or fruits. Further refining that list by considering only those pests which will be associated with the commodity as it moves along a specific pathway will again shorten the list.

For example, in a situation in which a request is made to import apple (*Malus pumila*) blossoms grown in Asia for export to Europe, the host is *Malus pumila*, the commodity is *Malus pumila* twigs and branches with buds and flowers, and the pathway is cold storage overseas shipping in the flower trade. If the PRA was approached on the basis of the whole host plant, the list of pests associated with *Malus pumila* would be very long. A commodity-based approach would result in a shortened list as only those pests potentially associated with twigs and branches with buds and flowers attached would be included, and this list would be further shortened if the ultimate pathway was considered, taking into account the impacts that cutting, inspecting, packaging, shipping and sorting for distribution would have on the commodity.

3.1 INITIATION POINTS

ISPM No. 2 (2007) explains that a PRA may be initiated as a result of:

- identification of a pathway that presents a potential pest risk (i.e. is a means of pest introduction or spread)
- identification of a pest that may require phytosanitary measures (pest may have been detected or intercepted, a request made to import it, or it may have been reported elsewhere)
- review or revision of existing phytosanitary policies and priorities
- identification of an organism not previously known to be a pest (such as an ornamental plant, a biological control agent or LMO)

These initiation points can involve pests already present in the PRA area but not widely distributed and being officially controlled, as well as pests absent from the PRA area, since both are covered by the definition of a quarantine pest.

A European Example of a Plant Pest PRA

Hydrocotyle ranunculoides is an aquatic plant that was introduced to Britain and the Netherlands by the aquatic nursery trade. It has been sold as an ornamental plant for tropical aquaria and garden ponds. Its invasive potential was first mentioned in a publication from 1936 and it was first recorded as naturalised in the south-east of the United Kingdom in the 1980s. Naturalisation in the Netherlands was recorded in the last decade of the twentieth century. Several EPPO countries are still free from *H. ranunculoides*, but there are concerns that it may be able to enter and establish in at least some of these countries. A PRA was done for Europe and the Mediterranean region to assess the risks of its further introduction into other EPPO countries. Options for management measures are provided in the PRA.

A New Zealand Example of a Plant Pest PRA

Concerns within the New Zealand Ministry of Agriculture and Forestry (MAF) over the level of biosecurity risk from Pinewood Nematode (*Bursaphelenchus xylophilus*) (PWN) have risen with increasing global trade in PWN host material, the rapid spread of pine wilt (spread by PWN) in East Asia, and recent findings of pathogenicity of other *Bursaphelenchus* spp. It has also become evident that the presence of this disease in New Zealand could impact the export of New Zealand forest products. This necessitated the completion of a pest risk analysis for *Bursaphelenchus* spp. to estimate its likelihood of entry, establishment and spread in New Zealand, and economic and/or environmental consequences. *B. xylophilus*, the most intensively studied of the *Bursaphelenchus* species, has been used as a model species. More information is available at: Biosecurity Risk to New Zealand of Pinewood Nematode (Bursaphelenchus xylophilus) (2004) at http://www.biosecurity.govt.nz/files/pests-diseases/forests/risk/pinewood-nematode.pdf

The following discussions are based on ISPMs No. 2 (2007) and No. 11 (2004).

3.1.1 IDENTIFICATION OF A PATHWAY

The following situations may give rise to the need for a new or revised PRA for a specific pathway:

- international trade is initiated in a commodity not previously imported into the country (usually a plant or plant product, including genetically altered plants or plant products), or a commodity from a new area or new country of origin
- a new treatment or process is proposed which potentially alters the pest risk of a commodity which is currently moved in international trade
- new plant species are imported for selection and scientific research purposes
- a pathway other than a commodity import is identified (natural spread, packaging material, mail, international garbage, etc.)
- a change in susceptibility of a plant to a pest is identified
- a change in virulence, aggressiveness or host range of a pest is identified

- a pest or pests are intercepted on a previously unsuspected pathway, such as a new host or with packing materials or planting media
- a commodity is proposed for importation in association with a substrate or packing material that has not previously been analysed

The pathway should be defined as precisely as possible. A list of pests likely to be associated with the pathway (e.g. carried by the commodity) may be generated. This is commonly referred to as a pest list. When a PRA is carried out for a commodity in which trade already exists, records of actual pest interceptions should be used to form the basis of the pest list.

Pest lists serve many purposes and are mentioned frequently in ISPMs. The pests listed on the pest list may or may not be quarantine pests in the importing country, the exporting country or both. Regulated pest lists are also generated by NPPOs. They are produced in accordance with ISPM No. 19 (*Guidelines on lists of regulated pests*) in order to inform other countries of the plant quarantine import requirements of the NPPO. In developing a pest list for a PRA, it may be helpful to examine regulated pest lists of the exporting country to determine if a pest is present or not, and if it is under official control if present.

If no potential quarantine pests are identified as likely to follow the pathway, the PRA may stop at this point and the rationale should be recorded.

Pathway PRAs

To start a pathway PRA, it is necessary to first define the pathway as precisely as possible. The description should include the Latin and common name(s) of the plant or plant product in question, its area of origin, any pertinent production practices in the area of origin, a description of any harvesting, packing, processing or inspection steps to which it is subjected prior to export, any in-transit treatments or shipping conditions which might influence its pest risk, its intended destination and end-use etc. For example, a request to import "blueberry material" would result in different PRA results if the commodity was fresh blueberry fruit harvested in commercial berry orchards in South America, frozen wild blueberry fruits packaged and shipped from Canada, blueberry canes grown in Asia for planting in a European country, or blueberry budwood selected from a virus-free certified block in the United States. Each of these commodities might be "blueberry material" but they represent very different pest risks.

The second step is generating a list of pests that could be associated with the commodity in question, given what is known of its origins and the conditions to which it has been exposed, and then determining which of these may be present on the specific pathway for which the PRA is being conducted. First, start with a list of pests that have been reported on the host species in the country of origin, screen out any that would not be associated with the commodity in question, and further eliminate any that would not be associated with the identified pathway. The result is a shorter list of pests potentially associated with the pathway. A PRA should begin for each pest on the list. To complete the list, consider any other pests which might be associated with the pathway, such as those potentially found in any packing materials, growing media or other substrates included in the pathway.

For example, for a request to conduct a PRA on cut flowers of a particular species from a specified country of origin, a practical first step would be to review the available information in the documentation provided by the exporter, the published literature, previous PRAs on that or related species, pest records, or in other sources, and generate a list of the pests potentially associated with that flower species in the country of origin. The list may then be refined based on which pests are likely to be associated with cut flowers only, and aspects of the species biology and life history, including time of year, which could affect the presence of the pest(s) on the commodity. A root-infecting beetle, for example, may not be associated with cut flowers and further consideration of it may be neither necessary nor appropriate. A rust fungus might be present on the host at certain times of year but not at the time of harvesting cut flowers. A pollen-borne virus, however, might be present in the pollen of cut flowers and therefore be a pest that requires further consideration in a PRA for cut flowers. If soil, growing media or packing materials are likely to be shipped with the cut flowers, then the final pest list may also include pests potentially associated with these substrates.

Using this process, a list of pests potentially associated with the pathway is generated. Each of these pests can then be analysed following the usual procedures for pest PRAs. A pathway PRA is, basically, a collection of pest PRAs for which the identified pathway is the same.

3.1.2 IDENTIFICATION OF A PEST

A new or revised PRA may become necessary as a result of identification or a report of a specific pest, for example:

- An emergency arises on discovery of an established infestation or an outbreak of a new pest within the PRA area—for example, the discovery of Asian Longhorned beetle (*Anoplophora glabripennis*) in Germany resulted in a PRA and an eradication program.

- An emergency arises on interception of a new pest on an imported commodity—for example, the interception of citrus leafminer (*Marmara gulosa*) on orange fresh fruit being imported to Chile resulted in a new phytosanitary measure for this commodity.
- A new pest is identified by scientific research—for example, *Meloidogyne fallax* is a recently described nematode (False Columbia root knot nematode), found in the Netherlands, and although very closely related morphologically to the Columbia root knot nematode (*Meloidogyne chitwoodi*), it is considered a distinct species with a slightly different host range, biology, etc..
- A pest is reported to be more injurious than previously known.
- There is a change in the status or incidence of a pest in the PRA area.
- A pest is introduced into an area—for example, Pine Wood Nematode (*Bursaphelenchus xylophilus*) has been introduced to Portugal resulting in a PRA and in eradication measures being implemented to prevent its spread.
- A pest is reported to be more damaging in an area other than in its area of origin—for example, many invasive weeds were originally introduced to their new countries as garden ornamentals and later escaped and established wild populations. An example is Skunk cabbage (*Lysichiton americanus*) which is native to North America and was introduced into Europe as a garden plant. Not considered to be harmful in its native North America, it is now establishing local populations (e.g. in Germany) that displace native vegetation.
- A pest is repeatedly intercepted—for example, in the European Union increasing detections of *Thrips palmi* (melon thrips) in consignments of orchid cut flowers from south east Asia initiated a PRA which concluded that stronger phytosanitary measures were justified on the pathway. Detections of *T. palmi* declined when the revised measures were in place.
- A request is made to import an organism—for example, a bio-control nematode for retail distribution or a bacterial culture for industrial applications.
- An organism is identified as a vector for other pests—for example, some nematodes, such as *Xiphinema* are known to vector some viruses and diseases of plants that are of regulatory concern.
- An organism is genetically altered in a way that impacts its potential to be a pest of plants.

Example PRAs

Example 1: The fungus *Sirococcus clavigignenti-juglandacearum* (butternut canker) is causing severe tree mortality on *Juglans cinerea* (butternut) in North America. Natural infection of *Juglans nigra* and *Juglans ailantifolia* var. *cordiformis* has also been found in the USA. The pathogen has been put on the EPPO Alert List as a result of a PRA completed for Europe and the Mediterranean region following reports of the fungus' effects in North America.

Example 2: In 2006, a small population of jointed goat grass (*Aegilops cylindrica* Host) was discovered along an abandoned railway line in the province of Ontario in Canada. This species had previously been considered absent from Canada. The discovery of this population triggered a request for a PRA on this species.

Example 3: In 2006, a small population of glassy-winged sharpshooter (*Homalodisca coagulate*) was detected on Easter Island (Rapa Nui), Chile. This pest of agricultural, ornamental and native plants is native to south-eastern United States and north-eastern Mexico. A PRA was conducted and new phytosanitary measures were implemented for aircraft from Tahiti (where the pest has also established) and Easter Island to continental Chile. Official control measures of suppression are in place to maintain continental Chile free of the pest.

Example 4: In 2003, western flower thrips (*Frankliniella occidentalis*) was discovered on capsicum peppers in cultivation around Beijing, China. *Frankliniella occidentalis* is a polyphagous pest from North America but is now found in many countries around the world. A PRA was initiated and alternative risk management options considered. Measures to inhibit the spread of the pest and eradicate the outbreak were recommended.

3.1.3 REVIEW OF PHYTOSANITARY POLICIES

A requirement for a new or revised PRA originating from policy reviews may arise in the following situations:

- an NPPO decides to review its phytosanitary regulations, requirements or operations
- an official control programme is developed to avoid unacceptable economic impact of specified regulated non-quarantine pests (RNQPs) in plants for planting
- a proposal made by another country or by an international organization is reviewed
- a new treatment is developed or proposed, an approved treatment process becomes unavailable due to regulatory, economic or technical reasons, or new treatment information on an existing treatment influences an earlier decision
- a dispute arises over a phytosanitary measure
- the phytosanitary situation in a country changes, a new country is created, or political boundaries are changed

A request for a PRA may also arise if a country's policies differ from those of another country relative to a specific commodity which is proposed for trade.

Example PRAs

An NPPO may elect to review its import policies for specified plants or plant products on a regular, or as-needed, basis as a way of ensuring that its import policies reflect the current scientific, economic and other information available. Three examples are:

- In the late 1990's Canada undertook to review some of its off-continent nursery-stock policies, as some tree and other horticultural species had historically been imported into the country without a PRA. Several genera of trees were reviewed, including *Acer* (maples), *Quercus* (oaks), and *Fraxinus* (ash). These reviews highlighted several quarantine pests that might potentially be of quarantine concern to Canada that until that time had not been regulated.
- In 2006, Servicio Agrícola y Ganadero, Chile decided to review phytosanitary regulations allowing the import of ornamental seed. The PRA considered over 100 species and included the concept of invasiveness potential of the exotic plants, as well as the consideration of seed borne pathogens. This review resulted in a new phytosanitary regulation.
- The decision to reconsider the basis for the entry prohibition of *Berberis* spp to Chile was triggered by a review of the phytosanitary regulations that were already in place. Some species or varieties of barberry are alternate hosts for *Puccinia graminis* f.sp. *tritici* which causes stem rust of wheat. Barberry, therefore, plays an important role in the epidemiology of this disease cycle. In Chile, however, the native species are not hosts and have no role in this disease cycle. A restriction was in place, which prohibited entry of other barberry species. The PRA considered:
  - new information about *Berberis* species and cultivars that were considered resistant to *Puccinia graminis* f.sp. *tritici* ,
  - information about the potential invasiveness of certain *Berberis* species and the potential threat to native *Berberis* species in Chile, and
  - information about the pest associated with seeds and other parts of the plant.

  A list of types of plant material to accept and possible species to authorize was proposed for further analysis and decision.

3.1.4 IDENTIFICATION OF AN ORGANISM NOT PREVIOUSLY KNOWN TO BE A PEST

New agricultural or environmental practices, such as the increased use of large-scale composting for disposal of organic waste or bio-remediation of polluted areas, may result in an interest within a country to import or produce new organisms not previously considered by the NPPO to be a pest. Other examples may include experimental crops, or organisms of interest in industrial applications, the pharmaceutical industry or biocontrol. In these instances, the NPPO may wish to consider if the organism that has not previously been considered to be a pest demonstrates any characteristics of a pest.

An organism not previously considered to be a pest may be considered for a PRA in situations where:

- a proposal is made to import a new plant species or variety for cropping, amenity or environmental purposes;
- a proposal is made to import or release a biological control agent or other beneficial organism;
- an organism is reported that is new to science or for which there is little information available;
- a proposal is made to import an organism for research, analysis or other purpose; or
- a proposal is made to import or release an LMO.

In these situations it would be necessary to determine if the organism is a pest and thus subject to Stage 2 – pest risk assessment.

Example PRAs

An example of a pest for which the available scientific information is rapidly changing is *Phytophthora ramorum*, the causal agent of sudden oak death. Because of the dramatic and serious impacts of the organism in some areas of California, PRAs have been conducted in many countries, including: Australia, Canada, New Zealand, the United Kingdom and the United States. Information on the organism's host range, life history, climatic limitations or preferences, and impacts is continually changing, necessitating frequent revisions and updates to PRAs. Revisions may be made to all or parts of a PRA on any one occasion and may significantly alter the conclusions of the PRA.

3.2 DETERMINATION OF AN ORGANISM AS A PEST

Many kinds of organisms may come to the attention of an NPPO, either by way of their association or potential association, with plants and plant products, or as a result of a request to import or export a product. Before commencing the pest risk assessment stage of the PRA, it is necessary to determine if the organism is a pest according to the IPPC definition. This initial step is often called pre-selection or pre-screening. The following text on this topic is based on ISPM No. 2 (2007).

Before any subsequent step can be taken, the taxonomic identity of the organism should be specified as much as possible. This ensures that any biological and other information used in the pre-screening process, or in any subsequent analysis, is relevant. If, as sometimes happens when a new organism is discovered, it has not yet been fully named or described, then it should at a minimum have been shown to be identifiable, to consistently produce injury to plants or plant products (e.g. symptoms, reduced growth rate, yield loss or any other damage), and to be transmissible or able to disperse. Determining that an organism is a pest, and therefore pertinent to the IPPC and subject to a PRA, should be a relatively straight-forward process; it is not intended to be a lengthy nor difficult activity requiring extensive expertise or resources. It is simply a step that ensures that the subsequent PRA steps that are taken are an appropriate means by which to assess the organism in question and that issues related to the organism are plant-related.

The taxonomic level for organisms considered in a PRA is usually the species. The use of a higher or lower taxonomic level should be supported by a scientifically sound rationale. In cases where levels below the species level are being analysed, the rationale for this distinction should include evidence of reported significant variation in factors such as virulence, pesticide resistance, environmental adaptability, host range or its role as a vector. LMOs are an example of when a variety-level PRA may be necessary.

Predictive indicators for being a pest should be identified. These are characteristics that, if found, would indicate that the organism may be a pest. The information on the organism should be checked against such indicators, and if none are found, it may be concluded that the organism is not a pest, and the analysis may be ended by recording the basis of that decision.

It may be helpful for an NPPO to develop a standard checklist of indicators against which new organisms are evaluated in determining whether or not they are pests and whether or not PRAs are required.

The following are examples of indicators to consider:

- Previous history of successful establishment in new areas to the detriment of existing plants or beneficial organisms—many pests have a history of successful establishment in one or more new areas following introduction. For example, potato blight, *Phytophthora infestans*, has a well-known history of establishment in new areas as a result of the importation or movement of infested potato tubers. Likewise, Plum Pox Virus is now found on several continents as a result of spread in infected propagative *Prunus* material such as budwood, rootstock or nursery plants.
- Phytopathogenic characteristics—for example the organism has characteristics in common with other plant disease-causing organisms or is known to cause a plant disease or to negatively affect plants elsewhere.
- Phytophagous characteristics—for example the organism has characteristics in common with other organisms that feed or live in or on plants, or it is known to be a pest of plants elsewhere.
- Presence detected in connection with observations of injury to plants or to beneficial organisms without any clear causal link—for example the organism is consistently associated with signs of damage on the host species although no causal relationship between the organism and the condition have yet been proven.
- Belonging to taxa (species, genus or family) commonly containing known pests.
- Capability of acting as a vector for known pests—for example the organism is a proven vector, is closely related to known vectors, or shares characteristics with proven vectors of known pests, such as viruses, bacteria or fungi that cause plant disease.
- Capable of causing adverse effects on non-target organisms beneficial to plants, such as pollinators or predators of pests of plants.

In addition to known pests of plants and disease-causing organisms which are readily screened as pests on the basis of their confirmed capability to cause direct or indirect damage to plants, other cases for consideration include plant species, biological control agents and other beneficial organisms, organisms new to science, intentionally introduced organisms and LMOs. These, too, may be pests and therefore subject to PRA.

3.2.1 PLANTS AS PESTS

Plants have been deliberately spread among countries and continents for millennia, and new species or varieties of plants for crops, aesthetics or other purposes continue to be discovered, bred or imported. While the majority of these are highly beneficial, some plant species or varieties may have harmful effects when transferred to regions beyond their natural range. They may escape from where they were initially released and invade unintended habitats such as arable land, natural habitats or semi-natural areas. Unwanted plants may also be introduced unintentionally into a country. For example, they may be introduced as contaminants of seeds for sowing or grain for processing, and subsequently become established in new areas. These plants are variously termed weeds, invasive species, invasive plants, pest plants, or plants as pests.

Plants as Pests

The gardening industry in Australia is the largest importer of introduced plants to that country. Sixty-six percent of the introduced plant species now known to be established in the Australian environment are escaped garden ornamentals. They are the largest source of agricultural weeds and make up 70% of the total agricultural, noxious and ecosystem weeds listed. Some examples of pathways by which plants as pests may be introduced include:

- contaminants of seeds for sowing, or in grain for feed or human consumption,
- soil,
- used machinery and equipment or vehicles,
- containers,
- ballast water,
- attached to wildlife or livestock and in livestock bedding,
- contaminated footwear,
- wool, and
- deliberate introductions as commodities for research and development, planting, consumption or processing.

Examples of the types of impacts that plants as pests may have is provided in the supplementary text on environmental risks in ISPM No. 11 (2004).

The first indicator that a plant species may become a pest in the PRA area is often the existence of reports of such behaviour elsewhere.

Some intrinsic attributes that may indicate that a plant species could be a pest include:

- Adaptability to a wide range of ecological conditions—reports of the plant's occurrence in many different areas where conditions differ widely, e.g., *Eichhornia crassipes* from tropical South America has been able to establish itself in warm temperate regions, such as California. *Myriophyllum aquaticum* is a submerged aquatic plant from Brazil that has become established in temperate areas of Europe.
- Strong competitiveness in plant stands—reports of the plant's ability to replace existing plants in a stand when introduced, e.g. *Rhododendron ponticum* forms

dense, shrubby thickets in Europe, which completely shade the ground underneath, eliminating any herbaceous plants.

- High rate of propagation—produces more numerous, vigorous seeds over a long time period throughout the growing season than other plants in the same area, e.g., *Amaranthus* spp. and *Heracleum mantegazzianum* both produce large numbers of seeds over an extended time because of a long flowering season.
- Ability to build up a persistent soil-seed bank—produces numerous, long-lived seeds that persist in the soil even when the plants themselves have been removed or killed, e.g., *Abutilon theophrasti* and *Ambrosia artemisiifolia* are annual weeds of cultivated fields and waste places that have seeds that can survive for many years in the soil until conditions are favourable for germination and growth.
- High mobility of propagules—seeds or other plant parts that are capable of establishing new plants are easily spread by wind, rain, surface water, wildlife and other means over a wide area, e.g., *Potamogeton crispus* is an aquatic weed whose seeds are spread in water. *Asclepias syriaca* produces large numbers of seeds bearing a pappus of hairs, which allows them to be spread by the wind. *Salsola kali* plants break off from the roots, allowing the plants to blow across the ground with the wind, distributing the seeds. *Frangula alnus* produces berries which are attractive to birds that spread the seeds. *Bidens pilosa* produces fruits with barbs that catch onto the hair of animals which transport them to new locations.
- Allelopathy—produces chemicals that suppress growth of other plants in its vicinity, e.g. *Centaurea maculosa*, produces a phytotoxin from its roots that causes the death of the roots of susceptible plants. *Tamarix ramosissima* secretes salt in its leaves which results in raising the salinity of the soil around the plant, suppressing growth of other species.
- Parasitic capacity—capable of getting nutrients or other necessary resources from other plants to the detriment of the host plant(s), e.g., *Arceuthobium* spp. is a genus of perennial parasites which attach themselves to branches of coniferous trees, affecting their growth rate and health. *Cuscuta* spp. is a genus of annual vines that attach themselves to the stems of many plants and deprive them of nutrients. *Striga asiatica* is a herbaceous plant that severely reduces yields of corn and sorghum, by attaching itself to their roots.
- Capacity to hybridize—capable of reproducing with members of different varieties or species, creating hybrids or crosses with different, and potentially more harmful, characteristics than those of the parent plants, e.g. *Spartina anglica* is an aggressively invasive grass of salt marshes and inter-tidal mud flats, which developed from hybridisation that resulted when *S. alterniflora* from North America was introduced into the range of *S. maritima* in western Europe.
- Capacity to acquire nutrients more effectively than competitors—by nitrogen fixation or by mycorrhizae. *Robinia pseudoacacia* is a tree which fixes nitrogen in root nodules. *Myrica faya* is a tree that uses mycorrhizae for absorption of nutrients.

Following consideration of whether or not a plant is a potential pest and should therefore be subjected to a PRA, the analyst may wish to consider whether or not the plant is a pathway for the unintentional introduction of pests. If neither is the case, the PRA may stop here and the rationale be recorded. If the plant is a pest or a potential pathway for other pests, the PRA should continue.

3.2.2 BIOLOGICAL CONTROL AGENTS AND OTHER BENEFICIAL ORGANISMS

Biological control agents and other beneficial organisms are intended to be advantageous to human interests; they are meant to aid in the production of desirable plants without causing injury to them (e.g., by reducing pest populations or assisting in nutrient acquisition or by being harmful to undesirable plants such as weeds (e.g., by reducing seed production or viability)).

ISPM No. 3 (*Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms*, 2005) recommends that PRAs be conducted either before import, or prior to the release of, biological control agents and other beneficial organisms.

In addition to the general attributes that characterise a pest, factors to be considered in screening this category of organism may include:

- effects on non-target organisms (for example, beneficial organisms that would not ordinarily be considered pests may be pests if they are potentially capable of having direct or indirect phytophagous or phytopathogenic effects on non-target organisms that are plants);
- deleterious effect on native species of the same genera or occupying the same ecological niche, through competition or displacement;
- contamination of cultures of beneficial organisms with other species, the culture thereby acting as a pathway for pests (for example cultures of fungi for cultivation of edible mushrooms may be contaminated with pathogens, such as viruses or other fungi, which could result in deleterious impacts on the mushroom industry if introduced and established); and
- reliability of containment facilities when such are required.

Biological control agents, or other beneficial organisms, that are pests may be subjected to a PRA. For those that are found not to be potential pests, the PRA may be halted and the rationale recorded.

3.2.3 ORGANISMS DIFFICULT TO IDENTIFY OR NEW TO SCIENCE

During inspection of imported consignments or during surveillance, organisms may be detected that are difficult to identify (e.g., damaged specimens or unidentifiable life stages) or are new to science. Although in such cases the information available may be very limited, a decision may need to be made as to whether phytosanitary action is justified. When organisms have been detected that are difficult or impossible to identify, recommendations for phytosanitary measures may have to be made based on incomplete identification or information.

In these cases, the pre-screening and PRA may be based on very little information, or on information about other, related pests, and the known or possible hosts at risk. The PRA process allows a decision to be taken based on available information. It also enables information gaps to be identified and recommendations for further studies to be specified.

It is recommended that specimens are deposited in an accessible reference collection for future further examination, and that the PRA be re-visited and revised as soon as additional information becomes available. In instances such as these, it is important to record the information that was used to make decisions, identify particular areas of uncertainty or lack of knowledge, and take measures to obtain the necessary information to make a better-informed decision later.

3.2.4 LIVING MODIFIED ORGANISMS (LMOS)

LMOs are organisms that possess a novel combination of genetic material, obtained through the use of modern biotechnology, and are designed to express one or more new or altered traits in order to improve certain properties of the organism. Types of LMOs for which a PRA may be conducted include the following:

- plants for use in agriculture, horticulture or silviculture, bioremediation of soil, for industrial purposes, or as therapeutic agents (e.g., LMO plants with an enhanced vitamin profile, ornamental LMO plants with a different flower colour than the parent plants, agricultural crops with improved pest resistance);
- biological control agents and other beneficial organisms modified to improve their performance (e.g., hypervirulent fungi developed for weed control); and
- pests modified to alter their pathogenic characteristics (e.g., hypovirulent fungi such as *Ophiostoma ulmi* or *Cryphonectria parasitica* developed to combat Dutch elm disease or chestnut blight, respectively).

The modification may result in an organism with a new trait that presents a pest risk beyond, or different from, that posed by the non-modified recipient or donor organisms, or similar organisms. Risks may include the following:

- increased potential for establishment, spread or direct or indirect impacts
- those resulting from inserted gene sequences that may act independently of the organism with subsequent unintended consequences
- potential to act as a vector for the introduction of a new genetic sequence into domesticated or wild relatives of that organism, resulting in an increase in the pest risk of that related organism
- in cases of a modified plant species, the potential to act as a vector for the introduction of an injurious genetic sequence into relatives of that species

Traditionally, PRAs are concerned with phenotypic rather than genotypic characteristics. Phenotypic characteristics are the observable physical or chemical traits which characterise the organism in question. However, genotypic characteristics, the genetic make-up of an organism, should also be considered when assessing the pest risks of LMOs. These genotypic characteristics may be more significant than phenotypic characters in some instances, and may result in distinct risks that otherwise would not be recognized. While genotypic characters are not always well-known for many organisms, they are frequently well-defined for LMOs.

Predictive indicators for being a pest that are more specific to LMOs include:

- phenotypic similarities or genetic relationships to known pest species,
- introduced changes in adaptive characteristics that may increase the potential for introduction or spread, and
- phenotypic and genotypic instability.

For LMOs, identification requires information regarding the taxonomic status of the recipient and the donor organism, a description of the vector, and knowledge of the nature of the genetic modification, the genetic sequence and its insertion site in the recipient genome.

Further potential risks of LMOs are outlined in Annex 3 of ISPM No. 11 (2004). A PRA may be carried out to determine whether the LMO is a pest, and subsequently to assess the pest risk. An LMO which is a plant may also require consideration under section 3.2.1 (Plants as Pests), to determine if it is a pest plant or a pathway for introduction of other pests before the screening process is completed. If, following the initiation stage, it is deemed unnecessary to conduct a pest risk assessment, the basis of the decision should be recorded if appropriate and the PRA may be stopped.

3.2.5 INTENTIONAL IMPORT OF OTHER ORGANISMS

In cases where a request is made to import an organism for scientific research, or educational, industrial or other purposes, the identity of the organism should be clearly defined. Information on the organism or closely-related organisms may be assessed to identify indicators that the organism in question may be a pest.

Organisms in this category may include a wide variety of types, including insects, bacteria, viruses, etc., and may be for a wide variety of uses, including organisms for research or use in industrial applications, food or beverage production or medical applications, or for research or production of pest control products, cosmetics or environmental remediation products. A pre-screening of these organisms will identify which, if any, should be subjected to a PRA prior to determining if they are potential quarantine pests and establishing appropriate conditions for their import or use. For those that are not pests, the PRA may be stopped at this point and the rationale recorded.

3.3 DEFINITION OF THE PRA AREA

ISPM No. 5 (2006) defines the PRA area as the area in relation to which the pest risk analysis is conducted. It should be described as precisely as possible in order to identify the area for which information is needed.

The PRA area is frequently defined by political boundaries (i.e., a country), however it is not necessarily so, depending on geography and political circumstances. It may be a whole country, part of a country or several countries together. It is important that the PRA clearly define the area to which it applies, and that all considerations in the PRA (i.e., assessment of potential distribution or potential impacts, consideration of other influences, or evaluation of phytosanitary measures) apply to the same area.

The PRA area is distinct from the endangered area. ISPM No. 5 (2006) defines the endangered area as the area where ecological factors favour the establishment of a pest whose presence in the area will result in economically important loss.

The PRA area may cover a broad and diverse area, e.g., a large country like Canada, a cluster of smaller countries as in the EPPO area, or a group of islands belonging to a single country. The endangered area, on the other hand, may be the whole of the PRA area or a sub-set of it since it is the area where conditions are such that establishment of the pest and impacts are considered to be possible. These conditions may not be consistent across the whole of the PRA area.

During the course of the pest risk assessment step, the analyst will identify which part(s) of the PRA area have:

- ecological and/or climatic condition suitable for the establishment and spread of the pest (including those in protected locations such as in a glasshouse), and

- host species (or near relatives) or alternate hosts and/or vectors present where relevant.

This information will be used to identify the endangered area at the end of the pest risk assessment stage of the PRA.

3.4 PREVIOUS PRAs

Before performing a new PRA, a check should be made to determine if the organism, pest or pathway has ever been subjected to a previous PRA by the NPPO. The validity of any existing analysis should be verified, as circumstances and information may have changed. The previous PRA's relevance to the PRA area being considered should be confirmed. A previous PRA may be determined to be irrelevant to the current situation if, for instance, it is out-of-date, the PRA area is widely different from the PRA area in the current situation, or the previously assessed pathway is not similar to the identified pathway.

The possibility of using a PRA done on a similar organism, pest or pathway may also be investigated, particularly when information on the specific organism is absent or incomplete. Information assembled for other purposes, such as environmental impact assessments on the same, or a closely related, organism may be useful but cannot substitute for the PRA.

3.5 CONCLUSION OF THE INITIATION STAGE

At the end of Stage 1, the initiation point has been determined and the PRA area will have been identified. Relevant information has been gathered, pathways and pests have been defined, and organisms have been identified as potential quarantine pests, individually or in association with a pathway.

Organisms that have been determined not to be pests, and pathways not carrying pests, do not need to be assessed further. The decision and rationale to stop the PRA at this point should be recorded and communicated, as appropriate.

4. STAGE 2: PEST RISK ASSESSMENT

ISPM No. 11 (*Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms,* 2004) provides guidelines for the further analysis of organisms found to be quarantine pests. If the pest is of non-quarantine significance, ISPM No. 21 (*Pest risk analysis for regulated non-quarantine pests*) may apply.

Stage 2 of PRA is the assessment of pest risk. There are three steps to this stage:

- Step 1: pest categorisation
- Step 2: assessment of the probability of introduction (entry and establishment) and spread
- Step 3: assessment of potential impacts of introduction and spread

Although the pest risk assessment steps are commonly documented sequentially, it is not necessary to complete them in this order. Pest risk assessment is an iterative process; it requires repeated consideration of the various elements which influence pest risk as information becomes available. The results of step 2, assessment of the probability of introduction and step 3, assessment of potential economic consequences of introduction and spread, are combined to provide an overall estimation of risk.

Pest risk assessment need only be as complex as is required by the circumstances to support a final decision and provide the necessary technical justification to defend decisions regarding phytosanitary measures. The pest risk assessment should be based on sound science, be transparent, and be consistent with other pest risk assessments conducted by the NPPO. For this reason, it is desirable to have a national system that provides a standard, comprehensive framework that lays out the criteria to assess all potential risk factors.

The pest risk assessment should consider all aspects of each pest including information about its geographical distribution, biology and economic importance in areas where it is already present. Expert judgement is then used to assess the likelihood that it will be introduced, and its potential for establishment, spread and economic importance in the PRA area. In characterising the risk, the amount of information available will vary with each pest and the sophistication of the assessment will vary with available tools. For example, one NPPO may have elaborate pest databases and geographical information systems; another may depend on books, printed soil maps, climate maps and expert opinion. In some cases, virtually no information may be available, or research may be needed to obtain it. Assessments will be limited by the amount and quality of information available. Countries where the pest is present may provide, upon request, available information for the country conducting the pest risk assessment.

4.1 APPROACHES TO PEST RISK ASSESSMENT

No single method of pest risk assessment has proven applicable to all situations; different methods may be appropriate in different circumstances. Pest risk assessments can be carried out with qualitative data, quantitative data or a combination of both.

This raises many questions: What are quantitative and qualitative pest risk assessments? Is the exclusive use of quantitative data sufficient to make the risk assessment itself quantitative, or must quantitative modelling also be used? If the latter, what kind of modelling is necessary? Is it enough to model the phenomena being assessed (e.g., the population dynamics of a pest of plants) in order to calculate the probabilities of particular outcomes (e.g., that the area occupied by the pest doubles within one year and increases by five times within three years) or must quantitative methods also be applied to calculate the pest risk associated with combinations of outcomes (e.g., that the distribution of the pest increases as described above, and that an affected industry loses 60% of its markets as a result)? There is no definitive answer to these questions because (i) there is no standard definition of "quantitative pest risk assessment," or "qualitative pest risk assessment," given in ISPM No. 5, and (ii) these terms are used differently in different contexts by different RPPOs and NPPOs.

For the purposes of this course, the terms "quantitative pest risk assessment," "qualitative pest risk assessment" and "semi-quantitative pest risk assessment" are understood as follows:

- A qualitative pest risk assessment presents a reasoned consideration of the relevant factors pertaining to the pest in question and expresses both the likelihood of its entry, establishment and spread and the severity of its consequences using non-numerical terms such as "high," "medium" and "low." Quantitative data may be included in this kind of risk assessment, but it is not used as a basis for quantitative modelling, either to calculate probabilities or risk. Numbers may even be substituted for non-numerical terms (e.g. "3" for "high" and "1" for "low") for the purpose of combining estimates of likelihood with one another, and with rankings of consequences. However, these numbers do not represent quantities (for, if outcome A has likelihood "high" and outcome B has likelihood "low," by substituting numbers as above, A is not thereby shown to be three times as likely as B).
- A quantitative pest risk assessment involves the use of modelling for the calculation of probabilities and risk. Accordingly, quantitative data is necessary, but not sufficient, for a quantitative risk assessment. A quantitative risk assessment also requires that the risk assessor develop a model that links various aspects of the biology of an organism its predicted behaviour in the PRA area, and its socio-economic impacts.
- 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 is not available or the same degree of precision is not required.

Qualitative pest risk assessments are the kind most commonly undertaken. Quantitative pest risk assessments are the least common, in part because of the need for better quality data to use in quantitative modelling. This does not mean that most pest risk assessments are unreliable, based on poor quality data and less-than-accurate predictive methods. For many purposes, qualitative pest risk assessments are perfectly adequate for making informed, reasonable decisions about a potential pest organism. Moreover, although a quantitative assessment is based more firmly on mathematical methods, the results are not necessarily more accurate than a qualitative assessment. Choosing the right model, identifying the pathways to include or exclude, determining the factors to be included in the model, and knowing the actual values to be used for each input variable and the type of mathematical distribution applied to them is a very complex process. It often requires that the analyst make assumptions that may be challenged by future studies.

It is important to understand that the pest risk assessment process whether qualitative or quantitative, inevitably involves a degree of bias. The analyst is invariably unable to access and review all the relevant literature and correspond with all knowledgeable experts on a particular pest organism, either because of linguistic barriers, time-constraints, unfamiliarity with certain publications or any number of other factors. The best that can be achieved is to ensure that an assessment is as thorough as possible, that all sources are documented and that the reasoning based on those sources is transparent. All the information, assumptions, uncertainties, methods and results must be carefully documented and the discussion and conclusions must be supported by a sound and rational discussion. The pest risk assessment should be fully referenced and subjected to a peer-review.

4.2 PEST CATEGORISATION (STEP 1)

Pest categorisation is the first step in the pest risk assessment stage of a PRA and its purpose is to determine whether any of those pests identified during the initiation stage satisfy the criteria for a quarantine pest. It includes all the main elements of a full pest risk assessment but is done in less detail and is essentially a quick assessment of whether the PRA should continue, in the case of a pest PRA, or whether a PRA on a particular pest is required in the context of a pathway PRA. The categorisation step provides an opportunity to eliminate organisms at an early stage in the pest risk assessment, before the in-depth examination is undertaken. Pest categorisation can be done with relatively little information, provided that the information available is sufficient to carry out the categorisation.

During this step it is important to consider such questions as: Does the pest meet the criteria for a quarantine pest? What is the potential for the pest to be associated with the commodity or pathway? What is the potential impact of the pest? How likely is introduction and establishment of the pest if no mitigation measures are applied to the pathway(s)?

If the pest satisfies the definition of a quarantine pest, expert judgement may be used to review the information collected to this point to determine whether the risk from the pest is acceptable or unacceptable. If the pest has potential economic importance and establishment is possible within the PRA area, the PRA may continue. If not, or if the risk is deemed to be acceptable, the PRA may stop at this point.

Where an organism does not meet the criteria for a quarantine pest, the PRA for that particular organism stops and the rationale is recorded. It may, however, be necessary to assess if the organism fulfils the criteria for a regulated non-quarantine pest according to ISPM No. 21 (*Pest risk analysis for regulated non-quarantine pests*). In this latter case, the pest need not meet the requirements of a quarantine pest for the PRA to continue.

4.2.1 ELEMENTS OF CATEGORISATION

ISPM No. 11 (2004) lists the following as primary elements for the categorisation of a pest as a quarantine pest:

- identity of the pest
- presence or absence in the PRA area
- regulatory status
- potential for establishment and spread in the PRA area
- potential for economic consequences in the PRA area

These criteria reflect those included in the definition of a quarantine pest and the criteria that should be considered in detail in a PRA.

The following discussions are based on ISPM No. 11 (2004).

4.2.1.1 IDENTITY

PRAs are generally conducted on organisms identified at the genus, species or sub-species level. Other situations such as groups of species may also be appropriate occasionally. The identity of the pest and any relationships between it and other known quarantine or regulated non-quarantine pests should be noted or defined. When identifying the species or other taxon for which the PRA applies, the analyst should take note of synonyms that also apply since these could help access information overlooked if only the valid name is used when gathering information.

The identity of the pest should be clearly defined to ensure that the assessment is being performed on a distinct organism, and that biological and other information used in the assessment is relevant to the organism in question.

Sometimes the identity of the pest is not clear and/or there may be controversy or confusion concerning its taxonomic classification. This can make it difficult to know whether information related to it is relevant or reliable. This should be noted in the PRA.

In cases where a vector is involved, the vector may also be considered a pest, to the extent that it is associated with the pest and is required for the pest's transmission.

4.2.1.2 PRESENCE OR ABSENCE IN THE PRA AREA

> Specimens are the most reliable evidence of the presence or absence of a pest in a country or area. They can be easily re-examined to verify the accuracy of the identification.

According to the definition, a quarantine pest must be "not present" or "present, but not widely distributed" in the PRA area and "under official control". If not, it does not meet the definition of a quarantine pest and the PRA is stopped. Knowledge of a pest's presence or absence in the PRA area is, therefore, one of the first pieces of information that should be obtained when categorising pests for the purposes of a PRA. A pest's distribution may influence the outcome of the categorisation step, the pest risk assessment stage or the complete PRA. For the pest categorisation step of a PRA, it is necessary to determine if a pest is:

- absent,
- present and not widely distributed, or
- present and widely distributed.

This determination requires information from numerous sources, including individual pest records, pest records from surveys, data on pest absence, findings from general surveillance and scientific publications or databases. Expert judgement may further contribute to a determination. Supplements No. 1 (*Guidelines on the interpretation and application of the concept of official control for regulated pests*) and No. 2 (*Guidelines on the understanding of potential economic importance and related terms including reference to environmental considerations*) to ISPM No. 5 (2006) provide further guidance on the interpretation and application of the terms used in the definition of a quarantine pest. Of critical importance to keep in mind is the need to document the references used and the decisions that are taken in determining whether or not a pest is present or absent in the PRA area and, if present, the extent to which it occurs there.

Knowledge of pest presence, absence or distribution within a country is also important for export purposes, as this information may be used to determine and report pest status, as described in ISPM No. 8. The components of survey and monitoring systems for the purpose of pest detection and guidance on the establishment of pest free areas and the preparation of pest lists are described in ISPM No. 6 (*Guidelines for surveillance*).

4.2.1.3 REGULATORY STATUS

If the pest is present but not widely distributed in the PRA area, it should either be under official control, or be expected to be under official control in the near future. Official control is defined by ISPM No. 5 (2006) as "*The active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for the management of regulated non-quarantine pests.*"

ISPM No. 5 (2006), Supplement No. 1 describes official control as including the following:

- eradication and/or containment in the infested area(s)
- surveillance in the endangered area(s)
- measures related to controls on movement into and within the protected area(s), including measures applied at import

Official control is subject to the phytosanitary principles for the protection of plants, in particular the principles of non-discrimination, transparency and technical justification (pest risk analysis). In the case of a quarantine pest that is present but not widely distributed, and, where appropriate, in the case of certain regulated non-quarantine pests, the importing country should define the infested area(s), endangered area(s) and protected area(s). For example, Asian longhorned beetle (*Anoplophora glabripennis*) is under official control in Germany. Measures being taken include: monitoring of the endangered areas, an early warning system, eradication measures, and emergency plans.

Official control:

- is mandatory—all persons involved are legally bound to perform the actions required;
- should be established or recognized by the NPPO under appropriate legislative authority; and
- should be performed, managed, supervised or, at a minimum, audited or reviewed by the NPPO.

> If a pest on an imported commodity has already been reported in the importing country and has never been subject to any official control it is inappropriate to categorise the pest as a potential quarantine pest. However, if official control is undertaken, the pest may then be categorised as a quarantine pest.

4.2.1.4 POTENTIAL FOR ESTABLISHMENT AND SPREAD IN THE PRA AREA

Evidence should be available to support the conclusion that the pest could become established and spread in the PRA area. The PRA area should have ecological or climatic conditions, including those in protected conditions such as under glass, suitable for the establishment and spread of the pest. All important biotic and abiotic factors must be analysed. Where relevant, host species (or near relatives), alternate hosts and vectors should be present in the PRA area.

4.2.1.5 POTENTIAL FOR ECONOMIC AND ENVIRONMENTAL CONSEQUENCES IN THE PRA AREA

There should be clear indications that the pest has the potential to have an unacceptable economic impact in the PRA area. At minimum there should be evidence that susceptible hosts are present and would suffer detrimental effects if the pest were introduced. Pests that have no potential impacts in the PRA area, (for example, because no hosts are known to be present or because climatic conditions would not permit establishment), do not meet the criteria for quarantine pests and need not be considered further.

Example of Pest Categorisation

An importer has made a request to import fresh bananas to Canada. There is a possibility that the bananas may be infested with live insects that feed exclusively on banana fruit and leaves. In this example, the PRA would be discontinued because bananas are not grown in Canada and the insect has no potential to become established in Canada or to have any subsequent economic or environmental impacts due to the unsuitability of the climate in the PRA area and the lack of suitable hosts. Another NPPO, of a country where bananas are grown and valued, would make a different decision about the same pest and the same pathway for its introduction and would determine that the insect meets the conditions for a quarantine pest because it has the potential to both become established and have an economic impact. In this latter case, the PRA would continue to further characterise the risk presented and identify appropriate phytosanitary measures.

4.2.2 ORGANISING PEST CATEGORISATION DATA

Each importing country may determine how it wishes to organise and convey the information considered during pest categorisation. Principles for organising the pest categorisation data should be based on ISPM No. 11 (2004).

An example of organization of pest categorisation data from a Canadian PRA

Pest Name	Occurrence in PRA area	Quarantine Pest (yes or no)	Background Information
Athelia rolfsii (Curzi) Tu and Kimbrough	present	no	Cosmopolitan; causes “southern blight”; very wide host range including *Avena*, *Hordeum* and *Triticum*; causes leaf blights, stem cankers, damping-off, crown and root rots (Farr *et al.*, 1989); seed-borne (Richardson, 1990).
Botrytis cinerea Pers.:Fr.	present	no	Cosmopolitan (Farr *et al.*, 1989); sometimes associated with a disease of spikelets and black point (Gair *et al.*, 1987); Richardson (1990) reports it on seed.

An example of organization of pest categorisation data from a New Zealand (NZ) PRA:

Scientific name	In NZ?	Vector of a hazard	More virulent strains on goods overseas	In NZ but not associated with goods	In NZ but not in region
Arbuscular mycorrhizae	N				
Ectomycorrhizae	N				
Phytophthora cinnamomi	Y	N	Y	N	N

Scientific name	In NZ but different host associations	Under official control or notifiable	No or little information on organism	Quarantine Pest?
Arbuscular mycorrhizae				Y
Ectomycorrhizae				Y
Phytophthora cinnamomi	Y	N	N	Y

4.2.3 CONCLUSION OF PEST CATEGORISATION

Pest categorisation is used to develop a list of potential quarantine pests when conducting a pathway PRA. This then forms the basis for a detailed assessment of the probability of introduction and spread of each species. If it has been determined that a pest has the potential to be a quarantine pest, the PRA for that pest continues; if the pest does not fulfil the criteria for a quarantine pest, the PRA for that pest stops. If complete information is not available, the uncertainties should be documented and the PRA should continue.

Getting Started on a PRA

A useful starting point for doing a PRA is the clear definition of what it is that is being subjected to a PRA and the area for which the PRA is applicable. If the PRA is a pest PRA, the scientific name of the organism, any synonyms, and common names in the country (countries) of origin must be correctly identified. If it is a pathway PRA, it is important to clearly describe the pathway. If the pathway is a commodity, describe where it is coming from, any processing or treatments that it has been subjected to, the intended means and route of transportation, its intended end-use, and any other factors which might affect the risk it represents. Likewise, if the pathway is a mode of transportation or other route of entry, e.g., packing materials, describe its origin, condition and any processing or other treatments it has been subjected to.

A second step is to confirm whether a PRA has already been completed on the pest or pathway in question, and if so, whether it is still valid, or if it should be considered to be incomplete, out-of-date or otherwise irrelevant to the case at hand. It is useful to have a standard national PRA format to follow with headings and guidance for what information should be included under each heading, as a starting point for any PRA. This ensures consistency between PRAs, but more importantly, it ensures that all categories of information are considered in any single analysis and no important factors are over-looked. With a standard format to follow, an individual or team can work towards filling in the blanks as information is acquired, and can identify the areas for which no information has yet been received and that require attention. The national PRA format should be consistent with the international standard, but need not follow the standard exactly and can reflect the NPPO's preferences and style.

Although ISPMs No. 11 (2004) and No. 21 lay out the elements that should be addressed in completing the pest risk assessment portion of the PRA, it is not necessary to develop the assessment in the sequence presented or to complete sections one by one. Information is not always received in the order in which it is presented in the ISPMs on PRA. Furthermore, completing a pest risk assessment is an iterative process; as new information is received, it may be necessary to revisit sections that have already been completed.

A checklist is very helpful to keep track of what is needed. Some analysts begin by incorporating the available information into a pest fact sheet, which may or may not be incorporated into the final pest risk analysis according to the preferences and format established by the NPPO for the PRA. Some examples of checklists are attached as Appendix 4. The pest fact sheet headings used in the CABI Crop Protection Compendium, or the CABI/EPPO pest facts sheets, are typical of those used in many NPPOs for displaying factual information about a pest. An example of a pest fact sheet is included in Appendix 3.

The length of time required to complete the pest risk assessment stage is highly variable. Some simple and straight-forward assessments may be completed by a single analyst with ready access to information in a matter of days, while other, more complex, assessments may require the work of several people for many weeks or months. In these latter cases, it is particularly helpful to keep track of the sources that have been checked and the contacts that have been made, to avoid duplication or inefficiency.

4.3 ASSESSMENT OF THE PROBABILITY OF INTRODUCTION (STEP 2)

Introduction of a pest involves both entry and establishment, i.e., the pest must first arrive in the new area and then it must find suitable conditions and establish a population there in order for it to meet the definition of introduction. Assessing the probability of introduction requires analysis of each of the pathways with which a pest may be associated, from its origin to its establishment in the PRA area.

> **Entry**
>
> ISPM No. 5 (2006) defines entry of a pest as "Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled" and establishment as "Perpetuation, for the foreseeable future, of a pest within an area after entry".

In a PRA initiated by a specific pathway (usually an imported commodity or goods associated with an imported commodity, e.g., packing materials), the probability of pest entry is evaluated for both that specific pathway and for other possible pathways for each of the pests being considered in the PRA. For PRAs initiated for a specific pest, all probable pathways are evaluated for that individual pest species.

> **A Checklist for Describing a Pathway**
>
> - Use scientific names when reference is made to an organism or disease agent. (e.g., Radiata pines (*Pinus radiata*), Limes (*Citrus latifolia*)).
> - Describe the nature, source(s) and intended use(s) of the commodity or organism where relevant. (e.g., frozen blueberries (*Vaccinnium* spp.) for consumption, wood and wood products from the USA for construction, live fungal cultures for mushroom production, Lychee (*Litchi chinensis*) fresh fruit from Taiwan for consumption, used cars from Japan).
> - Describe the relevant methods of production, manufacturing, processing or testing that are normally followed during production of the commodity. (e.g., pest management practices, inspection, surface treatments, industrial processing, fumigation, controlled atmosphere storage etc.).
> - Describe any quality assurance programs that may apply and how they are verified. (e.g., hazard analysis and critical control point (HACCP) programs for the production of regulated articles).
> - Describe the volumes, times of year, and destinations of commodities or organisms considered for entry into the country.

4.3.1 PROBABILITY OF ENTRY

ISPM No. 11 (2004) states that the probability of entry of a pest depends on the pathways from the exporting country to the destination, and the frequency and quantity of pests associated with them. Pathways are the means by which species are moved from one location to another. The higher the number of pathways, the greater their combined volume and the more frequent their occurrence, the greater the probability of the pest entering the PRA area.

For pest-initiated PRAs, known and documented pathways for the pest to enter new areas should be noted and potential pathways assessed. Some potential pathways may not exist at the time of the PRA, but may be considered as potential future pathways.

Example PRA

In 2006, the Canadian Food Inspection Agency (CFIA) completed a pest risk assessment on carpet burweed (*Soliva sessilis* Ruiz and Pav.). The species is primarily a weed of walkways, lawns, parks, and golf greens. The seeds of carpet burweed are spiny achenes that readily adhere to dispersal vectors such as feet, fur, footwear, clothing, tents, motor homes and camping gear. Potential pathways for this species that were identified included the movement of people (especially tourists) and animals (pets, livestock), as well as natural spread via population expansion. Intentional imports of plants or plant parts were not expected.

Pathways can be natural, such as wind and water currents, or man-made, such as plant products destined for international sale, or soil associated with nursery stock prepared for international trade. Man-made pathways are easier to address using phytosanitary measures than are natural pathways. Pathways that are intentional are those that result from deliberate actions, such as importing live plants for the nursery trade when the plant is the potential pest, or biocontrol agents for agricultural applications. Unintentional pathways are those where the movement of the pest species is an indirect result of an activity, such as the movement of species in ballast water or pests associated with an intended import of plants or plant products. When the potential pest is associated with a live plant imported for the nursery trade (for example, an insect or pathogen), the plant is an unintentional pathway for introduction of the pest.

Definitions

ISPM No. 5 (2007) defines a commodity as “a type of plant, plant product or article being moved for trade or other purposes”; a pathway as “any means that allows the entry or spread of a pest” and a regulated article as “any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved”.

For pest-initiated PRAs, each of the potential pathways by which the pest could enter the PRA area should be noted. These should include both natural movement and human-assisted passage. Interception data may provide evidence of the pest’s ability to be associated with a particular pathway and to survive during transport and storage. Examples of pathways to consider include forms of transport (rail cars, ships’ ballast, containers, etc.), commodities (fresh fruit, live plants, wood products, seeds and grains, etc.) or associated products (wood packaging, dunnage, bedding materials, planting media, etc.). Imported commodities are often packed into bags, or enclosed in wrapping or other packaging materials in their country of origin. They are loaded as baggage, bulk materials, or in containers in motor vehicles, sea vessels or airplanes for transport. Packing material such as paper, wood shavings or sawdust, is often used to support the goods during transport. All such packaging and packing material should be noted in the description of the pathway of entry of the commodity.

Identifying pathways requires consideration of such things as the life history of the pest in question, the production and harvesting practices in the country of origin, and international trade patterns and practices. The analyst needs to first identify which part or parts of the host(s) are most likely to be carriers of living life forms of the pest in question, and then for each of those plant parts determine if, when, and how they are imported to the PRA area and by what other means (or pathways) they might enter.

Apple Pest

As an example, consider a hypothetical insect that lays its eggs on the buds, twigs and young branches of apple trees. The larvae hatch, burrow into young fruit and develop there. They pupate in the fruit, the adults emerge and the insect's life cycle continues. From a biological perspective, commodities that are potential pathways are:

- fresh fruit (which could contain larvae or pupae, depending on the time of year and other factors),
- nursery stock (which could have eggs laid in the new buds),
- apple cuttings for flower arrangements,
- apple budwood for propagation, and possibly
- apple wood to which bark is still attached (which also might have eggs).

As part of the assessment of probability of entry, the analyst would need to identify if, when, at what volumes and from what areas apples were being intentionally imported, carried in passenger baggage, or entering the PRA area by mail order or other means. The analyst would also need to ask the same questions about apple nursery stock, cuttings for flower arrangements, budwood and apple wood. The analyst might also consider if apple wood is commonly used as a wood packaging material, dunnage, animal bedding, or if any of these plant parts are a desirable souvenir that is carried in passenger baggage. Each pathway will have a different likelihood as a route of entry for the pest, and the analyst must consider first each pathway individually, and then all pathways together, to draw a conclusion about how likely entry is to occur. Natural migration from nearby areas may also be a factor that contributes to likelihood of entry.

All possible routes of entry should be considered when evaluating the likelihood of entry. These include:

- on or in people—commodities might be carried in or on a person including the clothing they are wearing;
- personal baggage—including carry-on or checked baggage;
- personal effects—these are unaccompanied personal or household goods usually carried in containers;
- vessels—ships and aircraft may act as vectors for unwanted organisms or contain food, dunnage or personal effects that if removed from the vessel, could be considered a commodity;
- air courier cargo—this is courier mail and packages arriving by air. Both wrapping and contents may need to be assessed;
- international mail—Both packaging and contents may need to be assessed;
- container cargo—these are goods that are packed into containers for transport. The containers, packaging and contents may each require assessment;

- bulk cargo—these are goods transported in bulk form during transit;
- vehicles—this includes cars, trucks, farm equipment, military vehicles etc.; and
- by-products and waste.

All potential pathways should be assessed, whether or not they exist at the time of the PRA. The possibility of the pest arriving alone or in association with hosts or other material should be considered.

ISPM No. 11 (2004) lists the following factors which should be taken into account when assessing the probability of entry:

- probability of being associated with pathway at origin
- probability of survival during transport or storage
- probability of pest surviving existing pest management procedures
- probability of transfer to a suitable host

4.3.1.1 PROBABILITY OF BEING ASSOCIATED WITH PATHWAY AT ORIGIN

The likelihood of a pest being present on or in a pathway must be considered as a first step. The following are some points to be considered:

- Prevalence of the pest in the source area—Does the pest occur commonly? Is it an occasional pest or highly prevalent in the production area every year?
- Probability of the pest surviving agricultural or commercial practices in the country of origin—Do the producers of the commodity in the country of origin implement pest control measures, including integrated pest management, pesticide applications, or other practices, that would have a detrimental effect on the pest's survival?
- Occurrence of the pest in a life stage that would be associated with the commodity—For example, for a fruit pest, would viable life stages of the pest be present on the fruit at the time of harvest?
- Volume and frequency of movement along the pathway—Is the commodity imported frequently? In large or small volumes?
- Seasonal timing—Is the commodity harvested and prepared for shipping at a time of year when the pest would be present in the country of origin? Will it arrive in the country of destination at a time of year that would be suitable for establishment of the pest?
- Pest management and phytosanitary procedures applied at the place of origin—Are phytosanitary measures applied in the country of origin which would lessen the likelihood that the commodity will be infested when it is imported?

Apple Pest Continued

Continuing with the example of the hypothetical apple insect, each of the factors which contribute to the likelihood of its being associated with any one or more of the identified pathways at the point of origin will next be considered for each of the biologically feasible pathways: fresh fruit, cuttings for flower arrangements, etc., in order to determine the likelihood of the insect being associated with each. While apple fruit is a biologically feasible pathway, the analyst must consider: whether or not there is an active insect population in the area where the fruit is being grown, if the orchard is subject to pest management practices that would eliminate the insect, if the fruit itself is treated in a way that would eliminate the pest (e.g., inspection, fumigation, surface sterilisation), if the larvae will be present in the fruit at the time of harvest, how much fruit is being imported, at what time of year and in what quantities, and many other factors. All of these will influence how likely it is that imported fruit will be infested with living insects, just as they will influence an assessment of the likelihood that any of the other biologically feasible pathways will be actual pathways.

4.3.1.2 PROBABILITY OF SURVIVAL DURING TRANSPORT

Likewise, consideration of the probability that a pest will survive transport requires knowledge of the biology of the pest and information on the conditions of transport for each of the identified pathways. If the pest cannot survive, it cannot enter or become established in the PRA area. Some factors to consider in determining the likelihood of a pest surviving during transport and storage include:

- length of time in transport and storage in relation to the duration of the pest's life cycle;
- robustness of the life-stages present—for example, for some fungi, certain types of spores are very short-lived while others are very durable and long-lived, designed for survival of sub-optimal conditions;
- number of individuals, spores or propagules involved—for some species a single individual is enough to start a new population, but for other pests a large number of individuals are necessary;
- prevalence in the country of origin—the more prevalent the pest in the country of origin, the more likely it is to be present in or on the commodity in sufficient numbers to survive transit and be introduced to the country of destination; and
- commercial procedures (e.g. refrigeration, kiln drying of wood products) applied to consignments in the country of origin, country of destination, or during transport or storage—some common shipping procedures, such as controlled atmosphere storage or hot water dip treatment for certain plant products, may have deleterious effects on pests associated with the commodity, even though that is not the intended outcome of the treatment.

4.3.1.3 PROBABILITY OF PEST SURVIVING EXISTING PEST MANAGEMENT PROCEDURES

Existing pest management and phytosanitary measures may greatly influence the likelihood that the pest will either be present on the pathway, or survive transport and be capable of becoming established following import. It is important, therefore, to evaluate any treatments or procedures that the commodity will be subjected to for effectiveness in eliminating the pest(s) in question. Factors to consider include:

- the effectiveness against the pest in question of measures applied to consignments, between the point of origin and its end-use, to control other pests—for example, if the consignment is to be fumigated to control storage pests as a routine industry standard, and the fumigation treatment is effective in controlling the pest being assessed, then no further phytosanitary measures may be necessary to attain a satisfactory level of protection; and
- the probability that the pest will go undetected during inspection or survive other existing phytosanitary procedures—for example, if the inspection, treatment and other procedures to which the consignment will be subjected cannot be certain of detecting or eliminating the pest, then additional phytosanitary measures may be necessary.

Apple Pest Continued

Continuing with the apple-insect example, consider fresh apples - pest management procedures such as integrated pest management practices, insecticide applications, pruning, culling of excess fruit, fruit bagging and other practices in the orchard may greatly influence the presence and abundance of the insect on fresh fruit, or any of the other pathways identified. The risk analyst should ask the NPPO of the exporting country to provide information regarding the pest management practices in its country, and should review published and scientific information. Each of the identified pathways should be considered separately as not all pathways will have originated under the same conditions. Although fresh fruit or budwood may originate in well-tended orchards under tight pest management regimes, the same may not be true of apple wood, flower arrangements or other pathways.

4.3.1.4 PROBABILITY OF TRANSFER TO SUITABLE HOST

In order for the pest in question to establish a viable population in the importing country, it must not only be transported there in or on a pathway and survive all treatments and procedures to which that consignment is subjected, but it must then be capable of transferring to a suitable host in the PRA area. The probability of this transfer occurring increases if the pathway on which it is travelling is widely distributed both over time and space, thereby increasing the pest’s opportunities for encountering a suitable host at a suitable time of year. Other factors that will influence the pest’s probability of transfer to a suitable host include:

- Dispersal mechanisms, including vectors—for example, is the pest mobile? Can it fly or is it wind-dispersed? Are vectors also likely to be transported on the pathway, or will suitable vectors be available at the new site?
- Whether the imported commodity is sent to few or many destination points in the PRA area—the more areas to which the pathway is shipped, the greater the

opportunities for the pest to encounter suitable hosts and be successful in transferring.

- Proximity of entry, transit and destination points to suitable hosts—entry points that are in close proximity to suitable hosts are more vulnerable to introduction than are areas at a far distance from suitable hosts. Following the example of the hypothetical apple insect, the pest is more likely to be successful in transferring to a suitable host when the destination points for the identified pathways are close to orchard production areas or landscaped areas with fruit trees.
- Time of year at which import takes place—the pest may be more or less successful in transferring to a suitable host at certain times of the year depending on the life stage of the pest, the prevalent conditions at the destination point, and the pest's biology.
- Intended use of the commodity—end-uses such as planting, processing or consumption will all affect the chances of the pest transferring to a suitable host and becoming established, e.g., if the consignment is destined for processing, the pest may have a much reduced chance of establishment.

4.3.2 PROBABILITY OF ESTABLISHMENT

To estimate the probability of establishment of a pest, reliable biological information about the pest including its life cycle, consideration of the number of hosts, their geographic range and pattern of distribution, epidemiology, attributes of the abiotic environment (precipitation, temperature, soil type), and other factors affecting its survival should be obtained from the areas where the pest currently occurs. Just as importantly, the environmental conditions under which the pest does not survive are important to understand. The situation in the PRA area can then be compared with these areas (taking into account the environments in locations such as glasshouses, shadehouses and irrigated areas), and expert judgement can be used to assess the pest's probability of establishment. Introduced pests may behave much as they do in their native area if host plants are present in the PRA area, the climate is similar to the pest's area of origin and other significant factors (e.g., vectors, predators and parasites etc.) are similar. Case histories concerning comparable pests may be helpful and can be considered.

Transience

A transient pest may not be able to become established in the PRA area due to factors such as unsuitable climatic conditions, but could still have unacceptable economic consequences. According to ISPM No. 8 "Pest status is considered transient when a pest is present but establishment is not expected to occur based on technical evaluation." It further lists three types of transience:

- Non-actionable—where the pest has only been detected in isolated populations and is not expected to survive and no phytosanitary measures have been applied
- Actionable, under surveillance—where the pest population may survive into the immediate future but is not expected to establish and appropriate phytosanitary measures including surveillance are being applied
- Actionable, under eradication—where the pest population may survive into the immediate future and in the absence of phytosanitary measures may become established. Appropriate phytosanitary measures have been applied to eradicate it

In light of the available knowledge about the pest's biology, impacts and behaviour in areas where it is already present, there are a number of factors that will affect the risk of pest establishment and should be considered. They are outlined below.

4.3.2.1 AVAILABILITY OF SUITABLE HOSTS, ALTERNATE HOSTS AND VECTORS

An estimation of the availability of the key factors that would contribute to a pest's survival and importance in the PRA area is fundamental to estimating its potential significance in the PRA area. Comparing information on the pest's hosts, biology, and life history in areas where it is already present, with information about the PRA area, the analyst estimates the availability of those factors that are necessary for the pest's successful establishment in the PRA area.

The following factors may contribute to this assessment:

- Presence and abundance of potential hosts, including intermediate or alternate hosts, in the PRA area—usually a substantial population of host plants and, if necessary, vector(s), in the PRA area is required for successful establishment of the pest to occur. A serious pest of coconut palms, for example, will not establish a population successfully in an area where coconut palms are not present.
- Occurrence of suitable hosts and alternate hosts within sufficient geographic proximity to allow the pest to complete its life cycle—for example, many rust fungi require two quite different hosts to complete their life cycle. A rust that alternates between pome fruits and junipers will not be successful in maintaining a population in a region where no junipers are present.
- Presence of other plant species that could prove to be suitable hosts in the absence of the usual host species—highly adaptable pests may be successful in establishing new populations in the absence of their usual host(s). In these instances, history of adapting to new host plants following introduction elsewhere may be an important consideration.
- Presence of a suitable vector, if needed for pest dispersal, already confirmed or likely to occur in the PRA area—these vectors may be species that are already vectors elsewhere or new vector species.

4.3.2.2 SUITABILITY OF ENVIRONMENT

In order for pest establishment to be successful, interactions between the pest, its host and suitable vectors must be maintained in the PRA area. Estimating the suitability of the environment in the PRA area for establishment of a pest not yet present there presents a significant challenge to the pest risk analyst. The environmental attributes in the pest's natural ranges may not be indications of its environmental tolerance. It may be able to live within significantly broader habitat parameters. Climatic modelling systems may be useful for comparing climatic data from the known distribution of the pest to that of the PRA area. Analysis may involve the use of geographic information systems (GIS) and other computerised systems such as CLIMEX to model and map potential pest distributions in the PRA area, i.e., in quantitative or semi-quantitative pest risk assessments. Regardless of whether computerised or other modelling systems are used, the information and assumptions that contributed to the estimation of probability of establishment should be documented to support the findings of the pest risk assessment.

Phytophthora ramorum, the organism that causes sudden oak death, is of interest to many countries. Numerous models to predict its future distribution in North America and elsewhere have been developed comparing information on the species' temperature tolerance, its requirement for available moisture, soil pH, and other abiotic factors, with host range and density data. The modelling tools that have been used range from simple climate map comparisons using observation data to more complex algorithm-based computer simulations. Increasing accuracy in estimates of the critical environmental factors contributes to increasing precision and agreement between models.

The following environmental factors should be considered:

- All environmental factors that are critical to the development of the pest and its host(s) (and vector(s), if applicable), and to their ability to survive periods of climatic stress and complete their life cycles. These environmental factors include, but are not limited to: temperature, rainfall, soil type and condition, topography, and pest and host competition. Each pest will have its own unique set of environmental factors that are either critical to its survival, or beyond which it cannot survive. Comparisons of these factors with those available in the PRA area may be a valuable indicator of future events.
- The presence or absence of natural or potential enemies.
- The pest's ability to adapt to new conditions, including new climatic conditions, new hosts, new vectors etc. History of successful introductions, or failed introductions if known, will be an important consideration.
- The pest's suitability to establishment in a protected environment (e.g. in glasshouses).

4.3.2.3 CULTURAL PRACTICES AND CONTROL MEASURES

Just as pest control practices and other cultural practices in the area of origin influence the likelihood of a pest being present in or on a particular pathway, so do those practices in the PRA area influence a pest's chances of establishment there.

Where applicable, a comparison of practices employed during the cultivation or production of the host crops in the PRA area and the area of origin of the pest may be undertaken to contribute to better understanding of the pest's potential for establishment. In so doing, the analyst may consider the following factors among others:

- pest control programs or natural enemies already in the PRA area which reduce the probability of establishment, and
- availability (or lack) of suitable methods for pest control or eradication in the PRA area.

Those pests for which control is not feasible or economical may present a higher risk than those for which treatment is easily accomplished. Any control measures that have proven to be effective against the pest in any parts of its range should be noted.

4.3.2.4 OTHER PEST CHARACTERISTICS AFFECTING PROBABILITY OF ESTABLISHMENT

There are many factors that may influence a pest's probability of establishment and these should be identified and considered in the course of completing the pest risk assessment. Some of these factors are inherent characteristics of the pest itself, including:

- Reproductive strategy of the pest—characteristics that enable the pest to reproduce effectively in the new environment such as parthenogenesis or self-crossing, duration of the life cycle, number of generations per year, resting stage etc., may contribute to a higher likelihood of establishment.
- Genetic adaptability of the pest—species that are polymorphic and have a demonstrated ability to adapt to conditions such as those available in the PRA area (e.g. host-specific races or races adapted to a wider range of habitats or new hosts) may experience a greater likelihood of establishment. For example, genotypic and phenotypic variability facilitates a pest's ability to withstand environmental fluctuations, adapt to a wider range of habitats, develop pesticide resistance and overcome host resistance.
- Population level necessary for successful establishment—species that require a low number of individuals for establishment are more likely to become established than a species that requires many individuals for a population to be successful.

Knowledge of a pest's status elsewhere may be indicative of its potential importance in the PRA area. A pest that is a problem elsewhere following introduction may have proven ability to adapt and overcome unfavourable factors.

4.3.2.5 FINAL ESTIMATE OF PROBABILITY OF ESTABLISHMENT

In considering all of the factors that influence the pest's establishment in the PRA area, the analyst must conclude with a final estimate of likelihood of establishment, documenting the reasons for this estimate and noting sources of uncertainty that influence the analyst's confidence in the assessment. In a qualitative assessment, this estimate may be expressed descriptively, as in "not likely" or "very certain to occur". In a quantitative assessment, this estimate may be expressed in mathematical terms, such as "1 event every 500 years" or "9 times out of 100".

Canadian Example of a Qualitative Rating System for Establishment Potential

This rating reflects the potential host ranges of a pest introduced into new areas. The establishment potential is rated from negligible to high with consideration of the number of hosts, their geographic range and pattern of distribution, and attributes of the abiotic environment (precipitation, temperature, soil type). The proportion of the range of the host(s) under consideration that the pest can occupy will determine the rating.

Rating = negligible: The pest has no potential to survive and become established in the PRA area. Example: Stewart's wilt of corn (*Erwinia stewartii* (Smith) Dye) distribution is limited by the over-wintering capabilities of its insect vector, the corn flea beetle (*Chaetocnema pulicaria* Melsheimer). In most years, winter temperatures throughout Canada's corn-growing regions are too low to allow survival of the pest. Another example is *Atherigona orientalis* (minor fruit fly) which is distributed throughout tropical areas and does not have the potential for establishment in temperate climates.

Rating = low: The pest has potential to survive and become established in approximately one third or less of the range of the host(s) in the PRA area. Example: Oriental fruit moth (*Grapholita molesta* (Busck)) distribution in the province of Ontario, Canada, is primarily limited to the south, whereas its hosts are widely distributed in the province.

Rating = medium: The pest has potential to survive and become established in approximately one third to two thirds of the range of the host(s) in the PRA area. Example: Blueberry Maggot (*Rhagoletis mendax* Curran) distribution is limited by low winter temperatures to the more southerly portions of the range of *Vaccinium* species in Canada. It will not survive throughout the entire range of blueberry.

Rating = high: The pest has the potential to survive and become established throughout most or all of the range of host(s) in PRA area. Example 1: Current Old World distribution of Cherry Ermine Moth (*Yponomeuta padellus* (L.)) suggests that the pest could become established in North America wherever its hosts are found. Example 2: Soybean cyst nematode *(Heterodera glycines* Ichinohe) distribution is not limited by environmental conditions present in Canada. Based upon its current world distribution and known conditions affecting its survival, it is likely to survive wherever major host crops are grown.

4.3.3 PROBABILITY OF SPREAD AFTER ESTABLISHMENT, INCLUDING ESTIMATION OF SPREAD RATE AND MAGNITUDE

Probability of spread is the final element of step 2 to consider. This is a measure of the pest's ability to disperse from its point of introduction to new areas within the PRA area, where it may become established on suitable hosts. It is a measure not only of distance, but also of time, as both influence the importance of the pest and the conclusions, therefore, of the pest risk assessment stage. Natural means of spread include wind, water, soil, seed and pollen, and insect, fungal or nematode vectors. Some pests may be transported very long distances by these means of spread. Assessment of probability of spread is based primarily on biological information about the pest in the context of the conditions in the PRA area.

The estimate of probability of spread may be expressed in various ways:

- qualitative—expressed, for example, in terms of 'low', 'moderate' or 'high'
- semi-quantitative—expressed, for example, by the use of a numeric score (e.g. assigning values between 1 and 100)
- quantitative—expressed, for example, in terms of kilometres travelled per year

The approach taken to estimate the probability of spread is at the NPPO's discretion and will depend on factors such as technical and practical considerations, available data and time restrictions. A quantitative approach can only be used when adequate information or data is available and may be more or less appropriate depending on circumstances.

A pest with a high probability of spreading may also have a high probability of establishment because of the increased opportunities to encounter suitable host and environmental factors that increased mobility offers. In order to estimate the probability of a pest spreading, reliable biological information should be obtained from areas where the pest currently occurs and compared with the situation in the PRA area. Case histories concerning comparable pests can also be useful.

An assessment of the likelihood of spread of the pest can also be used to estimate how rapidly and how widely potential impacts may be expressed in the PRA area.

Examples of factors to consider during assessment of probability of spread include:

- biology of the pest, e.g. method of reproduction and dispersal, reproductive output, dispersal capability, vectors, facilitation of dispersal by natural factors. For plants this can include things such as growth habit, storage tissue, dormancy, etc.;
- suitability of the natural and/or managed environment for natural spread of the pest;
- presence of natural barriers, e.g., expanses of unsuitable habitat or absence of host(s);
- intended end-use of the commodity, e.g., fruit or grains destined for destructive processing may not be as effective a means of introducing certain pests of plants as seeds or live plants for planting;
- availability and abundance of potential vectors of the pest in the PRA area;
- the potential for movement with commodities within the PRA area following introduction, e.g., certain plant viruses are readily propagated and distributed with fruit stock if large volumes of stock are propagated vegetatively and distributed without virus testing;
- potential natural enemies of the pest in the PRA area;
- potential for hybridisation with natural relatives in the PRA area; and
- history of spread following introduction elsewhere.

In the case of plants intended for import, the assessment of spread addresses the plants' potential to spread from the intended habitat or use, to an unintended habitat where it may become established and spread further.

4.3.4 CONCLUSION ON THE PROBABILITY OF INTRODUCTION AND SPREAD

ISPM No. 11 (2004) states that the overall probability of introduction should be expressed in terms most suitable for the data, the methods used for analysis and the intended audience. For the purposes of consistency and transparency, an NPPO may wish to establish a standard format or process for combining the elements considered in the pest risk assessment stage of the PRA process and for drawing conclusions regarding a pest's likelihood of introduction (entry and establishment) and spread. Conclusions may be expressed qualitatively (e.g., entry, "establishment and spread are highly likely") or quantitatively (e.g., "entry, establishment and spread are estimated to occur 1 time for every 900,000 consignments"), or may be expressed as a comparison with the results obtained from pest risk assessments on other pests (e.g., "Pest A is less likely to enter, become established and spread than is Pest B").

Canadian Example of a Qualitative Method for Rating Natural Spread

This rating reflects natural means and rate of spread both into and within the PRA area. Natural means of spread include wind, water, soil, seed and pollen, and insect, fungal or nematode vectors. Some pests may be transported very long distances, hundreds or thousands of kilometres, by wind, and will therefore score very high for this component. Regulatory control may or may not be a feasible management option depending on the pest's current distribution.

Rating = negligible: The pest has little or no potential for natural spread in the PRA area. Example: Apple rosette agent is spread by budding and grafting. Natural spread is probably due to root grafting and is therefore highly localized and extremely slow.

Rating = low: The pest has potential for natural spread locally in the PRA area within a year. Example: Apple Proliferation Mycoplasma can spread locally, both within and between orchards, by means of insect vectors (meadow spittlebug and others).

Rating = medium: The pest has potential for natural spread throughout a physiographical region of the PRA area within a year. Example: Nun moth adults (*Lymantria monacha* (L.)) are able to fly great distances. Male flights of >80 km have been recorded and females carrying many viable eggs are known to have flown at least 40 km. During a major outbreak in then East Prussia (now Poland-Russia), the forests were invaded by moths carried by the south winds.

Rating = high: The pest has potential for rapid natural spread to all production areas of the PRA area. Example: Large numbers of urediospores of stem rust (*Puccinia graminis* Pers. f.sp. *tritici* Eriks and Henn) are transported by wind to the Prairie provinces of Canada from cereal production areas in the southern USA and Mexico each year, travelling as much as 2000 km. Control of its alternate host (*Berberis spp.*) eliminates local sources of over-wintered inoculum and reduces the impact of the disease.

4.4 ASSESSMENT OF POTENTIAL IMPACTS OF INTRODUCTION AND SPREAD (STEP 3)

Keeping in mind that pest risk is a product of a pest's likelihood of introduction and spread and its potential impacts, a necessary next step in the pest risk assessment stage of a PRA is the assessment of the pest's potential impacts. The purpose of this next step in the pest risk assessment process is to identify and quantify, as much as possible, the potential impacts that could be expected to result from a pest's introduction and spread. These impacts may take many forms; they may be economic, environmental or social impacts; and they may be direct or indirect. ISPM No. 5, Supplement No. 2 provides guidance on the interpretation of economic impacts, including environmental impacts, within the definition of a plant quarantine pest.

Information on the species' current behaviour and impacts in areas where it is already present is used in conjunction with information on the factors at risk in the PRA area and other pertinent information to extrapolate impacts on the PRA area should introduction occur.

Both quantitative approaches, such as cost:benefit analyses and cost effectiveness analyses, and more qualitative approaches, such as those frequently employed for environmental impact assessments, are valid. The selection of methods, the level of detail attained, and the precision of the impact assessment is at an NPPO's discretion, and is influenced by many factors, such as the availability of data.

The types and sources of information on impacts will vary greatly depending on the pest in question. Detailed data on economic impacts and the value of agricultural crops at risk, for instance, are sometimes readily available and methods for recording and assessing economic impacts are well-developed. On the other hand, assessment of environmental or social (human) impacts is a newer science and an area in which impacts are not as readily measured in quantifiable terms. Therefore the assessment of environmental or social impacts, when undertaken, is frequently in the form of a qualitative study.

The IPPC emphasises the rights of members to adopt phytosanitary measures with respect to pests for which the economic damage caused to plants, plant products or ecosystems within an area cannot be easily quantified. With respect to pests of plants, the scope of the IPPC covers the protection of cultivated plants in agriculture (including horticulture or forestry), uncultivated or unmanaged plants, wild flora, habitats and ecosystems.

4.4.1 Assessment of Potential Economic Consequences

A good starting point for evaluating the potential impact of the pest in the PRA area is to consider the economic losses it has caused in other parts of its range, particularly in those areas where climatic conditions, crop production practices or other factors are similar to those in the PRA area. ISPM No. 11 (2004) provides guidance on factors to consider when assessing potential economic consequences, including environmental consequences. It states that, after obtaining information on areas where the pest currently occurs, "this information should be compared with the situation in the PRA area. Case histories concerning comparable pests can usefully be considered".

Consistent with the IPPC, Article 5.3 of the WTO-SPS Agreement states that "...Members shall take into account as relevant economic factors: the potential damage in terms of loss of production or sales in the event of entry, establishment or spread of a pest or disease; the costs of control or eradication in the territory of the importing Member; and the relative cost-effectiveness of alternative approaches to limiting risks".

Minor and Major Effects

An example of a pest having a minor effect is Septoria leaf spot (*Septoria ampelina* Berk. and Curtis). Infection results in leaf drop in grape that is premature by a few days only, with no treatment necessary and no economic losses. One having a more severe impact is Apple maggot (*Rhagoletis pomonella* (Walsh)),a fruit borer. Losses may be up to 75% of fruit if left untreated.

The economic impact component of the pest risk assessment requires an analysis of potential pest effects. The economic impact assessment begins with a biological profile of a pest which provides scientific information about the pest and its interaction with its hosts. This provides the basis for an economic profile to be developed. The economic profile determines the economically pertinent effects of the pest and provides an indication of the appropriate scope and analytical approach for estimating economic impacts. The biological and economic profiles together form the economic impact assessment.

In order to assess the economic impacts of a pest, it is important to gather information both on the pest itself (i.e., its economic impacts or effects elsewhere), and on the factors at risk (i.e., the value of the pest's potential hosts in the PRA area). The assessment of potential economic impact requires extrapolation of the potential impacts to the PRA area, a process that can present considerable challenges.

Each situation may be different. Economic effects may be limited to a minor effect on a minor crop, or they may have a major effect on a key plant commodity in an agribusiness sector. In this context, the pest's presence and way in which its effects are manifested are an important consideration.

4.4.2 IDENTIFYING PEST EFFECTS

Direct effects are the initial, immediate effects caused by the pest on the host or, in the case of pest plants, habitat. For example, a pest may have a direct effect by impacting the yield of a crop or shortening the productive life of its host(s). Direct effects initiate indirect effects. For example, the direct effect of lowering yield by an unacceptable amount may cause a grower to apply additional control measures or adopt changes in production practices. The costs of the additional measures, or the change in cost to production practices, are indirect effects. Another example of an indirect effect is lowering the eligibility of affected commodities for marketing and export.

In order to assess the potential total impact of the pest in question, it is important to first identify what impacts are possible.

4.4.2.1 DIRECT PEST EFFECTS

When assessing direct pest effects, the following should be considered (keeping in mind that economic effects include environmental and social effects):

- the value of the known or potential host plants (in the field, under protected cultivation or in the wild) in the PRA area
- types, amount and frequency of damage (e.g., frequent reductions in yield or occasional seed crop failure) reported in areas where the pest is already present
- crop losses, in yield and quality, reported in areas where the pest is present (e.g.,

Examples of Direct Pest Effects

All species of oak are susceptible to oak wilt, caused by *Ceratocystis fagacearum* (Bretz) Hunt, although less severe symptoms are demonstrated by those in the white oak group. Red oaks are usually killed within a few weeks to one year of initial infection.

Blue mould (*Peronospora tabacina* (Adam)) of tobacco may cause yield losses as high as 80 - 90% through severe damping-off, wilting or necrosis leading to death of both seedlings and field plants.

some fungal diseases result in reduced seed production, while others do not affect total yield, but do affect the overall quality of the harvest, and therefore its value)

- biotic factors (e.g., adaptability and virulence of the pest) affecting damage and losses (e.g., some pests are multiple races, strains or biotypes, some of which are more virulent and damaging than others; pests for whom a vector is necessary may have a greater impact in areas where their vectors are already present and established than in areas where vectors are not found or are not common)
- abiotic factors affecting damage and losses (e.g., climatic or soil conditions may greatly influence the potential impacts of the pest, by limiting the number of generations per year, the magnitude of the pest population that develops, or the time of year at which a pest outbreak occurs)
- rate of spread (e.g., pests that are capable of rapid, long distance spread are more able to reach a larger proportion of the vulnerable host population than are pests that are not as mobile, and therefore are also more capable having greater impacts)
- rate of reproduction (e.g., pests that reproduce rapidly once established may be more capable of having negative effects than those that build up populations more slowly. An assessment of impacts may include consideration of the expected population growth relative to that of the host population to determine the importance of rate of reproduction to potential impacts)
- control measures, their efficacy and cost (e.g., knowledge of the costs and effectiveness of control measures that are applied in areas where the pest is already present may contribute to better understanding of the impacts of the pest there and a more accurate estimate of expected costs in the PRA area should the pest be introduced. Furthermore, knowledge of the control measures that may be effective and are available in the PRA area may contribute to estimates of both increased costs of production following introduction and the magnitude of the impacts likely to be experienced)
- effect of existing production practices (e.g., production practices that are already in place in the PRA area may be effective in reducing the impacts of the pest at no additional costs to the producer; conversely, they may inadvertently contribute to the development and spread of the pest and thereby enhance its impacts)
- environmental effects (e.g., direct environmental impacts include reduction of keystone plant species, reduction of plant species that are major components of their ecosystem, reductions of endangered native plant species, significant reduction, displacement or elimination of other plant species etc.)

4.4.2.2 INDIRECT PEST EFFECTS

When assessing indirect pest effects, the following should be considered (keeping in mind that economic effects include environmental and social effects):

- effects on domestic and export markets, including effects on export market access (e.g., the introduction of the pest may result in restrictions on exports of affected commodities to other importing countries. Knowledge of the export significance of the commodities at risk in the PRA area and the quarantine importance of the pest in question to importing countries for that commodity may contribute to an improved estimate of the potential effect of the pest on markets if it were to be introduced)

- changes to producer costs or input demands (e.g., establishment of the pest may result in an increased economic or environmental cost in the form of increased applications of pesticides during production or an additional processing step for the same level of market access and return)
- changes to domestic or foreign consumer demand for a product resulting from quality changes (e.g., some pests may not result in marked yield loss that necessitates pest control measures, but their presence nonetheless affects the final product in a way which makes it less desirable to consumers, such as reduced sugar content of fresh fruits due to the presence of a virus disease of fruit trees)
- environmental and other undesired effects of control measures (e.g., in addition to the negative economic consequences of the increased need for pest control products, the application of these products may have environmental impacts that may be considered as indirect environmental consequences of the pest's introduction and establishment)
- feasibility and cost of eradication and containment (e.g., an NPPO may wish to consider the possibility of undertaking an eradication of the pest should it become established and estimate the costs and feasibility of any actions taken as part of the estimate of the total overall potential effects of the pest)
- capacity to act as a vector for other pests (e.g., the pest may be a vector of another agent that is already present in the PRA area, or it may be a pathway for introduction of another pest; in either case, the potential impacts of these additional pests may be considered to be indirect effects of the pest in question)
- resources needed for additional research and advice (e.g., an NPPO may wish to consider the additional costs that will be incurred either by producers, the affected industry group overall or by the NPPO and other government agencies in the PRA area as a result of a need for expert advice and research to address the direct and indirect effects of the pest if it is introduced)
- social and other effects (e.g. depending on the nature of the damage caused by the pest, its effects may extend to social impacts such as loss of tourism, loss of employment, impacts on human health, loss of symbolic values, etc.)
- environmental effects (e.g. indirect environmental effects may include such things as effects on plant communities, effects on designated environmentally sensitive areas or protected areas, changes in ecological processes and the structure, stability or processes of an ecosystem, effects on human use (e.g. water quality, animal grazing etc.), costs of environmental restoration)

Information on actual and potential effects of pests, direct or indirect, may be found in a variety of sources, including published scientific or economic journal articles, government department reports, research reports and industry accounts. In addition, it may be useful to solicit expert advice. In cases of a PRA resulting from a request to import, the importing NPPO may also request information on pest effects and control measures in the exporting country which can contribute significantly to the estimation of potential impacts.

Example of Indirect Pest Effects

A bark beetle, *Scolytus multistriatus*, is believed to have established in the early- to mid-1980's in the Auckland region of New Zealand from imported wood packaging material. The beetle itself was not expected to cause any more harm than already introduced bark beetles and has a limited ability to cause direct unwanted impacts. In 1989 Dutch elm disease (*Ophiostoma novo-ulmi*) was first discovered in Auckland. While this disease can spread through root grafting, the presence of an insect vector, in this case *Scolytus multistriatus*, has considerably increased the extent of the unwanted harm this disease can cause. Therefore an indirect effect of the establishment of *Scolytus multistriatus* in New Zealand has been the increased impact from Dutch elm disease.

4.4.3 ANALYSIS OF ECONOMIC CONSEQUENCES

ISPM No. 11 (2004) provides guidance on the analysis of economic consequences associated with the introduction and establishment of a pest. Various factors in the PRA area may influence the consequences of a pest's introduction and establishment. Having identified the impacts associated with the pest in areas where it is already present, these factors can be considered in estimating the potential future impacts in the PRA area. The analyst may elect to consider those that are pertinent to the specific pest in question.

4.4.3.1 TIME AND PLACE FACTORS

ISPM No. 11 (2004) indicates the following time and place factors that may influence the consequences of pest introduction and establishment:

- Economic consequences are expressed over a period of time, one year, several years or an indeterminate period. There may be a lag between establishment of the pest and expression of economic consequences (e.g., some pests such as rust fungi attacking cereal crops cause almost immediate effects and losses are measurable within a short time of introduction; other pests, such as fruit tree viruses or forest insects may go undetected initially and take years to build a population level to the extent necessary to cause measurable consequences).
- The consequences may change over time (e.g., in cases of agricultural pests, it may be possible for the affected industry to adapt to the pest and thereby experience reduced consequences of its introduction. This may be achieved by various means such as developing and implementing pest control measures, crop rotations, or developing pest-resistance varieties, etc. In other circumstances, a pest's effects may become more serious over time due to increases in its population, expansion of its range, adaptation of the pest to new hosts, climatic conditions or other factors).
- Other factors to consider include whether the pest occurs at one, few or many points in the PRA area and the rate (e.g., slow or rapid) and expected manner of spread in the PRA area (e.g., a pest that can only spread slowly will have a more gradual impact than a rapidly spreading pest, and will allow more time for human intervention or adaptation).
- Appropriate analysis may be used to estimate potential economic consequences over the period of time when a pest is spreading in the PRA area (e.g., it may be possible to identify lost markets and project what their value to a particular

industry's, and a country's economy, would have been had the pest not established in the PRA area).

- Expert judgement and estimations may contribute to a more precise estimate of potential consequences and may reduce the level of uncertainty in the assessment. An NPPO may solicit expert advice and input to parts or all of a PRA from various sources, such as domestic or foreign government agencies, universities or other research institutions etc.

Examples of Rate of Spread Impacting Regulatory Actions

Factors such as extent of incursion and rate of spread may also impact on regulatory actions and the feasibility of quarantine. For example, the introduction of the A2 mating type of *Phytophthora infestans* (potato late blight) into Canada in the early 1990s was found to have occurred in several areas. Due to the potential for rapid spread on the wind, no regulatory actions were taken. Similarly, the introduction of Pepino mosaic virus in greenhouse tomato production in Canada was widely reported in a very short time. The virus can be symptomless and very easily transmitted by mechanical means. Regulatory action in terms of containment was deemed to be inappropriate due to the combination of those factors.

A few cysts of golden nematode (*Globodera rostochiensis*) introduced into an uninfested field will require several generations of multiplication before cyst numbers are readily detectable by soil sampling, and a few more generations before any visible damage is observed in the growing crop (i.e., for golden nematode a population of 100 million cysts ha-1). This could take many years in areas where potatoes are grown interspersed with non-host crops, during which time the nematode will inevitably have spread to other locations.

When *Thrips palmi* was discovered in Queensland, Australia, a containment and eradication campaign was not implemented after consideration of the costs and likelihood of success.

4.4.3.2 ANALYSIS OF COMMERCIAL CONSEQUENCES

Many direct and some indirect effects of a pest will be of a commercial nature, or have consequences for a specific market. It is useful to identify and quantify these effects (which may be positive or negative), wherever possible, taking into account the effect of pest-induced changes on:

- producer profits resulting from changes in production costs, yields or prices (the introduction and establishment of the pest may necessitate addition control measures or changes in production practices which result in an increase in production costs);
- quantities demanded or prices paid for commodities by domestic and international consumers (increases in prices or decreases in quality may reduce consumer demand for the commodity);
- crop losses or crop failure resulting in loss of customers (some pests may have severe direct effects on the crop which result in a failure by the affected grower(s) to fulfill commodity supply commitments, with the result that the buyer seeks alternative suppliers in other areas); and
- market effects, including loss of markets or change in markets which result in changes in related costs (establishment of a pest that is a quarantine pest for a trading partner may result in loss of access or increased costs to access markets for affected commodities, or it may necessitate a diversion of the commodity from

a high value market (e.g. fresh market fruit sales) to a lower value market (e.g. fruit processing)).

4.4.3.3 ANALYTICAL TECHNIQUES

There are analytical techniques that can be used in consultation with economists to provide a more detailed analysis of the potential economic impacts of a pest. The use of analytical techniques is often limited by lack of expertise within the NPPO or lack of information and uncertainties in the data. There may also be difficulties in expressing some effects in monetary terms (e.g., non-commercial and environmental effects are often not measured in monetary terms and only qualitative information can be provided). Nonetheless, it is helpful to consider the various methods of analysis that are available. Regardless of the method used, it is necessary to document assumptions made and the areas of uncertainty in determining the economic impact assessment.

ISPM No. 11 (2004) refers to the following analytical techniques that can be used:

- Partial budgeting— a method of investigating changes in revenue (sales) and costs at a small scale, e.g. changes as a result of the presence of a quarantine pest to an individual farmer or grower. The aim of the analysis is to estimate the financial impact of the change. Partial budgets list only those items of income and expense that are altered by the change (e.g. caused by the pest). This technique is a suitable planning and decision-making method to compare the costs and benefits of alternative options faced by a business. Partial budgeting is a suitable technique to use if the economic effects of the pest are generally limited to producers and are considered to be relatively minor. Partial budgeting is the simplest technique and hence the most widely used in PRA.
- Partial equilibrium analysis— a complex economic technique to estimate economic market variables such as equilibrium prices and quantities traded. The effects of events are examined only in the markets which are directly affected. Supply and demand curves are used to depict the price effects of events. Producer and consumer surplus is used to measure the welfare effects on participants in the market. This technique is recommended if a significant change in producer profits or consumer demand is expected. Partial equilibrium analysis is necessary to measure net changes arising from the potential pest impacts on producers and consumers. The partial equilibrium approach is considered adequate, by economists, for the study of most markets because feedback effects are swamped by the direct effects of events in any individual market and feedback effects are considered negligible.
- General equilibrium analysis—tries to give an understanding of the whole economy using a bottom up approach, starting with individual markets and agents. If the economic changes are significant to a national economy and could cause changes to factors such as wages and interest rates then this approach should be used to establish the full range of economic effects. General equilibrium analysis is highly complex and there are very few examples of it being used in the phytosanitary arena.

A formal economic analysis may not always be necessary in the pest risk assessment stage of a PRA. Depending on the potential importance of the pest, the anticipated reaction to the final conclusions of the PRA, and the time and resources available to the NPPO, this step in the pest risk assessment stage may be accomplished using less formal procedures. A brief record of the known economic effects (direct and indirect) of the pest in the area(s) where it is known to occur, and a description of the factors at risk, including domestic and export production, may be sufficient to estimate the potential economic consequences of the pest to a satisfactory degree. For assessments of this nature, it may be helpful for the NPPO to identify the key questions and key values it will consider at this stage and follow a standardised format for analysis of economic consequences.

Regardless of the approach taken, the analysis of economic consequences may be either qualitative or quantitative. Wherever possible the output of the analysis of economic consequences should be expressed in monetary values, however, qualitative or quantitative measures without monetary values can also be used. It is important to specify sources of information, assumptions and methods of analysis. The part of the PRA area where presence of the pest will result in economically important loss should also be identified as appropriate, as this is important in defining the endangered area at a later stage in the PRA process.

4.4.3.4 ENVIRONMENTAL AND SOCIAL CONSEQUENCES

Economic consequences include environmental and social consequences, as discussed in ISPM No. 5, Supplement No. 2. As has been noted, some of the direct and indirect effects of the introduction of a pest will be of an economic nature, or otherwise affect a measurable value (such as market price or total export value) that can be easily identified. Other effects, however, are not as easily identified or measured in quantitative terms. Examples of impacts which are not as readily quantified, but which may nonetheless be considered in analysing a pest's potential consequences, include:

- environmental effects (such as effects on ecosystem stability, biodiversity and aesthetic values); and
- social effects (such as effects on property values, employment and tourism).

If quantitative measurement of such consequences is not feasible, qualitative information about the consequences may be considered, provided an explanation of how this information has been incorporated into decisions is included.

The analysis of environmental impacts is a relatively new area of science and one which is rapidly developing. Methods and techniques for quantifying environmental values for the purposes of environmental impact assessments are being developed for the purposes of evaluating risks associated with industries such as mining, pesticides, engineering and road construction. These developments contribute to better understanding of possible means by which to evaluate the environmental consequences of introduction and establishment of a pest of plants.

Similar to the approach taken for analysing economic consequences related to the trade of plants and plant products, when analysing environmental and social consequences it is useful to begin by identifying the existing environmental and social effects (both direct and indirect) that have been reported in the area(s) where the pest occurs, and also to identify those that could be experienced if the pest becomes established in the PRA area. Possible environmental and social effects that may be considered include:

- Direct Environmental Effects
    - Loss of keystone species—a keystone species is one that is of fundamental importance to the integrity of the ecosystem and that characterises that ecosystem. Pests which directly threaten the survival of a keystone species by reducing its viability or ability to reproduce, for example, have

higher potential environmental consequences than does a pest which threatens a species of lesser importance in that ecosystem.

- Loss of threatened or endangered species—a pest that has a direct effect on a plant that is threatened or endangered due to other factors, may have a more serious overall impact on the status of that plant species than would otherwise be anticipated, due to its vulnerability. Threatened or endangered species are frequently at a critical point in their survival due to multiple pressures and are therefore more susceptible to attack by introduced pests than would be the case under normal circumstances.
- Reduction in range or viability of keystone species.
- Reduction in range or viability of threatened or endangered species.

Examples of Direct Environmental Effects

Pinus sylvestris is an important keystone species in European forests; it can play a critical role in forest biocenosis, has relationships with many plants and animals, and affects resource availability. It is very susceptible to the pinewood nematode *Bursaphelenchus xylophilus*.

Chestnut blight (*Cryphonectria parasitica* (Murrill) Barr) spread rapidly throughout the eastern forests of the USA from Maine to Georgia, destroying chestnut trees and subsequently causing tremendous economic and ecological disruption throughout the Appalachian forests.

Outbreaks of nun moth (*Lymantria monacha* (L.)) in Europe have resulted in losses of large areas of forest. In the immense outbreak of 1853-1863, 147,000,000 m^3 of timber was killed and the forest was permanently lost. The area was subsequently converted to agriculture.

- Indirect Environmental Effects
  - Change in habitat composition—a pest that has a detrimental effect on a host's vigour, viability or reproductive success may indirectly result in shifts in the composition of plants within an ecosystem by placing stress on one species thereby favouring others. As well, a pest itself may cause displacement of a native species. The long-term consequences of these shifts in the balance between species can be far-reaching and irreversible.
  - Loss of habitat or nourishment for wildlife—effects on wildlife may be an indirect result of introduction and establishment of a pest of plants. For example, a fungal disease that infests pine cones may result in inedible or non-existent seeds, potentially resulting in critical shortages of food for specialist feeders.
  - Change in soil structure or water table resulting from changes in plant composition of critical habitat—a pest of plants that has a direct detrimental effect on a riparian species, or an invasive plant that invades wetlands, may indirectly cause a rise or fall in the water levels of wetlands.
  - Change in ecosystem processes—a pest that kills large expanses of trees may result in an increase in dry standing timber and an elevated fire hazard situation.

- Impacts of risk management options such as pesticide application, introduction of exotic biocontrol agents etc.

Example of Indirect Environmental Effects

In parts of Brazil and India, introduced Eucalyptus spp. cause immeasurable ecological problems as a result of their high consumption of water, which leads to exhaustion of water tables, turns rich soil into desert-like soil and destroys native flora.

- Social Effects
    - Loss of employment—for example loss of European forestry jobs in the 19th century as a consequence of the outbreak of nun moth (see text box above).
    - Reduction in property values—urban and home landscaping, with trees and shrubs for instance, significantly influences property values, municipal tax rates and insurance rates. Direct pest effects on those plants, or measures to manage the pest if it was to become established, when significant enough, may indirectly affect property values, tax rates and insurance rates.
    - Loss of tourism—direct effects on host plants may be critical enough to reduce their aesthetic value and reduce their tourist appeal, resulting in loss of tourist-related income to affected communities. Recreational values may be impacted, for example, an aquatic invasive plant may make beaches and waterways weedy and unsuitable for swimming, boating or other forms of recreation.
    - Reduction or loss of availability of traditional plants for cultural purposes—some cultures place special value on certain native or other plants, and threats posed to those plants by the pest in question may represent a significant social impact.
    - Human health risks—certain pests of plants produce allergens which cause human health effects. For example pollen of certain pest plants or spores produced by certain types of seed-borne fungi can cause severe allergies in sensitive people necessitating medical attention and precautionary measures.

Example of Social Effects

Some of the social consequences of the invasive plant, carpet burweed (*Soliva sessilis* Ruiz and Pav.) include reduced use and enjoyment of parks, beaches, sports fields and golf courses due to its spiny seeds that cause physical discomfort. It also negatively impacts the aesthetics of parks and golf courses by forming unsightly brown patches during the summer.

4.4.4 CONCLUSION OF ASSESSMENT OF POTENTIAL IMPACTS

After considering and assessing the economic, environmental and social consequences of the introduction (entry and establishment) of a pest, this stage of the pest risk assessment concludes by combining the assessments of different types of consequences into a single assessment of overall potential impacts. The combination of effects assessments and the drawing of a conclusion about overall consequences may be a numerical exercise when the assessment is a quantitative one (e.g., the pest is estimated to cause 1.2 - 1.8 million dollars damage to the grain industry annually), it may be qualitative (e.g., the pest is expected to cause a very high level of damage), or it may be semi-quantitative, combining both qualitative and quantitative measures.

An NPPO may find it helpful to develop a standard format and procedure for calculating overall risks, recognizing that different levels of precision and detail will be obtained for different pests, and that each assessment of economic consequences presents its unique challenges. In drawing conclusions about the overall consequences of the pest, any assumptions, weaknesses in the data used, or uncertainty should be noted.

An example of an economic impact matrix		
	Market Impacts	Non-Market Impacts
Direct Pest Effects	Timber products Pest/fire resistant species Control costs	Urban ornamental Wildlife habitat
Indirect Pest Effects	Tourism Trade Fire Hazard	Nutrient cycle Hydrology Political effects

White pine blister rust (WPBR) provides a good example of a species whose impacts can be recorded in all four of the quadrants of the above matrix. WPBR is an introduced forest pathogen in North America, having been introduced on more than one occasion with pine seedlings imported from Europe. Its biology, distribution and impacts have long been a subject of research in Canada and the United States in an effort to slow its spread and reduce the effects of the fungus. Impacts of WPBR are wide and varied, they include: loss of timber, a requirement to change planting and harvest practices, loss of native pine diversity and abundance with subsequent impacts on forest composition, wildlife habitat and food availability, and social impacts resulting from the impacts of the disease on the timber industry and costs to taxpayers of government and academic research, survey and control operations over many years.

4.5 OVERALL ASSESSMENT OF PEST RISK

The overall assessment of risk requires the combination of likelihood of pest introduction and consequences of that introduction, if it occurs. Each potential pest or pathway should be dealt with individually and there should be a final evaluation made of the likelihood of entry, establishment, spread and potential consequences of the pest on each of these pathways and overall. From this an overall risk rating can be assigned and utilised in the next stage of PRA, pest risk management.

There are different methods for combining the elements of likelihood and impact into an overall assessment of pest risk. The methods used are dependant on the time and resources available to the pest risk analyst, the needs of the NPPO, the critical nature of the assessment and other factors. The key feature of this step is its agreement with the definition of risk (i.e., risk is a product of likelihood and potential impacts). The calculation may be quantitative when both sides of the equation are numerical, it may be qualitative when both factors are qualitative, or it may be semi-quantitative.

After all available and relevant information has been accumulated the pest risk analyst must make a judgement on the overall risk presented by the pest and indicate whether or not that risk is acceptable. If the risk is acceptable, the PRA may be halted at this point. If the risk is not acceptable, risk mitigation measures may be considered and the PRA continues to the pest risk management stage.

Example of a Risk Rating Guideline

In this model, likelihood of introduction may be rated negligible, low, medium or high in accordance with the NPPO guidelines for assessing probability. Likewise, a pest’s potential consequences may range from negligible to high. Each of the ratings can be assigned a standard numeric value for the purposes of combining them. The overall risk rating for the pest is assigned by combining likelihood and consequence ratings in accordance with the guidelines below. By establishing a structured approach to combining the elements which contribute to overall risk and interpreting the overall risk rating which results, an NPPO ensures consistency and transparency in its pest risk assessment process.

Guidelines for the interpretation of overall risk ratings are of critical importance in standardising the interpretation of pest risk assessment results as part of the PRA process. In this example, an overall pest risk rating of negligible is acceptable and the PRA may be discontinued. For all other results, the PRA continues to evaluate potential mitigation measures appropriate to the level of risk identified.

Negligible: The likelihood of introduction is negligible. No specific phytosanitary measures are necessary.

Low: No specific phytosanitary measures may be necessary. Various factors including production practices, pre-shipment inspection, packaging, current port-of-entry inspection, end-use, season of importation, etc. are expected to provide sufficient phytosanitary security.

Medium: Specific phytosanitary measures may be necessary.

High: Specific phytosanitary measures are strongly recommended. Port-of-entry inspection alone is not considered sufficient to provide phytosanitary security.

Likelihood of Introduction (Rating and Numerical Score)	Consequences of Introduction (Rating and Numerical Score)	Overall Risk Rating
Negligible (0)	Negligible (0)	Negligible
Negligible (0)	Low (1)	Negligible
Negligible (0)	Medium (2)	Negligible
Negligible (0)	High (3)	Negligible
Low (1)	Negligible (0)	Negligible
Low (1)	Low (1)	Low
Low (1)	Medium (2)	Low
Low (1)	High (3)	Low
Medium (2)	Negligible (0)	Negligible
Medium (2)	Low (1)	Low
Medium (2)	Medium (2)	Medium
Medium (2)	High (3)	Medium
High (3)	Negligible (0)	Negligible
High (3)	Low (1)	Low
High (3)	Medium (2)	Medium
High (3)	High (3)	High

4.6 UNCERTAINTY

Uncertainty is inherent to any PRA as complete information is seldom available. Most analyses performed during pest risk assessment use historical data to predict the future, and this can result in varying degrees of uncertainty. Information about the degree of uncertainty and the sources of uncertainty can be valuable when decisions are being made on the acceptability (or not) of the pest risk as described during the risk assessment stage of the PRA.

Uncertainty can be grouped into types of uncertainty and sources of uncertainty, as described in the following table.

Type of uncertainty	Possible sources of uncertainty	Methods to cope with uncertainty
Uncertainty in data value	Missing data, inaccurate data, non-representative data	Collect further data, analysis of statistical properties of datasheets, validate data with observation
Structural uncertainty	Some pathways not considered, pathways described inappropriately, inadequate epidemiological models	Define limits to the risk being examined, specify assumptions, compare contrasting models, compare model outputs using different inputs
Unpredictability	Random events in complex systems, pest behaviour, human behaviour	Specify all plausible scenarios, state assumptions and subjective judgments

Dealing with Uncertainty in a Pest Risk Assessment

A pest risk assessment is being conducted to predict the likelihood of an outbreak of a cereal rust disease following the importation of cattle feed comprised of cereal grains grown in an infested area. One method of doing this is to describe the steps that must occur in order for introduction (entry and establishment) to occur, gather data on each of those steps to determine the likelihood of introduction, or frequency of each event, and use that information to calculate the likelihood and frequency of the overall occurrence. In order for an outbreak to occur, the following chain of events must happen:

- There must have been an outbreak of the rust at the time of harvest in the country of origin, and the rust must have developed sufficiently for there to be mature spores in or on the grain seeds that are harvested.
- Viable rust spores must remain with the grain after it has been cleaned and processed.
- The grain must be imported.
- The rust spores must remain viable for the duration of the shipping process.
- The grain must be delivered to a region where suitable hosts and climatic conditions occur at a time of year when the hosts are susceptible.
- Infested grain must escape from its containers and be scattered in the vicinity of susceptible hosts, or
- Infested grain must be fed to cattle who are subsequently put to graze in an area with susceptible hosts, and
- The spores must survive digestion by cattle and be deposited in or near susceptible hosts.

For each of these steps, values are assigned; in most cases, these values are probabilities, e.g., an outbreak at the time of harvest is known to have occurred and have been significant, therefore the probability of this step is 1. The frequency of shipments is also known, and its value can be assigned. For most other steps, however, there is no scientific data available which will give us absolute values. Estimates in these cases will be based on information which may range from very poor to excellent.

One way to deal with the uncertainty that results from the lack of data is to seek expert opinions and judgement. Using the available information and the opinions of several experts, values can be assigned to each of the steps in the scenario, and a conclusion drawn with respect to the likelihood and frequency of outbreaks of cereal rust. In this example, expert opinion can also be solicited regarding the impact of these uncertainties on the overall conclusions of the PRA, since the significance of uncertainty varies between steps in the scenario. High uncertainty respecting one estimate, such as the percentage of rust spores that are mature at the time of harvest, may have a less significant impact on the overall conclusions of the assessment than uncertainty in another area, such as the survival rate of spores in the digestive tract of cattle. Expert judgement can be used to identify the critical points in the process where uncertainty is highest, and where errors in the estimate may have the greatest impact on the overall assessment.

4.6.1 IDENTIFICATION OF UNCERTAINTY

Estimation of the probability of introduction (entry and establishment) of a pest and of the consequences of introduction involves many uncertainties. In particular, this estimation is an extrapolation of information from where the pest actually occurs to the hypothetical occurrence of the pest in the PRA area. Uncertainty may be attributed to things such as:

- flaws in methodology,
- lack of expertise,
- incomplete, inconsistent or conflicting data,
- imprecision in data,
- natural variability in data,
- subjective judgement,
- statistical variations,
- diseases of uncertain aetiology,
- symptomless carriers of pests,
- natural plasticity of pests,
- barriers to obtaining complete information,
- biological unknowns of the pest or pathways, and
- other impediments.

ISPM No. 11 (2004) emphasises the importance of documenting the areas of uncertainty and the degree of uncertainty in the pest risk assessment, and of indicating where expert judgement has been used. Where expert judgment is used, it is necessary to consult with a wide range of experts and consider all points of view. It is helpful to identify and document any assumptions that have been made and the impact these assumptions have made on the level of uncertainty and the conclusion of the pest risk assessment. Identification of the assumptions and uncertainties will provide the decision-maker with a comprehensive and objective view of the pest risk. Documenting the uncertainty will contribute to transparency of the process and may also be useful for identifying and prioritising research needs or areas where phytosanitary measures might be applied to reduce uncertainty.

Uncertainty vs. Variation

It is important to understand the difference between "uncertainty" and "variation". Variation is often described for a population as the natural distribution around a mean. In other words you would expect variation in, for example, the heights of a population of people. Uncertainty occurs when we attempt to extrapolate from a sample to a larger population. If we measure the heights of all 1000 people in a group, we will be able to determine the variation of heights within that population (of 1000 people). If we were to only measure the heights of 100 of those 1000 people, we could estimate from that sample the variation for the whole population but we would be introducing some degree of uncertainty. This uncertainty is often expressed as confidence intervals at a described level (e.g. 95% confidence).

Although uncertainty occurs in most pest risk assessments, pest risk assessment of pests of uncultivated and unmanaged plants often involves greater uncertainty than that of pests of cultivated or managed plants, due to the lack of information, complexity of natural ecosystems and variability associated with pests, hosts or habitats.

Uncertainty will be considered again during Stage 3 of the PRA, pest risk management.

4.6.2 End of Stage 2 – Pest Risk Assessment

At the conclusion of the pest risk assessment stage, information will have been gathered, evaluated and documented which:

- identifies the PRA area,
- identifies the pest or pathway that is being analysed,
- categorizes the pest(s),
- estimates each pest's potential to be introduced and its potential impacts,
- calculates the overall potential pest risk,
- indicates whether the pest risk is acceptable or not, and if mitigation measures may be required, and
- identifies gaps in information, assumptions and uncertainty associated with the overall pest risk assessment.

For pests that present an acceptable level of risk, the PRA stops at this point and rationale is documented. For pests that present an unacceptable risk, the PRA continues to Stage 3, pest risk management.

A PRA asks what could happen, how likely is it to happen, what would the consequences be, do we want to do anything about it and, if so, what can be done about it. At the conclusion of the pest risk assessment stage, the analyst will have the answers to all but the last of these questions. The final stage of the PRA, pest risk management, will answer the final question, what can be done about the pest risk that has been identified.

5. STAGE 3 - PEST RISK MANAGEMENT

The last stage in the PRA process is pest risk management; the process of determining appropriate management options to reduce the risks identified in Stage 2, pest risk assessment, to an acceptable level. According to ISPM No. 11 (2004), as a result of the pest risk assessment stage:

- all or some of the categorised pests may be considered appropriate for pest risk management;
- for each pest, all or part of the PRA area may be identified as an endangered area;
- a quantitative or qualitative estimate of the probability of introduction of a pest(s), and a corresponding estimate of the economic consequences, will have been obtained and documented; or
- an overall rating may have been assigned.

For those pests presenting unacceptable risks, the conclusions from the pest risk assessment are used to support decisions on the strength and nature of the measures to be used to reduce these risks to an acceptable level. The guiding principle for pest risk management should be to manage risk to achieve the required degree of protection that can be justified, and is feasible, within the limits of available options and resources. ISPM No. 11 (2004) describes pest risk management as the process of identifying ways to react to a perceived risk, evaluating the efficacy of these actions and determining the most appropriate mitigation options to achieve the desired level of protection.

Endangered Area

The known presence or absence of the pest in the PRA area is very important. In some circumstances it is possible that only a portion of the PRA area is threatened by the pest. This area should be delineated and risk management considered only for this area. It is referred to as the Endangered Area.

If the pest risk assessment determines that a specific pest presents an unacceptable risk, phytosanitary measures may be proposed to manage that risk and achieve the importing country's appropriate level of protection. Any phytosanitary measures chosen must be justified by the PRA and the level of phytosanitary protection required should be appropriate to the pest risk. The rationale for selecting measures should be apparent.

Management options can consist of existing measures or they can be new measures that have been, or have to be, developed specifically to address the risk from the pest or pathway under consideration. New measures may also be the result of a request from an importing country to consider a different mitigation measure, or changes in the phytosanitary status in the importing or exporting country.

Phytosanitary measures to prevent the establishment and spread of damaging pests and diseases may include any combination of measures including pre- or post-harvest treatments, inspection at various points between production and final distribution, surveillance, official control, documentation, or certification. A measure or combination of measures may be applied at any one or more points along the continuum between the point of origin and the final destination.

They may be applied:

- in the exporting country before export of the commodity,
- in transit,
- at the border of the receiving country, or
- at suitable points within the importing country.

The ultimate goal is to protect plants and prevent the introduction of quarantine pests.

The measures applied by individual countries will vary depending on economic, biological, administrative and other factors. Phytosanitary measures should be applied to the minimum area necessary for the effective protection of the endangered area, be consistent with the pest risk involved, be feasible and effective, and represent the least restrictive measures available to attain the required level of protection. Each country must select the measures it will require or implement, based on the desired level of protection and these other factors.

It should not be assumed that because a pest already occurs in a country, it is of little or no importance from a plant protection point of view. If, for example, a pest occurs in one part of the country, but not in another, a new introduction from abroad could have the effect of accelerating the spread of the pest, or adding to the gene pool of pests already present. In situations in which a pest is already present in the country, but not widely distributed, official control measures to prevent its further spread within the country from the infested area to the uninfested area must be in place for import measures to be justifiable.

The conclusion of the pest risk management stage will be the identification of appropriate mitigation measures that will lower the risk of the pest(s) of concern to an acceptable level.

5.1 Level of Pest Risk

As it is not usually possible, or appropriate, to achieve no or zero risk, a risk management approach should be followed that identifies measures to reduce the risk to a suitable or acceptable level. ISPM No. 1 (*Phytosanitary principles for the protection of plants and the application of phytosanitary measures in international trade*, 2006) describes the principle of managed risk as “Because some risk of introduction of a quarantine pest always exists, countries shall agree to a policy of risk management when formulating phytosanitary measures”. In implementing this principle countries should decide what level of risk is acceptable to them. There are a number of ways of expressing the acceptable level of risk.

For example:

- reference to existing phytosanitary requirements, e.g., the risk is equivalent to that associated with products which have been subjected to treatment X, the risk is equivalent to that accepted for imported product Y
- indexed to estimated economic losses, e.g., the risk is estimated to be $2 million in losses in 5-10 years
- expressed on a scale of risk tolerance, e.g., the risk is unacceptable
- compared with the level of risk accepted by other countries, e.g., the risk is equivalent to that accepted by country Z for this product

Although methods for quantifying risk exist (e.g., there is a one in a million chance of introduction of pest A in the next 20 years if the commodity is imported), this can be very difficult to do and in a plant protection context, pest risk is often described very qualitatively. Similarly "level of risk" is frequently a descriptive or qualitative measure (e.g., the pest presents a low risk, or introduction of the pest is very unlikely to occur). Precise quantification of pest risk, or elements contributing to overall pest risk, may be appropriate under some circumstances, but on the whole, a qualitative approach to describing level of pest risk is adequate, provided rationale used is consistent and transparent.

An NPPO may consider establishing national guidelines for estimating overall risk and interpreting those findings to determine acceptability (or not) of the identified risk.

5.2 ACCEPTABILITY OF PEST RISK

Pest risks may be deemed to be either acceptable or unacceptable. There are many reasons a particular risk may be considered to be acceptable. As risk is defined as the product of likelihood and impact, if either of these factors is extremely low or non-existent, then the overall risk is also extremely low or non-existent. It is a country's sovereign right to determine how low the risk must be for it to be acceptable. Some examples of possible rationales for accepting risk are:

- The level of the risk is so low that phytosanitary measures to further lower it are not appropriate.
- The risk is such that there is no phytosanitary measure available to mitigate it.
- The cost of phytosanitary measures is excessive compared to their benefit (this applies particularly to lower ranked risks).
- The benefits presented (e.g., economic benefits of import of a commodity) outweigh the pest risks to such a degree that the risk is justified.
- Addressing the risk by means other than phytosanitary measures is more effective than available phytosanitary measures.

If the level of risk determined by the pest risk assessment stage of the PRA is found to be unacceptable, then the first step in the pest risk management process is to identify possible phytosanitary measures that will reduce the pest risk to an acceptable level. Conversely, if the level of risk determined in the pest risk assessment stage is acceptable, then no further analysis is required and the PRA is complete.

5.3 IDENTIFICATION OF POSSIBLE RISK MANAGEMENT OPTIONS

An initial step in the pest risk management stage is to identify the possible options which could be applied to mitigate the identified pest risk(s) including, where available, measures set by international standard-setting bodies.

ISPM No. 11 (2004) states that appropriate measures should be chosen based on their effectiveness in reducing the probability of introduction of the pest to an acceptable level. The choice should be based on the following considerations, which include several of the phytosanitary principles outlined in ISPM No. 1 (2006):

- Phytosanitary measures shown to be cost-effective and feasible—the benefit from the use of phytosanitary measures is that the pest will not be introduced and the PRA area will, consequently, not be subjected to the potential economic consequences. The cost: benefit analysis for each of the minimum phytosanitary measures found to provide acceptable security may be estimated. Those measures with an acceptable cost: benefit ratio should be considered.

- Principle of "minimal impact"—measures should not be more trade restrictive than necessary to reduce the level of risk to an acceptable level. Measures should be applied to the minimum area necessary for the effective protection of the endangered area.
- Reassessment of previous requirements—no additional measures should be imposed if existing measures are effective.
- Principle of "equivalence"—if different phytosanitary measures with the same effect are identified, they should be accepted as alternatives. For example, an exporting country can provide evidence to show that the efficacy of its treatment is equivalent to another recognized by the importing country even though it was not carried out according to the recognized procedures of the importing country. The importing country can then objectively assess the exporting country's claim.
- Principle of "non-discrimination"—if the pest under consideration is established in the PRA area but of limited distribution and under official control, the phytosanitary measures in relation to import should not be more stringent than those applied within the PRA area. Likewise, phytosanitary measures should not discriminate between exporting countries of the same phytosanitary status.

Measures can range from total prohibition to permitting import subject to visual inspection. In some cases more than one phytosanitary measure may be required in order to reduce the pest risk to an acceptable level.

The following options are commonly adopted to mitigate the risk of pests of plants:

- options preventing or reducing infestations in the growing crop, e.g., pest management practices, monitoring, etc.
- options ensuring that the area, place, or site of production is free from the pest, e.g., surveillance and monitoring, treatments, etc.
- options for application to consignments and commodities, e.g., post-harvest treatments, inspections, etc.
- options for other types of pathways, e.g., certification of packing materials, transportation pathways, etc.
- options to be applied within the importing country, e.g., inspection at point of entry, end-use restrictions, treatments, etc.
- prohibition or restriction of commodities
- requirement for phytosanitary certificate or other compliance measures

Common Regulatory Measures Applied to Plants, Plant Products and Other Items Prior to Export

- import from declared pest free areas only (ISPM No. 4)
- importation restricted to certain times of the year (such as when symptoms are visible or susceptible organs absent)
- import limited to plants from officially inspected crops certified to be free of the pest
- material required to have been subjected to specified chemical or physical treatment(s)
- material required to be free of relevant symptoms
- material required to have been trimmed (e.g., debarked timber)
- plants required to have been propagated from appropriately tested and maintained parent material
- material required to have been grown on land that has been tested and found free of pests
- material required to be free of soil or organic debris
- a representative sample that is tested and found free of relevant pests
- plants required to have been cultivated and not collected from the wild

5.3.1 OPTIONS FOR PHYTOSANITARY MEASURES FOR CONSIGNMENTS

Consignments are shipments of plants or plant products leaving from an exporting country and destined for an importing country. ISPM No. 5 (2006) defines a consignment as “a quantity of plants, plant products and/or other articles being moved from one country to another and covered, when required, by a single phytosanitary certificate (a consignment may be composed of one or more commodities or lots)”

It is the exporting country’s obligation to ensure that the consignment (or shipment) meets the requirements for import established by the importing country. Measures for consignments are those measures applied specifically to the consignment either at the time of exporting, during shipment, or upon arrival in the importing country. The exporting country may be required to officially document that the specified phytosanitary measures have been conducted according to the requirements of departure from the exporting country.

It may be helpful to maintain a complete list of possible mitigation measures for a particular commodity type from which to select options that might be applicable in a particular circumstance. When new information becomes available, the checklist can be updated.

Example of Mitigation Measures

Based on the findings of the risk assessment (Biosecurity Risk to New Zealand of Pinewood Nematode (*Bursaphelenchus xylophilus*) (2004) at http://www.biosecurity.govt.nz/files/pests-diseases/forests/risk/pinewood-nematode.pdf), the following measures were recommended to mitigate the risk of entry and establishment of insect vectors of pinewood nematode (PWN) to prevent the establishment of the nematode in New Zealand:

- Review the import health standard for wood packaging material to impose mandatory treatment for all coniferous wood packaging material before entering New Zealand. Recommended treatments should exceed either fumigation with methyl bromide at 48 g/m^3 for more than 24 continuous hours and at a minimum temperature of 10°C, or heat treatment to a minimum continuous core temperature of 56°C for more than 30 minutes. Currently these treatments are expected to become mandatory for all imported solid wood packaging material entering New Zealand during 2005.
- Ensure the New Zealand border clearance systems for general imported cargo are sufficient to detect any significant increase in the entry of *Monochamus* spp and other insect vectors as hitch-hiker pests.
- Test all species and life-stages of *Monochamus* intercepted at the New Zealand border or post-border for the presence of *Bursaphelenchus* nematodes.
- Undertake post-border surveillance for *Monochamus* spp. and PWD in New Zealand to ensure early detection for eradication.
- Include in general surveillance testing for the presence of *Bursaphelenchus* spp in dead or dying coniferous trees with wilt symptoms in high risk areas.

Examples of phytosanitary measures which may be applied to consignments include:

- Inspections or testing for freedom from a pest—this is a practical measure for visible pests or for pests which produce visible symptoms on plants and plant products, for example, inspection of fresh fruit in the packing house at the time of packing for the presence of mites.
- Inspection and certification at points of origin—the exporting country may be asked to inspect the shipment and officially document (certify) that the shipment is free from regulated pests before export.
- Prohibition of parts of the host—an importing country may prohibit specific parts of a host plant that could be a pathway for movement of a quarantine pest, and allow importation of other parts of the same host because the pest would not be present on that part, for example, a pest that is present on fruits and leaves of a deciduous flowering shrub is not necessarily present on dormant planting stock.
- Pre-entry or post-entry quarantine—the importing country may define certain control conditions, inspection and possible treatment of shipments upon their entry into the country. Often this involves isolating the shipments from other material capable of harbouring regulated pests until such time that it can be determined that the imported material is free from such pests, for example, fruit tree planting stock may be grown in isolation from hosts or vectors of specified virus diseases until such time that it can be tested and proven to be virus-free.

- Specified conditions for preparation of the consignment—the importing country may specify steps which must be followed in order to prepare the consignment for shipment. These conditions can include things such as packaging requirements, clean-up requirements and movement of the commodity under quarantine, e.g., a requirement for shipments of fresh fruit to be packaged in new containers only, instead of re-used containers, may be effective in preventing the inadvertent movement of hitchhiker insects or soil which may contaminate used containers.
- Removal of the pest from the consignment by treatment or other methods—the importing country may specify chemical or physical treatments which must be applied to the consignment before it may be imported. For example, chemical treatments such as fumigants, insecticides, fungicides and herbicides, or physical treatments such as cold storage or heat treatment may be effective in eliminating specified quarantine pests from the shipment. Regulations and international obligations pertaining to the use of chemical pest control products must be respected while establishing treatment requirements of this nature, e.g., the use of methyl bromide.

> Mango is an economically important export crop for India, yet trade to some countries is impacted by the presence of the stone weevil (*Sternochetus mangiferae*). Mango fruits exported from India are required to be free from *S. mangiferae*, however, infested mango fruits show no external symptoms as the insect completes its entire life cycle within the stone/nut. In the past, mango fruits were randomly selected from a consignment and cut open to determine presence or absence of *S. mangiferae*. The entire consignment would be rejected in the event of detection in a single infested fruit. This method of detection is destructive and not suitable for small consignments. Non-destructive x-ray radiography was tested and found to be a reliable technique for detecting internal infestation of *S. mangiferae*. This makes it an appropriate tool for phytosanitary certification of mango fruits to various countries where *S. mangiferae* is of quarantine concern.

- Prevention of establishment by limiting the use, distribution or timing of the consignment—the importing country may restrict the end use of the product (e.g., for processing only) or the distribution of the product following importation in order to reduce the risk posed by certain pests to an acceptable level.
- Permitting importation during periods of the year when climatic conditions are not conducive to successful introduction, or when the pest is not present on the consignment, may be an effective measure for some pests or commodities. For example, potatoes for consumption may sometimes be imported from higher risk areas, if treated with a sprout inhibitor and packaged into small bags and sold in urban areas, where they are much less likely to be planted.

5.3.2 Options for Preventing or Reducing Infestation in the Crop

Rather than relying on measures to be taken on specific consignments, an importing country may specify measures which must be taken in the producing country to prevent infestation of the crop during its production. Depending on which pest is being targeted, measures taken to protect the crop may be more effective than measures applied to the consignment that is ultimately produced from the crop.

Prevention of infestation of the crop may include the following measures:

- Treatment of the crop, field or place of production—this may include field sanitation practices such as removal of plant parts that harbour over-wintering pests, use of chemical control agents, monitoring programs, removal of alternate hosts or bagging of fruit to protect it from pests. For example, bagging pome fruits protects them from attack by adult insects seeking suitable sites to lay their eggs; the resulting harvested fruits are free from insect larvae.
- Restricting the composition of a consignment—an importing country may specify the content of a consignment of plants or plant products so that it is composed of plants belonging solely to resistant or less susceptible species. For example, imported tobacco transplants from the USA to Canada are prohibited due to tobacco blue mould pathogen (*Pernospora hyoscyami f.s p. tabacina*). Peppers, also a host, but a less susceptible host, are permitted entry, but require a fungicide treatment.
- Growing plants under protected conditions to prevent infestation in the crop—the importing country may specify that plant products must have to be produced under protected conditions, such as in a glasshouse, in order to prevent infestation of the crop by specified quarantine pests to be allowed to be imported. For example, cut flowers produced in glasshouses may be protected from insect-transmitted viruses which would otherwise infest the plants during the growing season.
- Specifying time of harvest—harvesting plants at a certain age or at a specified time of year when the crop is less susceptible to infestation or infection may be an effective means of avoiding contamination by a pest that is present in the producing country. The importing country may specify when the crop must be harvested in order to prevent the resulting consignment from being infested. For example, when in the unripe stage of maturity, bananas are accepted as being non-hosts to the fruit fly species of economic significance present in Australia. Bananas must be harvested, packed and exported in the unripe (i.e. mature green) stage to New Zealand. Consignments containing bananas at the colour break to full ripe stage will be rejected for export to New Zealand. Specifying time of harvest may also be particularly important in the case of transient pests which occur each year but are not present all year round. For example, tobacco blue mould does not over-winter in all areas in North America where tobacco is grown. Its progress northward from milder areas where over-wintering is possible may be tracked throughout the growing season. Tobacco harvested before the arrival of tobacco blue mould is disease-free.
- Crop certification—the importing country may specify that production of the commodity be undertaken under an officially monitored certification scheme to ensure stock is free from disease. For example, production of virus-free fruit trees under a national virus-free fruit tree certification program may be an effective means of ensuring pest freedom in stock prepared for export.

5.3.3 OPTIONS ENSURING THAT THE AREA, PLACE OR SITE OF PRODUCTION IS FREE FROM THE PEST

In order to satisfy an importing country's requirement that a consignment be pest-free when the pest in question is known to be present in the exporting country, the exporting country may elect to establish a pest-free area or pest-free place(s) of production within its country. ISPMs No. 4 (*Requirements for the establishment of pest free areas*) and No. 10

(*Requirements for the establishment of pest free places of production and pest free production sites*) relate to the establishment of pest free areas and pest free places of production and pest free production sites. ISPM No. 4 identifies a pest free area as being "an area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained".

Establishing a pest free area or place of production or production site allows for the exportation of plants, plant products and other regulated articles from that area or place in the exporting country to an importing country where the pest is a quarantine pest, without the need for application of additional phytosanitary measures. Pest free status, established according to ISPM No. 4 or No. 10, may be used as the basis for phytosanitary certification of plants and plant products with respect to the stated pest, for the purposes of exporting. The exporting country may also inspect the crop to confirm freedom from the pest and provide that certification.

5.3.4 OPTIONS FOR OTHER TYPES OF PATHWAYS

Pests may move between areas or countries by many pathways in addition to the shipment of consignments of plants or plant products discussed so far. The measures mentioned above to detect a pest in a consignment, or prevent infestation of a consignment, may be used or adapted for other pathways, including packing materials, packaging, vehicles, containers, passenger baggage, and international garbage.

The following factors should be considered:

- If the pest is entering the PRA area by natural spread or is likely to enter in the future, phytosanitary measures to control human-assisted entry may have little long-term impact. In this instance, other approaches, such as containment or suppression in the PRA area after entry by the pest could be considered. Stem rust of wheat, for example, is spread long distances in North America by means of wind-blown spores. Preventing introduction on imported wheat seed or straw by the application of phytosanitary measures is, therefore, not effective to protect the crop. Instead, prevention of the sexual life stages of the rust by removal and control of the rust's alternate host is an effective measure to protect the threatened wheat crop.
- Measures for human travellers and their baggage could include targeted inspections, publicity and fines or incentives. In a few cases, treatments may be possible. Targeted public education and awareness programs, disposal bins at points of entry and other similar programs may be more effective for eliminating introduction and spread of quarantine pests by means of travellers' baggage.
- Certain types of pests may move quite effectively by means of contaminated machinery or modes of transport, e.g., gypsy moth egg masses laid on containers in loading areas, or soil adhering to military vehicles returning from the field. Vehicles may be subjected to cleaning, disinfestation and/or inspection prior to release at the destination.

Methyl bromide is an odourless, colourless gas that has been widely used as a fumigant and is a very effective treatment for many commodities. It targets insect pests, soil-borne pathogens, weed seeds and nematodes. However, its use for non-quarantine purposes is being phased out for environmental reasons under the *Montreal Protocol on Substances that Deplete the Ozone Layer*. While the use of methyl bromide for quarantine purposes is not covered under the *Montreal Protocol*, member countries are encouraged to use alternatives where they are available. One alternative treatment that is being considered by many countries is irradiation. ISPM No. 18 (*Guidelines for the use of irradiation as a phytosanitary measure)* provides technical guidance on the procedures for the application of irradiation as a phytosanitary treatment.

5.3.5 OPTIONS WITHIN THE IMPORTING COUNTRY FOR PREVENTING OR REDUCING CROP INFESTATION

Certain phytosanitary measures may be effective when applied to imported consignments within the importing country. This option places the burden of responsibility and expense on the importing country rather than the exporting country. Measures that may be taken within the importing country to prevent establishment and spread of imported pests include:

- Inspection of consignments at the point of entry—many countries have facilities at their points of entry to conduct inspections of regulated articles prior to entering their country, or to conduct surveillance for early detection of pests. The purpose of the inspection is to ensure that import requirements for freedom from the pest in question have been met and to detect new potentially quarantine pests.
- Treatment, containment or disposal of imported consignments to limit spread of introduced pests—when imported consignments do not meet the importing country's requirements, including situations where live pests are detected during inspections, it may be necessary to undertake immediate action to prevent entry and establishment of the pest or pests found. These actions may include chemical or physical treatment, re-direction of the consignment to a different end-use (e.g., diverting fresh fruit to a processing plant instead of to retail outlets when it is found to be infested with live insects of concern), returning the consignment to the exporting country or to a third country where the pest is not a quarantine pest, or destructive disposal of the consignment.
- Public education programs in the importing country—the importing country may wish to conduct education programs to inform importers, industry representatives, government officials, and other stakeholders of the pest risks presented by quarantine pests and of measures that can be taken to prevent their introduction into the country. Education programs can further be used to limit the extent of any consequences following introduction and establishment of a quarantine pest. For example, an education program in which travellers receive information about what plants or plant products they should not bring back from foreign countries may help to prevent the introduction of quarantine pests by those means.

5.3.6 Prohibition of Commodities

Sometimes there are no treatments or inspection techniques available to ensure that material is free from a quarantine pest and the only safe option is to prohibit the entry of the material possibly carrying the pest. Prohibition is usually considered to be a measure of last resort.

Partial Prohibition

A country may feel that a certain area within their borders requires special protection to prevent the entry of a regulated pest. The country may then prohibit entry of material capable of moving the regulated pest into this area. Conversely, an importing country may only accept material from another country if the exporting country demonstrates that the material comes from an area within the exporting country that is free from the regulated pest.

5.4 Phytosanitary Certification

Pest risk management includes the consideration of appropriate compliance procedures. The most important of these is export certification (refer to ISPM No. 7: *Export certification system*). The issuance of Phytosanitary Certificates (refer to ISPM No. 12: *Guidelines for phytosanitary certificates*) provides official assurance that a consignment meets specified import requirements and confirms that pest risk management options have been followed.

ISPM No. 12 states that importing countries should only require Phytosanitary Certificates for regulated articles. Regulated articles may include commodities such as:

- plants, bulbs and tubers, or seeds for propagation;
- fruits and vegetables;
- cut flowers and branches;
- grain; and
- growing medium.

Phytosanitary Certificates may also be used for certain plant products that have been processed where such products, by their nature or that of their processing, have a potential for introducing regulated pests. A Phytosanitary Certificate may also be required for other regulated articles where phytosanitary measures are technically justified. For example, solid wood packaging materials are a well-documented pathway for the introduction and spread of pests, despite their being a constructed product. Imposition of phytosanitary measures, including a requirement for a Phytosanitary Certificate, is therefore justifiable. Similarly, used containers, road building equipment or vehicles may constitute a pathway for entry of pests and may be identified as regulated articles that are subject to phytosanitary certification. Importing countries should not require Phytosanitary Certificates for plant products that have been processed in such a way that they have no potential for introducing regulated pests, or for other articles that do not require phytosanitary measures.

5.5 Evaluation of Options

When all the pest risk management options have been identified, they should each be evaluated. One or more pest risk management options may then be selected on the basis of their costs and benefits overall.

When evaluating options, consider the following factors:

- Effectiveness in achieving the expected outcome—does the measure have the effect that is desired, for example, does it kill all the insects in the consignment?
- Efficiency in achieving the expected results—is the measure appropriate for what is required to have the desired result?
- Reproducibility—will the treatment have the same results each time it is applied in the same manner to the same product?
- Cost-effectiveness—does it cost less to apply the pest risk management option than to not apply it and experience the effects of the pest? Is there a less costly option available that would have the same results?
- Potential adverse consequences to human health, economic values, plant and/or animal health, environmental values etc. associated with each option—does the option increase certain risks while reducing others? Are there possible negative impacts of the measure? How could the risks be reduced or eliminated?
- Expected costs associated with each option including resource and time requirements as well as monetary costs—what are the treatment costs, both to the importer and to the NPPO administering it?
- Impacts the resource requirements have on other programs—will expending resources on this activity result in an inability to deliver other programs and will there be negative consequences?

For each available pest risk management option, assumptions and uncertainties should be noted and taken into account during evaluation. At the conclusion of the evaluation, the positive and negative aspects of each option should be noted and options appropriate to the level of risk presented should be selected.

5.6 Selection of Options

A pest risk management strategy may consist of a simple approach using one pest risk management option or a multi-faceted approach using several options to varying degrees. In many cases it is unlikely that any single pest risk management option will provide a complete solution, and a combination of options will prove to be the most effective means of achieving the desired level of protection. For example, a series of phytosanitary measures including production in a certified orchard practising good management, packing house inspection and in transit cold storage treatment may be necessary to prevent introduction of a specified insect pest with imported grapes from a country where the pest is known to occur.

Use of a flexible approach can be beneficial by improving the effectiveness and efficiency of individual pest risk management practices and it can provide solutions that are easier to implement and more generally accepted. The most appropriate phytosanitary measures are those that are feasible, effective and provide reasonable benefits given the costs. An analysis of cost-effectiveness can help identify the least costly pest risk management option for meeting an identified goal. In general, the preferred pest risk management options will be those whose adverse impacts are as low as reasonably feasible.

Many options may not prove to be feasible for a variety of reasons including legal, political or economic reasons, or because they do not reduce the pest risks to the extent needed. It is frequently possible to eliminate options after a cursory examination of their costs and feasibility. Priority should be given to options that prevent risks, rather than options that control them.

Apple Pest Continued

In concluding the PRA for the hypothetical apple insect, the pest risk management stage will have identified different levels of overall pest risk for each of its potential pathways. For this example let's say that the level of risk associated with apple wood, animal bedding and other artefacts was determined to be acceptable and that the PRA did not continue past the pest risk assessment stage. Some pathways, however, were identified for which the level of risk was not acceptable, namely apple fruit, budwood and apple twigs and blossoms. For each of these pathways, it was necessary to identify a range of possible mitigation measures and select preferred options. This process entailed considerable research, consultation with experts, communication with stakeholders and peer review.

For each pathway, a single or series of phytosanitary measures was identified which will reduce the overall risk of introduction of this insect by the pathway in question to an acceptable level. For fresh apples, because they are imported in large volumes and visual inspection does not provide an adequate level of inspection alone, the PRA has concluded by recommending orchard certification to ensure orchard pest management measures are implemented, coupled with a wash treatment and cold atmosphere storage in transit. The exporting country is able to comply with these conditions and a trial importation period, during which the importing country will verify the effectiveness of these measures, is initiated. For the budwood, because it is produced under highly controlled circumstances in low volumes for occasional import to a select number of sites, the PRA has concluded that certification by the exporting NPPO is all that will be necessary. The apple twigs and blossoms may be imported without restriction during specified times of the year when host phenology and climate are not amendable to the pest's successful introduction.

A method or series of methods which are expected to have the same result on pest risk are said to be equivalent, though not identical. For example, a combination of field inspection and seed health testing may have the same result mitigating the risk of entry of a seed-borne pest in imported seed lots, as a single fumigation treatment or surface pesticide treatment would. Exporting countries may be required to comply with import restrictions which require one or another of these measures (or series of measures) but not all, since no additional protection is provided to the importing country by the sequential application of all possible mitigation measures. When several options prove to be equivalent and each provide the desired level of protection, the importing country may elect to offer a choice of equivalent measures from which the exporting country may select their preferred option to meet the importing country's requirements.

ISPM No. 14 (*The use of integrated measures in a systems approach for pest risk management*) can provide further information on the selection of risk management options.

5.7 CONCLUSION OF PEST RISK MANAGEMENT

> To facilitate the pest risk management process and documentation of results, an NPPO may consider developing a check-list or database of risk management options and their possible applications from which to select phytosanitary measures for consideration in the PRA.

The pest risk management process results in either no appropriate measures being identified, or selection of one or more management options that have been found to lower the risk associated with the quarantine pest(s) to an acceptable level. The importing country may wish to document the evaluation of pest risk management options and the reasons for selecting preferred options, as this information may prove useful in cases of disagreement, failure of options to achieve the desired results, or in future cases of a similar nature. These management options form the basis for phytosanitary regulations or requirements which may be developed by the NPPO in response to the risk presented by the pest.

The conclusion of the pest risk management stage marks the end of the PRA. As for other stages of the PRA, pest risk management is an iterative process; it is not necessary to complete each step sequentially. Continual review and revision is required as new information is obtained. Pest risk communication throughout the PRA process is helpful and will ensure complete information is acquired at each stage, that stakeholders have an understanding of the issues involved and that the NPPO has all the necessary information to complete the PRA process adequately.

Ensuring Quality in PRAs

Throughout the course of completing the PRA, the analyst should strive for quality, consistency and transparency, in keeping with the principles of the IPPC. The PRA is the cornerstone of the IPPC and forms the basis for future actions by the NPPO, including development of regulations, implementation of phytosanitary measures on imported commodities, and surveillance, control or eradication measures taken within the NPPO. In reviewing the PRA as it is completed, the analyst may ask the following questions:

- Is the PRA complete? Has everything been documented?
- Have all the factors identified in the relevant ISPMs been addressed?
- Is the approach taken in this PRA thorough and consistent with that of other PRAs conducted by my NPPO?
- Have the relevant principles of the IPPC been respected?

Once satisfied that the PRA is of sufficient quality, it should then be subjected to a peer-review. The reviewer should consider the following:

- Have all information sources been comprehensively searched? Is the information used up-to-date, correctly interpreted and properly referenced?
- Is the PRA clearly written? Are all judgements fully justified, documented and referenced? Is the PRA sufficiently detailed to support the conclusions?
- Have appropriate methods been used in situations of high uncertainty? Has uncertainty been considered adequately?

6. MONITORING AND REVIEW

The implementation of particular phytosanitary measures should not be considered to be permanent as new information may arise or pest situations may change, necessitating a re-evaluation of any decision.

Evaluation of phytosanitary measures is a key component of accountability and measures should be monitored to ensure that they are effective and achieve the intended end-point. ISPM No. 1 (2006) states that "As conditions change and as new facts become available, phytosanitary measures shall be modified promptly, either by inclusion of prohibitions, restrictions or requirements necessary for their success, or by removal of those found to be unnecessary".

Evaluating the results of the pest risk management decision can provide important information about whether:

- the measures taken were successful,
- the predicted costs and benefits were accurate,
- any changes are needed in order to improve success,
- any information gaps or other uncertainties hindered success, and
- any new information has emerged that may change or impact the PRA decision.

A pest risk management decision may also be re-visited if a more effective pest risk management option or a less costly one of equal effectiveness is proposed. Information supporting the PRA should periodically be reviewed to ensure that any new information that becomes available is taken into account along with its impact on the PRA decision. PRAs may need to be revised as a result of things such as: changes in the distribution of the pest either in the exporting country or in the importing country, a change in the volume of trade, new international trade, host plants newly grown in the PRA area that were not grown at the time of the PRA, improved diagnostic tests, improved availability of treatments, new policy decisions or climate changes.

7. REFERENCES

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APPENDIX 1—LIST OF ISPMS (AS OF 2007)

ISPM No. 01 (2006) *Phytosanitary principles for the protection of plants and the application of phytosanitary measures in international trade*

ISPM No. 02 (2007) *Framework for pest risk analysis*

ISPM No. 03 (2005) *Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms*

ISPM No. 04 (1995) *Requirements for the establishment of Pest Free Areas*

ISPM No. 05 (2007) *Glossary of phytosanitary terms*

ISPM No. 06 (1997) *Guidelines for surveillance*

ISPM No. 07 (1997) *Export certification system*

ISPM No. 08 (1998) *Determination of pest status in an area*

ISPM No. 09 (1998) *Guidelines for pest eradication programmes*

ISPM No. 10 (1999) *Requirements for the establishment of pest free places of production and pest free production sites*

ISPM No. 11 (2004) *Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms*

ISPM No. 12 (2001) *Guidelines for phytosanitary certificates*

ISPM No. 13 (2001) *Guidelines for the notification of non-compliance and emergency action*

ISPM No. 14 (2002) *The use of integrated measures in a systems approach for pest risk management*

ISPM No. 15 (2002) with modifications to Annex 1 (2006) *Guidelines for regulating wood packaging material in international trade*

ISPM No. 16 (2002) *Regulated non-quarantine pests: concept and application*

ISPM No. 17 (2002) *Pest reporting*

ISPM No. 18 (2003) *Guidelines for the use of irradiation as a phytosanitary measure*

ISPM No. 19 (2003) *Guidelines on lists of regulated pests*

ISPM No. 20 (2004) *Guidelines for a phytosanitary import regulatory system*

ISPM No. 21 (2004) *Pest risk analysis for regulated non quarantine pests*

ISPM No. 22 (2005) Requirements for the establishment of areas of low pest prevalence

ISPM No. 23 (2005) *Guidelines for inspection*

ISPM No. 24 (2005) *Guidelines for the determination and recognition of equivalence of phytosanitary measures*

ISPM No. 25 (2006) *Consignments in transit*

ISPM No. 26 (2006) *Establishment of pest free areas for fruit flies (Tephritidae)*

ISPM No. 27 (2006) *Diagnostic protocols for regulated pests*

ISPM No. 28 (2007) *Phytosanitary treatments for regulated pests*

ISPM No. 29 (2007) *Recognition of pest free areas and areas of low pest prevalence*

APPENDIX 2—EXAMPLE OF A REGIONAL MODEL FOR PRA

European and Mediterranean Plant Protection Organisation—Guidelines on Pest Risk Analysis N.B. This template should be used together with PM5/3 (2) *Decision-support scheme for quarantine pests* which contains the necessary explanations for a proper understanding of the scheme

Stage 1: Initiation

The aim of the initiation stage is to identify the pest(s) and pathways which are of phytosanitary concern and should be considered for risk analysis in relation to the identified PRA area.

1. Give the reason for performing the PRA

The PRA may be initiated for one or several reasons, the most common being:

PRA initiated by the identification of a pathway:

- international trade is initiated in a commodity not previously imported into the country, or a commodity from a new area or new country of origin
- new plant species are imported for breeding or research purposes
- a pathway other than a commodity import is identified (natural spread, packing material, mail, garbage, passenger baggage, etc)

In such cases, a list of pests likely to be associated with the pathway should be generated and preferably prioritized, based on pest distribution, pest status and expert judgment.

PRA initiated by the identification of a pest:

- an established infestation or an incursion of a pest has been discovered in the PRA area
- a pest has been detected in an imported consignment
- a pest has been identified as a risk by scientific research
- a pest has invaded a new area, other than the PRA area
- a pest is reported to be more damaging in a new area than its area of origin
- a pest is observed to be detected more frequently in international trade
- a request is made for the intentional import of a pest
- a previous PRA is being re-evaluated
- an organism has been identified as a vector for other pests

In some cases, a PRA may be initiated as above by an organism which is not known to be a pest, but whose pest potential in the PRA area needs to be evaluated.

PRA initiated by the review or revision of a policy:

- phytosanitary regulations are being revised, e.g. following a national decision or new information on treatments or processes
- a proposal made by another country or by an international organization (RPPO, FAO) is assessed
- a dispute arises on phytosanitary measures

Go to 2

2. Specify the pest or pests of concern and follow the scheme for each individual pest in turn. For intentionally introduced plants specify the intended habitats.

   If no pest of concern has been identified the PRA may stop at this point.
   Go to 3

3. Clearly define the PRA area.

   The PR area can be a complete country, several countries or part(s) of one or several countries.

   Go to 4

Earlier analysis

The pest, or a very similar pest, may have been subjected to the PRA process before, nationally or internationally. This may partly or entirely replace the need for a new PRA.

4. Does a relevant earlier PRA exist?

   if yes—Go to 5
   if no—Go to 6

5. Is the earlier PRA still entirely valid, or only partly valid (out of date, applied in different circumstances, for a similar but distinct pest, for another area with similar conditions)?

   if entirely valid—end
   if partly valid proceed with the PRA, but compare as much as possible with the earlier PRA—Go to 6
   if not valid—Go to 6

Stage 2: Pest Risk Assessment

Section A: Pest categorization

Identify the pest (or potential pest)

6. Is the organism clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?

   if yes indicate the correct scientific name and taxonomic position-Go to 8
   if no—Go to 7

7. Even if the causal agent of particular symptoms has not yet been fully identified, has it been shown to produce consistent symptoms and to be transmissible?

   if yes—Go to 8
   if no—Go to 17

Determining whether the organism is a pest

8. Is the organism in its area of current distribution a known pest (or vector of a pest) of plants or plant products?

   if yes, the organism is considered a pest—Go to 10
   if no—Go to 9

9. Does the organism have intrinsic attributes that indicate that it could cause significant harm to plants?

   if yes or uncertain, the organism may become a pest of plants in the PRA area—Go to 10
   if no—Go to 17

Presence or absence in the PRA area and regulatory status (pest status)

10. Does the pest occur in the PRA area?

    if yes—Go to 11
    if no—Go to 12

11. Is the pest widely distributed in the PRA area?

    if not widely distributed—Go to 12
    if no—Go to 17

Potential for establishment and spread in the PRA area

For a pest to establish, it should find host plants or suitable habitat in the PRA area. Natural hosts should be of primary concern but, if such information is lacking, plants which are recorded as hosts only under experimental conditions or accidental/very occasional hosts may also be considered. The pest should also find environmental conditions suitable for its survival, multiplication and spread, either in natural or in protected conditions.

12. Does at least one host-plant species (for pests directly affecting plants) or one suitable habitat (for non parasitic plants) occur in the PRA area (outdoors, in protected cultivation or both)?

    if yes—Go to 13
    if no—Go to 17

13. If a vector is the only means by which the pest can spread, is a vector present in the PRA area? (if a vector is not needed or is not the only means by which the pest can spread **go to 14**)

    if yes—Go to 14
    if no—Go to 17

14. Does the known area of current distribution of the pest include ecoclimatic conditions comparable with those of the PRA area or sufficiently similar for the pest to survive and thrive (consider also protected conditions)?

    if yes—Go to 15
    if no—Go to 17

Potential for economic consequences in PRA area.

There should be clear indications that the pest is likely to have an unacceptable economic impact in the PRA area. Unacceptable economic impact is described in ISPM No. 5 Glossary of phytosanitary terms, Supplement No. 2: Guidelines on the understanding of potential economic importance and related terms. Climatic and cultural conditions in the PRA area should be considered to decide whether important economic (including environmental or social) damage or loss to plants may occur in the PRA area. The effect of the presence of the pest on exports from the PRA area should also be allowed for. In some cases, the pest may only be potentially harmful, as suggested by its intrinsic attributes.

15. With specific reference to the plant(s) or habitats which occur(s) in the PRA area, and the damage or loss caused by the pest in its area of current distribution, could the pest by itself, or acting as a vector, cause significant damage or loss to plants or other negative economic impacts (on the environment, on society, on export markets) through the effect on plant health in the PRA area?

    if yes or uncertain—Go to 16
    if no—Go to 17

Conclusion of pest categorization

16. This pest could present a risk to the PRA area (Summarize the main elements leading to this conclusion)

    Go to section B

17. The pest does not qualify as a quarantine pest for the PRA area and the assessment for this pest can stop (summarize the main reason for stopping the analysis).

    For a pathway analysis, go to 4 and proceed with the next pest.
    If no further pests have been identified the PRA may stop at this point.

Section B: Assessment of the probability of introduction and spread and of potential economic consequences

This part of the risk assessment process firstly estimates the probability of the pest being introduced into the PRA area (its entry and establishment) and secondly makes an assessment of the likely economic impact if that should happen. From these assessments, it should be possible to estimate the level of risk associated with the pest, which can then be used in the pest risk management phase to determine whether it is necessary to take phytosanitary measures to prevent the introduction of the pest, and if the measures chosen are appropriate for the level of risk.

The evaluation is based on the replies to a series of questions, mostly expressed in the first instance as the choice of an appropriate phrase out of a set of five alternatives (e.g. very unlikely, unlikely, moderately likely, likely, very likely). It is important to identify especially high or especially low risks. The user of the scheme should add to all replies any details which appear relevant indicating the source of information used.

Answer as many of the following questions as possible. If any question does not appear to be relevant for the pest concerned, it should be noted as "irrelevant". If any question appears difficult to answer no judgement should be given but the user should note whether this is because of lack of information or uncertainty.

1. Probability of introduction

Introduction, as defined by the FAO Glossary of Phytosanitary Terms, is the entry of a pest resulting in its establishment.

Probability of entry of a pest

Identification of pathways

Closed pathways may also be considered, as the pests identified may support existing phytosanitary measures. Furthermore, some pathways may be closed by phytosanitary measures which might be withdrawn at a future date. In such cases, the risk assessment may need to be continued. Data on detections in imported consignments may indicate the ability of a pest to be associated with a pathway. For a PRA initiated by the identification of a pathway, this is the main pathway to be considered.

For pathways consisting of intentionally imported plants do not consider entry, but go directly to establishment. Spread from the intended habitat to the unintended habitat which is an important judgement for intentionally imported plants is covered by questions 1.33 to 1.35.

1.1 Consider all relevant pathways and list them.

Relevant pathways are those with which the pest has a possibility of being associated (in a suitable life stage), on which it has the possibility of survival, and from which it has the possibility of transfer to a suitable host. Make a note of any obvious pathways that are impossible and record the reasons.

Go to 1.2

1.2 Estimate the number of relevant pathways, of different commodities, from different origins, to different end uses.

very few, few, moderate number, many, very many—Go to 1.3

1.3 Select from the relevant pathways, using expert judgement, those which appear most important. If these pathways involve different origins and end uses, it is sufficient to consider only the realistic worst-case pathways. The following group of questions on pathways is then considered for each relevant pathway in turn, as appropriate, starting with the most important.

Go to 1.4

<u>Probability of the pest being associated with the individual pathway at origin.</u>

1.4 How likely is the pest to be associated with the pathway at origin?

very unlikely, unlikely, moderately likely, likely, very likely—Go to 1.5

1.5 Is the concentration of the pest on the pathway at origin likely to be high, taking into account factors like cultivation practices, treatment of consignments?

very unlikely, unlikely, moderately likely, likely, very likely—Go to 1.6

1.6 How large is the volume of the movement along the pathway?

minimal, minor, moderate, major, massive—Go to 1.7

1.7 How frequent is the movement along the pathway?

very rarely, rarely, occasionally, often, very often—Go to 1.8

Probability of survival during transport or storage

1.8 How likely is the pest to survive during transport/storage?

very unlikely, unlikely, moderately likely, likely, very likely—Go to 1.9

1.9 How likely is the pest to multiply/increase in prevalence during transport /storage?

very unlikely, unlikely, moderately likely, likely, very likely—Go to 1.10

Probability of the pest surviving existing pest management procedures

1.10 How likely is the pest to survive or remain undetected during existing phytosanitary measures?

very unlikely, unlikely, moderately likely, likely, very likely—Go to 1.11

Probability of transfer to a suitable host or habitat

1.11 In the case of a commodity pathway, how widely is the commodity to be distributed throughout the PRA area?

very limited, limited, moderately widely, widely, very widely—Go to 1.12

1.12 In the case of a commodity pathway, do consignments arrive at a suitable time of year for pest establishment?

if yes—Go to 1.13
if no—Go to 1.15

1.13 How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

very unlikely, unlikely, moderately likely, likely, very likely—Go to 1.14

1.14 In the case of a commodity pathway, how likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) to aid transfer to a suitable host or habitat?

very unlikely, unlikely, moderately likely, likely, very likely—Go to 1.15

Consideration of further pathways

1.15 Do other pathways need to be considered?

if yes—Go back to 1.13
if no—Go to conclusion on the probability of entry and then 1.16

Conclusion on the probability of entry

The overall probability of entry should be described and risks presented by different pathways should be identified.

Probability of Establishment

For plants which are intentionally imported, the assessment of the probability of establishment concerns the unintended habitat.

Availability of suitable hosts or suitable habitats, alternate hosts and vectors in the PRA area

1.16 a) Specify the host plant species (for pests directly affecting plants) or suitable habitats (for non parasitic plants) present in the PRA area.
b) Estimate the number of host plant species or suitable habitats in the PRA area.

very few, few, moderate number, many, very many

1.17 How widespread are the host plants or suitable habitats in the PRA area? (specify)

very limited, limited, moderately widely, widely, very widely

1.18 If an alternate host is needed to complete the life cycle, how widespread are alternate host plants in the PRA area? (not relevant for parasitic plants)

N/A, absent, limited, moderately widely, widely, very widely

1.19 If the pest requires another species for critical stages in its life cycle such as transmission, (e.g. vectors), growth (e.g. root symbionts), reproduction (e.g. pollinators) or spread (e.g. seed dispersers), how likely is the pest to become associated with such species?

N/A, very unlikely, unlikely, moderately likely, likely, very likely

Suitability of the environment

1.20 How similar are the climatic conditions that would affect pest establishment, in the PRA area and in the current area of distribution?

not similar, slightly similar, moderately similar, largely similar, completely similar

1.21 How similar are other abiotic factors that would affect pest establishment, in the PRA area and in the current area of distribution?

not similar, slightly similar, moderately similar, largely similar, completely similar

1.22 If protected cultivation is important in the PRA area, how often has the pest been recorded on crops in protected cultivation elsewhere?

N/A, never, rarely, sometimes, often, very often

1.23 How likely is that establishment will not be prevented by competition from existing species in the PRA area?

very unlikely, unlikely, moderately likely, likely, very likely

1.24 How likely is that establishment will not be prevented by natural enemies already present in the PRA area?

very unlikely, unlikely, moderately likely, likely, very likely

Cultural practices and control measures

1.25 To what extent is the managed environment in the PRA area favourable for establishment?

Not at all favourable, slightly favourable, moderately favourable, highly favourable, very highly favourable

1.26 How likely is it that existing control or husbandry measures will fail to prevent establishment of the pest?

very unlikely, unlikely, moderately likely, likely, very likely

1.27 How likely is it that the pest could survive eradication programmes in the PRA area?

very unlikely, unlikely, moderately likely, likely, very likely

Other characteristics of the pest affecting the probability of establishment

1.28 How likely is the reproductive strategy of the pest and the duration of its life cycle to aid establishment?

very unlikely, unlikely, moderately likely, likely, very likely

1.29 How likely are relatively small populations or populations of low genetic diversity to become established?

very unlikely, unlikely, moderately likely, likely, very likely

1.30 How adaptable is the pest?

Adaptability is: very low, low, moderate, high, very high

1.31 How often has the pest been introduced into new areas outside its original area of distribution? (specify the instances, if possible)

never, very rarely, occasionally, often, very often

1.32 Even if permanent establishment of the pest is unlikely, how likely are transient populations to occur in the PRA area through natural migration or entry through man's activities (including intentional release into the environment) ?

N/A, very unlikely, unlikely, moderately likely, likely, very likely

Conclusion on the probability of establishment

Probability of spread

1.33 How likely is the pest to spread rapidly in the PRA area by natural means?

very unlikely, unlikely, moderately likely, likely, very likely

1.34 How likely is the pest to spread rapidly in the PRA area by human assistance?

very unlikely, unlikely, moderately likely, likely, very likely

1.35 How likely is it that the spread of the pest will not be contained within the PRA area?

very unlikely, unlikely moderately likely, likely, very likely—Go to conclusion of spread

Conclusion on the probability of spread

Go to Conclusion on the probability of introduction and spread

Conclusion on the probability of introduction and spread

The overall probability of introduction and spread should be described. The probability of introduction and spread may be expressed by comparison with PRAs on other pests.

Go to 1.36

Conclusion regarding endangered areas

Based on the answers to questions 1.16 to 1.35 identify the part of the PRA area where presence of host plants or suitable habitats and ecological factors favour the establishment and spread of the pest to define the endangered area.

Go to 2 Assessment of potential economic consequences

2. Assessment of potential economic consequences

The main purpose of this section is to determine whether the introduction of the pest will have unacceptable economic consequences. It may be possible to do this very simply, if sufficient evidence is already available or the risk presented by the pest is widely agreed. Start by answering Questions 2.1 - 2.9. If any of the responses to questions 2.2, 2.3, 2.4, 2.6, 2.8 or 2.9 is “major" or "massive” or "very likely" or "certain", the evaluation of the other questions in this section may not be necessary and you can go to 2.16 unless a detailed study is required. In cases where the organism has already entered and is established in part of the PRA area, responses to questions 2.1, 2.5 and 2.7, which refer to impacts in its area of current distribution, should be based on an assessment of current impacts in the PRA area in addition to impacts elsewhere.

Expert judgement is used to provide an evaluation of the likely scale of impact. If precise economic evaluations are available for certain pest/crop combinations, it will be useful to provide details.

The replies should take account of both short-term and long-term effects of all aspects of agricultural, environmental and social impact.

In any case, providing replies for all hosts (or all habitats) and all situations may be laborious, and it is desirable to focus the assessment as much as possible. The study of a single worst-case may be sufficient. Alternatively, it may be appropriate to consider all hosts/habitats together in answering the questions once. Only in certain circumstances will it be necessary to answer the questions separately for specific hosts/habitats.

Consider potential hosts/habitats identified in question 1.16 when answering the following questions:

Pest effects

2.1 How great a negative effect does the pest have on crop yield and/or quality to cultivated plants or on control costs within its current area of distribution?

minimal, minor, moderate, major, massive

2.2 How great a negative effect is the pest likely to have on crop yield and/or quality in the PRA area?

minimal, minor, moderate, major, massive

2.3 How great an increase in production costs (including control costs) is likely to be caused by the pest in the PRA area?

minimal, minor, moderate, major, massive

2.4 How great a reduction in consumer demand is the pest likely to cause in the PRA area?

minimal, minor, moderate, major, massive

2.5 How important is environmental damage caused by the pest within its current area of distribution?

minimal, minor, moderate, major, massive

2.6 How important is the environmental damage likely to be in the PRA area?

minimal, minor, moderate, major, massive

2.7 How important is social damage caused by the pest within its current area of distribution?

minimal, minor, moderate, major, massive

2.8 How important is the social damage likely to be in the PRA area?

minimal, minor, moderate, major, massive

2.9 How likely is the presence of the pest in the PRA area to cause losses in export markets?

impossible/very unlikely, unlikely, moderately likely, likely, very likely/certain

As noted in the introduction to section 2, the evaluation of the following questions may not be necessary if any of the responses to questions 2.2, 2.3, 2.4, 2.6, 2.8 or 2.9 is “major" or "massive” or "very likely" or "certain". You may go directly to point 2.16 unless a detailed study of impacts is required.

2.10 How easily can the pest be controlled in the PRA area?

very easily, easily, with some difficulty, with much difficulty, impossible

2.11 How likely is it that natural enemies, already present in the PRA area, will not suppress populations of the pest if introduced?

very unlikely, unlikely, moderately likely, likely, very likely

2.12 How likely are control measures to disrupt existing biological or integrated systems for control of other pests or to have negative effects on the environment?

impossible/very unlikely, unlikely, moderately likely, likely, very likely/certain

2.13 How important would other costs resulting from introduction be?

minimal, minor, moderate, major, massive

2.14 How likely is it that genetic traits can be carried to other species, modifying their genetic nature and making them more serious plant pests?

impossible/very unlikely, unlikely, moderately likely, likely, very likely/certain

2.15 How likely is the pest to act as a vector or host for other pests?

impossible/very unlikely, unlikely, moderately likely, likely, very likely/certain

Conclusion of the assessment of economic consequences

2.16 Referring back to the conclusion on endangered area (1.36), identify the parts of the PRA area where the pest can establish and which are economically most at risk.

Go to degree of uncertainty

Degree of uncertainty

Estimation of the probability of introduction of a pest and of its economic consequences involves many uncertainties. In particular, this estimation is an extrapolation from the situation where the pest occurs to the hypothetical situation in the PRA area. It is important to document the areas of uncertainty and the degree of uncertainty in the assessment, and to indicate where expert judgement has been used. This is necessary for transparency and may also be useful for identifying and prioritizing research needs.

It should be noted that the assessment of the probability and consequences of environmental hazards of pests of uncultivated plants often involves greater uncertainty than for pests of cultivated plants. This is due to the lack of information, additional complexity associated with ecosystems, and variability associated with pests, hosts or habitats.

For pest-initiated risk assessments—Go to conclusion of the risk assessments
For pathway-initiated risk assessments—Go back to 1.4 to evaluate the next pest, if all pests have been evaluated go to conclusion of the risk assessment

Conclusion of the pest risk assessment

<u>Entry</u>

Evaluate the probability of entry and indicate the elements which make entry most likely or those that make it least likely. Identify the pathways in order of risk and compare their importance in practice.

<u>Establishment</u>

Evaluate the probability of establishment, and indicate the elements which make establishment most likely or those that make it least likely. Specify which part of the PRA area presents the greatest risk of establishment.

Economic importance

List the most important potential economic impacts, and estimate how likely they are to arise in the PRA area. Specify which part of the PRA area is economically most at risk.

Overall conclusion of the pest risk assessment

The risk assessor should give an overall conclusion on the pest risk assessment and an opinion as to whether the pest or pathway assessed is an appropriate candidate for stage 3 of the PRA: the selection of risk management options, and an estimation of the pest risk associated.

Stage 3: Pest risk management

The pest risk management stage is the third stage in pest risk analysis. It provides a structured analysis of the measures that can be recommended to minimize the risks posed by a pest or pathway. The pest risk management part may be used to consider measures to prevent entry, establishment or spread of a pest . It explores options that can be implemented (i) at origin or in the exporting country, (ii) at the point of entry or (iii) within the importing country or invaded area.

Before considering the available risk management options, a judgement on the acceptability of the risk posed by the pest or pathway is required. In this scheme, the methods whereby risk management options are selected differ according to whether the introduction is intentional or unintentional, whether the organism is absent or already present in the PRA area and the type of entry pathway. The options are structured so that, as far as possible, the least stringent options are considered before the most expensive/disruptive ones. Options to prevent unintentional entry on commodities are distinguished from options to prevent natural spread/movement or entry with other pathways such as passenger luggage. It should be noted that measures recommended for intentional introductions are often restricted to prohibiting imports and to actions that can be taken in the importing country.

The scheme requires a judgement on the reliability of each potential measure identified. A reliable measure is understood to mean one that it is efficient, feasible and reproducible. Limitations of application in practice should be noted. Once all potential measures have been identified, the extent to which they are cost-effective and can be combined with other measures is evaluated. A pest may enter by many different pathways and a pathway may transport many pests. It is therefore important to repeat the process for all relevant pests and pathways of concern.

In considering your responses to the following questions, please note that helpful information may be obtained from the pest risk assessment stage, particularly from the section concerning the entry of a pest (1.1-1.15). References to the relevant sections of the risk assessment stage have been added.

Risk associated with major pathways

Acceptability of the risk

A decision has to be made to determine whether the risk from any pest/pathway combination is an acceptable risk. This decision will be based on the relationship between the level of risk identified in the pest risk assessment stage (i.e. the combination of the probability of introduction and the potential economic impact) and the importance/desirability of the trade that carries the risk of introduction of the pest.

2.17 Is the risk identified in the Pest Risk Assessment stage for all pest/pathway combinations an acceptable risk?

If yes—STOP
If no—Proceed through the risk management scheme following the instructions below

Types of pathways

In most cases, the pathways to be studied will be particular commodities of plants and plant products, of stated species, moving in international trade and coming from countries where the pest is known to occur, and the questions are intended primarily for these situations. However, the pathways identified in the pest risk assessment may also include other types of pathways, e.g. natural pathway (pest spread), transport by human travellers, conveyances packing material and traded commodities other than plants and plant products, and these also need to be assessed for suitable measures. Therefore, this section explains how to analyze the other types of pathways. For plants, it is particularly important to prioritize the pathways and to identify their relative importance, as some important pathways may not currently be regulated (grain, wool, hides, sand, gravel...).

Instructions for working through the Risk Management stage

Pest-Initiated Analysis

In the case of an analysis concerning an unintentional introduction of a pest, go to question 3.2 and proceed through steps 3.2-3.9, which relate to different pathways on which the pest being analyzed may be carried. Thereafter continue with the questions concerned with the measures that might be applied to each pathway. Repeat the process for every major pathway.

For the intentional import of pest plants, the focus should be on measures preventing the establishment and spread of the organism in unintended habitats within the PRA area. The main pathway for these plants is usually the trade with ornamental plants intended for planting. For such cases go directly to question 3.28 (measures that can be taken in the importing country). This still allows the option of prohibiting import (3.36) to be considered. However, if the organism is also entering the area unintentionally, then measures may be required to prevent introduction through unintentional pathways and steps 3.2-3.27 should also be followed. Options for managing the unintentional introduction of pest plants are covered by following the procedures for pathway-initiated analysis.

Pathway-Initiated Analysis for a commodity of plants and plant products

In the case of a pathway-initiated analysis for a commodity of plants and plant products, since the precise pathway is already known, begin with question 3.10 to consider possible measures for this pathway and repeat the process as far as question 3.40 for each of the pests identified in the pest risk assessment as presenting a risk to the PRA area. When all the pests have been considered, go to 3.41 to integrate the measures for the commodity. (Note that the probabilities for entry of a particular pest with other pathways, including existing pathways, may also need to be investigated).

In considering your responses to the following questions, please note that helpful information may be obtained from the pest risk assessment stage, particularly from the section concerning entry (1.1-1.15). References to the relevant sections of the risk assessment stage have been added.

2.18 Is the pathway that is being considered a commodity of plants and plant products?

If yes—Go to 3.10
If no—Go to 3.3

2.19 Is the pathway that is being considered the natural spread of the pest (see answer to question 1.33)?

If yes—Go to 3.4
If no—Go to 3.8

2.20 Is the pest already entering the PRA area by natural spread or likely to enter in the immediate future? (see answer to question 1.33)

If yes—Go to 3.5
If no—Go to 3.37

2.21 Could entry by natural spread be reduced or eliminated by control measures applied in the area of origin?

If yes—possible measures: control measures in the area of origin—Go to 3.6

2.22 Could the pest be effectively contained or eradicated after entry? (see answer to question 1.27, 1.35,)?

If yes—possible measures: internal containment and/or eradication campaign—Go to 3.6

2.23 Was the answer "yes" to either question 3.5 or question 3.6?

If yes—Go to 3.37
If no—Go to 3.43

2.24 Is the pathway that is being considered the entry with human travellers?

If yes—possible measures: inspection of human travellers, their luggage, publicity to enhance public awareness on pest risks, fines or incentives. Treatments may also be possible—Go to 3.29
If no—Go to 3.9

2.25 Is the pathway being considered contaminated machinery or means of transport?

If yes—possible measures: cleaning or disinfection of machinery/vehicles—Go to 3.29

For other types of pathways (e.g. commodities other than plants or plant products, exchange of scientific material, packing material, grain, wool, hides, sand, gravel ...), not all of the following questions may be relevant; adapt the questions to the type of pathway.

Go to 3.37

Existing phytosanitary measures

Phytosanitary measures (e.g. inspection, testing or treatments) may already be required as a protection against other (quarantine) pests (see stage 2: question 1.10). The assessor should list these measures and identify their efficacy against the pest of concern. The assessor should nevertheless bear in mind that such measures could be removed in the future if the other pests are re-evaluated.

2.26 Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?

If appropriate, list the measures and identify their efficacy against the pest of concern—Go to 3.11

Identification of appropriate risk management options

This section (questions 3.11 to 3.28) examines the characteristics of the pest to determine if it can be reliably detected in consignments by inspection or testing, if it can be removed from consignments by treatment or other methods, if limitation of use of the commodity would prevent introduction, or if the pest can be prevented from infecting/infesting consignments by treatment, production methods, inspection or isolation. "Reliably" should be understood to mean that a measure is efficient, feasible and reproducible. Measures can be reliable without being sufficient to reduce the risk to an acceptable level. In such cases their combination with other measures to reach the desired level of protection against the pest should be envisaged (see question 3.31). When a measure is considered reliable but not sufficient, the assessor should indicate this. The efficiency, feasibility and reproducibility of the measures should be evaluated by the assessor for each potential management option identified. Limitations of application of measures in practice should be noted. **Cost effectiveness and impact on trade are considered in the section “evaluation of risk management options” (questions 3.33 to 3.35).**

Answer all questions from 3.11 to 3.22 (but note that questions 3.11 to 3.22 are not relevant for the intentional introduction of pest plants)

Options for consignments

Detection of the pest in consignments by inspection or testing

2.27 Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?

If yes—possible measure: visual inspection—Go to 3.12

2.28 Can the pest be reliably detected by testing (e.g. for pest plant seeds in a consignment)?

If yes—possible measure: specified testing—Go to 3.13

2.29 Can the pest be reliably detected during post-entry quarantine?

If yes—possible measure: import under special licence/permit and post-entry quarantine—Go to 3.14

Removal of the pest from the consignment by treatment or other phytosanitary procedures

2.30 Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?

If yes—possible measure: specified treatment—Go to 3.15

2.31 Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment? (This question is not relevant for pest plants)

If yes—possible measure: removal of parts of plants from the consignment—Go to 3.16

2.32 Can infestation of the consignment be reliably prevented by handling and packing methods?

If yes—possible measure: specified handling/packing methods—Go to 3.17

Prevention of establishment by limiting the use of the consignment

2.33 Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

If yes—possible measure: import under special licence/permit and specified restrictions—Go to 3.18

Options for the prevention or reduction of infestation in the crop

Prevention of infestation of the commodity

2.34 Can infestation of the commodity be reliably prevented by treatment of the crop?

If yes—possible measure: specified treatment and/or period of treatment—Go to 3.19

2.35 Can infestation of the commodity be reliably prevented by growing resistant cultivars? (This question is not relevant for pest plants)

If yes—possible measure: consignment should be composed of specified cultivars—Go to 3.20

2.36 Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water...)?

If yes—possible measure: specified growing conditions—Go to 3.21

2.37 Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?

If yes—possible measure: specified age of plant, growth stage or time of year of harvest—Go to 3.22

2.38 Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

If yes—possible measure: certification scheme—Go to 3.23

Establishment and maintenance of pest freedom of a crop, place of production or area

Note that in this set of questions pest spread capacity is considered without prejudice to any other measure that can be recommended. For some pests, growing the plant in specific conditions can prevent natural spread (e.g. production in a glasshouse may provide protection against pest with high capacity for natural spread). These measures should have been identified in question 3.20.

In answering questions 3.23 to 3.26 refer to the answer to question 1.33 of the risk assessment section.

2.39 Has the pest a very low capacity for natural spread?

If yes—possible measure: pest freedom of the crop, or pest-free place of production, or pest-free place of production and appropriate buffer zone, or pest-free area—Go to 3.27
If no—Go to 3.24

2.40 Has the pest a low to medium capacity for natural spread?

If yes—possible measure: pest-free place of production, or pest-free place of production and appropriate buffer zone, or pest-free area—Go to 3.27
If no—Go to 3.25

2.41 Has the pest a medium capacity for natural spread?

If yes—possible measure: pest-free place of production and appropriate buffer zone, or pest-free area—Go to 3.27
If no—Go to 3.26

2.42 The pest has a medium to high capacity for natural spread

Possible measure: pest-free area—Go to 3.27

2.43 Can pest freedom of the crop, place of production or an area be reliably guaranteed?

If no—possible measures identified in questions 3.23-3.26 would not be suitable—Go to 3.28

Consideration of other possible measures

2.44 Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

If no—possible measures: internal surveillance and/or eradication campaign—Go to 3.29

Evaluation of risk management options

This section evaluates the risk management options selected and considers in particular their cost effectiveness and potential impact on international trade.

2.45 Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

If yes—Go to 3.30
If no—Go to 3.31

2.46 Taking each of the measures identified individually, does any measure on its own reduce the risk to an acceptable level?

If yes—Go to 3.33
If no—Go to 3.31

2.47 For those measures that do not reduce the risk to an acceptable level, can two or more measures be combined to reduce the risk to an acceptable level?

If yes—Go to 3.33
If no—Go to 3.32

2.48 If the only measures available reduce the risk but not down to an acceptable level, such measures may still be applied, as they may at least delay the introduction or spread of the pest. In this case, a combination of phytosanitary measures at or before export and internal measures (see question 3.29) should be considered.

Go to 3.33

2.49 Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

Go to 3.34

2.50 Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Go to 3.35

2.51 Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

If yes for pathway-initiated analysis—Go to 3.38
If yes for pest-initiated analysis—Go to 3.37
If no—Go to 3.36

2.52 Envisage prohibiting the pathway.

For pathway-initiated analysis—Go to 3.42 (or 3.38)
For pest-initiated analysis—Go to 3.37

2.53 Have all major pathways been analyzed (for a pest-initiated analysis)?

If yes—Go to 3.40
If no—Go to 3.1 to analyse the next major pathway

2.54 Have all the pests been analyzed (for a pathway-initiated analysis)?

If yes—Go to 3.39
If no—Go to 3.1 to analyse the next pest

2.55 For a pathway-initiated analysis, compare the measures appropriate for all the pests identified for the pathway that would qualify as quarantine pests, and select only those that provide phytosanitary security against all the pests.

Go to 3.41

2.56 Consider the relative importance of the pathways identified in the conclusion to the entry section of the pest risk assessment

Go to 3.41

2.57 All the measures or combination of measures identified as being appropriate for each pathway or for the commodity can be considered for inclusion in phytosanitary regulations in order to offer a choice of different measures to trading partners.

Go to 3.42

2.58 In addition to the measure(s) selected to be applied by the exporting country, a phytosanitary certificate (PC) may be required for certain commodities. The PC is an attestation by the exporting country that the requirements of the importing country have been fulfilled. In certain circumstances, an additional declaration on the PC may be needed (see EPPO Standard PM 1/1(2): Use of phytosanitary certificates).

Go to 3.43

2.59 If there are no measures that reduce the risk for a pathway, or if the only effective measures unduly interfere with international trade (e.g. prohibition), are not cost-effective or have undesirable social or environmental consequences, the conclusion of the pest risk management stage may be that introduction cannot be prevented.

Conclusion of Pest Risk Management.

Summarize the conclusions of the Pest Risk Management stage. List all potential management options and indicate their effectiveness. Uncertainties should be identified.

Monitoring and review

Performance of measure(s) should be monitored to ensure that the aim is being achieved. This is often carried out by inspection of the commodity on arrival, noting any detection in consignments or any entries of the pest to the PRA area.

Information supporting the pest risk analyses should be reviewed periodically by the pest risk analysts to ensure that any new information that becomes available does not invalidate the decision taken. The analysts should in particular be aware that new international trade may be initiated, host plants may newly be grown in the PRA area which were not grown at the time the PRA was conducted, climate may change, new policy decisions may influence the result of a previous analysis.

APPENDIX 3—EXAMPLE OF A PEST FACT SHEET

Pest Fact Sheet for: *Ditula angustiorana* (Haworth) Lepidoptera: Tortricidae (Adapted from Meijerman and Ulenberg 2000; CABI 2005).

Current Scientific Name

Ditula angustiorana (Haworth), (Brown 2005).

Other Scientific Names

Batodes angustiorana (Haworth) (Meijerman and Ulenberg 2000; Brown 2005).
Tortrix angustiorana Haworth (Razowski 2002; Brown 2005);
Tortrix rotundana Haworth (Razowski 2002; Brown 2005);
Paedisca dumeriliana Duponchel (Razowski 2002; Brown 2005).

Common Names

English

Red-barred tortrix, fruit tree tortrix, vine tortrix (Zhang 1994).

Notes on Taxonomy and Nomenclature

The species has also often been referred to as *Capua angustiorana* Haw. (Pape 1964). “According to Meijerman and Ulenberg (2000) based on studies by Razowski (1987), *Ditula* must be regarded as a synonym of *Eudemis* (Olethreutinae), and synonymization of *Batodes* with *Ditula* was therefore incorrect. Thus, the current scientific name is *Ditula angustiorana* (Haworth)” (Brown 2005).

Host Range

Ditula angustiorana has a wide host range that includes many economically important plant species.

Azalea (Carter 1984);
Begonia, (Meijerman and Ulenberg 2000);
Buxus, (Meijerman and Ulenberg 2000);
Crataegus, (Meijerman and Ulenberg 2000);
Fagus, (Meijerman and Ulenberg 2000);
Fuchsia, (Meijerman and Ulenberg 2000);
Geranium, (Meijerman and Ulenberg 2000);
Hedera, (Razowski 2002);
Hippophae, (Meijerman and Ulenberg 2000);
Ilex, (Zhang 1994);
Juniperus (Razowski 2002);
Larix, (Zhang 1994);
Laurus, (Razowski 2002);
Lonicera, (Meijerman and Ulenberg 2000);
Malus, (Razowski 2002);
Picea, (Zhang 1994);
Pinus, (Zhang 1994);
Pinus sylvestris L., (Meijerman and Ulenberg 2000);
Prunus (apricot, plum, cherry, damsons; Zhang 1994; Meijerman and Ulenberg 2000);
Pyrus, (Razowski 2002);

Quercus, (Zhang 1994);
Quercus garryana Dougl., Garry oak (Pest Facts Sheet, Government of British Columbia 2006);
Rhododendron, (Zhang 1994);
Rubus, (Meijerman and Ulenberg 2000);
Smilax (Meijerman and Ulenberg 2000);
Taxus (Zhang 1994);
Taxus brevifolia Nutt., Western yew, (Prentice 1966);
Thuja plicata Donn ex D. Don., Western red cedar, (Prentice 1966);
Viscum, (Razowski 2002);
Vitis, (Zhang 1994).

Numerous other tree, shrub and herbaceous plants are also hosts (Razowski 2002).

Distribution List

Asia
Asia Minor (Bradley et al. 1973; Razowski 2002). However, Meijerman and Ulenberg (2000) are doubtful.

Europe (Common throughout Central and Southern Europe, Alford 1984; Parenti 2000).
Belgium,
http://webhost.ua.ac.be/vve/Checklists/Lepidoptera/Tortricidae/Dangustiorana.htm (Accessed 14/06/06); Karsholt and Razowski 1996);
Denmark, (Karsholt and Razowski 1996);
England, (Bradley et al.1973);
Germany, (Parenti 2000);
Ireland, (Bradley et al.1973);
Italy, Sardinia (Karsholt and Razowski 1996);
Luxemburg, (Karsholt and Razowski 1996);
Netherlands, (Sorauer 1953);
Portugal, (Karsholt and Razowski 1996);
Scotland, (Bradley et al.1973);
Spain, (Karsholt and Razowski 1996);
Sweden, (Svensson 1979);
Switzerland, (Karsholt and Razowski 1996).

Africa
North Africa; (Meijerman and Ulenberg 2000).

North America
United States of America,
California, http://bscit.berkeley.edu/eme/calmoth_species_list.html (Accessed 14/06/06), Freeman 1958), (Alameda, Santa Cruz, San Mateo, and Humboldt counties), http://bscit.berkeley.edu/cgi/calmoth_query?stat=BROWSE&query_src=eme_BrowseCalmothNames&where-genus=Ditula (Accessed 14/06/06);
Oregon, unconfirmed (Straby 1966);
Washington, (Lagasa 2003)
Canada,
British Columbia (Freeman 1958; MacKay 1962; Prentice 1966).

DOUBTFUL RECORDS: Northeastern U.S.A., unconfirmed (Lattin 1998);
Dr. J. Brown, Smithsonian Institute Museum, Entomology has no records (*pers. comm*. 2006).

Biology and Ecology

"There is usually one generation a year (Razowski 2002), however, in warmer climates there may be up to 2 or 3 generations (Dickler 1991). Adults usually occur in late June or early July, the males often flying in sunshine (Matthey 1967; Figure 2). Eggs are laid on the upperside of leaves in moderately large batches, 15 to 70 eggs/female (Schwenke 1978; Matthey 1967; Carter 1984). On average, females lay about 50 eggs/mass. The newly emerged larvae feed on the foliage and after the second moult they will also attack the fruits. In autumn, while still small (2nd or possibly 3rd instar), they spin silken hibernacula (cocoons) on buds, spurs or in bark crevices, and then overwinter in this stage until early spring. They then attack buds, young leaves and, later, blossom trusses and fruitlets, often sheltering in spun leaves causing only minor damage. Larvae mine the leaves early on and then chew out holes in the leaves (Pape 1964; Figure 3). The larvae are very active if disturbed. Pupation occurs in May or June in a cocoon spun in a folded leaf, in webbed foliage or amongst dead leaves on the ground (Matthey 1967; Alford, 1984, 1995). Adults live about 9 to 15 days (Matthey 1967). About 10% mortality occurs, caused by parasitoids and another 11% by disease (Matthey 1967). Adults of both sexes fly at night and come to light".

Natural dispersal

Adults disperse locally at night by flight. Larvae may also disperse locally by wind on silken threads.

Movement in trade

Small larvae overwinter in the bracts of buds, and therefore, can easily be transported in plants for planting or other nursery stock (Matthey 1967). *Ditula angustiorana* was intercepted in 1964 on *Rhododendron* plants for planting originating from Oregon, U.S.A. and destined for Quebec, Canada (Straby 1966). The CFIA recently reported an interception of *D. angustiorana* into British Columbia in 2005 in a shipment of *Taxus* spp. nursery plants originating from the Netherlands (D. Parker, pers. comm. OPL-CFIA 2006).

Economic Impact

In Europe, Dickler (1991) lists *D. angustiorana* as a minor pest. This species is reported as an occasional pest in Great Britain and in green-house environments (Carter 1984). Generally, however, this insect species does not reach pest status in continental Europe (Carter 1984). The larvae are rarely sufficiently numerous to cause economic injury to leaves, flowers or developing fruitlets, and grazing of mature fruits, such as apples and pears, is superficial. Grazed fruit may reduce marketability, however, such fruit drops naturally or is culled by hand (J. Garland, pers. comm. PHRA, CFIA 2006). Although *Taxus* is a preferred host, large numbers of egg masses laid on this species resulted in little or negligible damage (Frankenhuyzen and de Jong 1980).

In Canada, Ditula angustiorana is a solitary feeder which has not caused any economic damage since its first discovery about 1924 (i.e., more than 80 years; Powell 1964).

Phytosanitary Risk

Small larvae (2nd or 3rd instar larvae) overwinter in buds, in rolled leaves or on twigs of the host, and may easily be moved with plants for planting or other nursery stock.

Symptoms
Larvae are leafrollers that mine and defoliate leaves, graze on buds or flowers and chew on developing fruit. Damage on fruit is superficial.

Morphology
"Adult: 13-18 mm wingspan; forewing base colour red brown (most apparent as a characteristic semi-elliptical patch on the dorsum) with dark purplish brown and black (males) or brown (females) markings; hindwings dark brown. Veins R4 and R5 in forewing stalked. The head, thorax and abdomen are dark brown. Antennae are simple, filiform (Carter 1984).

Egg: pale yellowish brown, flat and almost circular; laid in a scale-like batch.

Larva: 12-18 mm long; body slender, pale yellowish green to brownish green or greyish green, darker above, with light green pinacula; head greenish yellow or yellowish brown, marked with blackish brown; prothoracic plate yellowish green, light brown or dark brown; anal comb greenish or brownish, with four teeth; thoracic legs green, tipped with blackish brown; spiracles small, the last twice the diameter of others. The thoracic shield is usually yellow, grading to brown laterally (MacKay 1962).

Pupa: 8 mm long; light brown, darker dorsally; cremaster elongate, with eight tightly hooked setae, and dorsal abdominal spines well developed.

Minor variation occurs in the intensity of the colouration and markings".

Detection and Inspection Methods
Inspectors should look for egg masses or small cocoons near terminal buds of host plants or for rolled leaves shaped like small cigars. The larvae and egg masses are cryptic and not easily detected at ports of entry. *Ditula angustiorana* is attracted to the pheromone lure blend, Z11-14Ac or E11-14Ac (Frérot 1985; Cross 1996). The pheromone is available commercially.

Control
Biological Control [See Natural Enemy List, following]. There are probably sufficient biological controls to maintain population levels at or below economic thresholds, including Canada.

Integrated Control
Mechanical control is preferred for leafrollers, such as *Archips xylosteana*, in non-bearing apple orchards in Kyustendil, Bulgaria (Borovinova and Iliyana 2004). Such control, however, may not be necessary given the low level of damage usually encountered with *D. angustiorana*.

Chemical Control
In Europe, spraying parathion, dimethoate or phosphamidon insecticides in May and June has controlled this pest (Pape 1964). Similar pesticide controls for *Cydia pomonella* (Linnaeus) could be effective against *D. angustiorana*. Regularly scheduled sprays with organophosphate or carbamate insecticides provide adequate control for production of fruit for export (Wearing et al. 1991).

Natural Enemy List

Pathogens

Bacillus thuringiensis alesti attacking larvae *Nomuraea rileyi*

Parasitoids

Macrocentris linearis (Nees) (Braconidae: Macrocentrinae) (Matthey 1967);
Apanteles xanthostigma Hal. (Braconidae: Microgastrinae) (Matthey 1967);
Meteorus ?ictericus (Nees) (Braconidae: Euphorinae) (Matthey 1967);
Lypha dubia (Fall.) (Diptera: Tachinidae) (Matthey 1967);
Oedemopsis scabricula (Grav.) (Ichneumonidae) (record from Canada; Meijerman and Ulenberg 2000).

APPENDIX 4—SAMPLE CHECKLISTS FOR PRA

European and Mediterranean plant protection organization (EPPO) check-list of information required for pest risk analysis (PRA).

This check-list contains all the information that should be considered before deciding that a particular organism qualifies to be declared a quarantine pest. The list is intended to be used in conjunction with a stepwise decision-making scheme on pest risk assessment; schemes of this type are being developed, at different levels of complexity, by EPPO and FAO. References should be noted for all items of information. If no information is found under a heading (which will often be the case), indicate this.

Section 1. The organism

1. Name and taxonomic position (including any taxonomic subdivisions, difficulties or confusion: subspecies, pathotypes, *formae speciales*, overlapping species, synonymy)
2. Relationship with known quarantine pests
3. Methods for identification for inspection purposes
4. Methods for detection

Section 2. Biological characteristics of the pest

1. Life cycle:

   (a.) for invertebrates

- rate of development (typical times, or degree days, for successive life-cycle stages; reproduction rate)
- number of generations per year (univoltine, multivoltine, how voltinism is controlled)
- obligate alternation between hosts
- parthenogenetic multiplication
- typical timing of the life cycle in the growing season, and relation to that of the host plant

   (b.) for pathogens

- rate of development, possible number of infection cycles per growing season
- obligate alternation between hosts
- (for fungi) anamorphic spore stages
- (for fungi) occurrence of teleomorph (regular, irregular, rare, unknown)
- typical timing of the life cycle in the growing season and relation to that of host plants

2. Dissemination and dispersal:

   - natural means, speed and range of dissemination
   - agricultural, horticultural or forestry practices affecting rate of natural spread or causing spread directly
   - vectors: occurrence of known natural vectors or related species with vector potential in PRA area

3. Survival of adverse conditions:

   (a.) for invertebrates

   - capability for winter or summer diapause and relevant climatic cues; physiological adaptations for survival of low temperatures, desiccation etc. in or out of diapause

   (b.) for pathogens

   - formation of special long-lived survival stages (e.g. sclerotia)
   - possibilities for survival: in soil, on cultivated hosts, on wild hosts, on obligate alternate hosts, on seeds, on contaminated surfaces, machinery etc. (including longevity and survival time of dormant stages)

4. Adaptability:

   - records of changes in the behaviour of the pest (extension of geographical range; extension of host range; extension to glasshouse hosts)
   - records of special forms or strains of the pest (adapted to different geographical areas; adapted to different hosts; with different damage potential)
   - related species known to be adaptable pests

Section 3. Geographical distribution of the pest

1. Present occurrence in PRA area
2. World distribution (map if possible), by countries and areas within countries or by region or continent (e.g. West Africa) depending on information available, with indication if possible on status of each record (confirmed or not, old or new, pest established or not)
3. Area of origin and history of any spread from area of origin
4. Overlap of world distribution of the pest with that of major hosts

Section 4. Host plants of the pest

1. Host plants reported in areas where the pest now occurs, with indication whether:

   - a major or minor host
   - naturally affected or only under artificial conditions
   - cultivated or wild

For a polyphagous pest, select some important cases.

2. Host plants from the above list growing in PRA area (or related plants likely to be affected); with indication for each whether:
   - grown in open, under protection or both
   - important in whole area, several parts of area, small part of area, not important
   - economic crop, amenity plant (gardens or public spaces), important wild plant in environment, not important
3. Nature of the host range (e.g. polyphagous, mainly on one plant family, specific to one plant species, etc.).

Section 5. Potential of the pest for establishment in PRA area

1. Ecoclimatic zones of the pest's distribution comparable with those found outdoors in PRA area by reference to an EPPO-recommended ecoclimatic map.
2. Records of the pest in protected cultivation, with indication whether in areas where the pest also occurs outdoors.
3. Climatic conditions (e.g. temperature, rainfall, RH, day length) which have been shown to be conducive or suppressive to survival, development, reproduction and dispersal of the pest (where such conditions are not explicitly known, infer as far as possible what elements in the pest's geographical distribution gives clues of these conditions).
4. Data on climatic conditions in PRA area for host plants outdoors and in protected cultivation as appropriate.

Section 6. Control of the pest

1. Control measures in regular use in any part of the pest's geographical range, particularly in areas where the climate is comparable to that of PRA area:
   - current control measures using plant protection products, together with an estimate of their efficacy
   - evidence of resistance to plant protection products
   - biological control agents and their effects (natural; employed for control; occurring in PRA area)
   - cultural or other control measures not using plant protection products
   - special control problems and cultural (or storage) practices that favour or suppress the pest
   - possibilities for production of certified or classified pest-free material
   - possibilities for treatment of consignments against the pest
2. Records of eradication (successful or attempted):
   - methods used
   - features of the biology of the pest which make it amenable to eradication

Section 7. Transport of the pest

1. Method of natural spread elsewhere in the world (cf. 2.2).

2. Pattern of international trade in the major host plants of the pest:

   - main exporting countries
   - main importing countries
   - form of transport
   - state in which transported (plant in full growth, dormant plant, micropropagated plant, etc.)

3. Records of interceptions of the pest (or related species) on host plants in international trade.

4. Records of the movement of the pest (or related species) between countries other than on host plants:

   - with travellers
   - on non-plant products
   - on non-host plants
   - on vehicles
   - on aircraft, etc.

5. Specific pathways for the pest from infested host plants in its country of origin to susceptible host plants in PRA area. Records of actual movement along such pathways.

Section 8. Economic impact of the pest

1. Type of damage:

   - whole plant, part of plant or plant product
   - recorded damage thresholds
   - capacity to vector other pests

2. Recorded economic impact on each major host plant (including, if possible, variation in different areas and years): major pest, minor pest or insignificant.

3. Estimated effect of the presence of the pest on exported commodities on:

   - countries to which they can no longer be exported
   - conditions under which they can be exported
   - market value

4. Effect of control measures used against the pest on the control of other pests (particularly interaction with existing biological or integrated control measures).

5. Any undesirable side-effects (e.g. on environment) of use of plant protection products to control the pest.

6. Costs of control, with comparison if possible between the costs arising if pest becomes established and the estimated costs of exclusion (i.e. cost-effectiveness analysis).

APPENDIX 5—FURTHER READING AND RESOURCES

Search Tools

General Search Engines:

- Google (http://www.google.com/)
- AllSearchEngines (http://www.allsearchengines.com/): A useful collection of search engine websites

Literature Searches:

- Agricola (http://agricola.nal.usda.gov/): AGRICOLA (AGRICultural OnLine Access) is a bibliographic database of citations to the agricultural literature created by the U.S. National Agricultural Library.
- Caribbean Journal of Science (http://caribjsci.org/): The CJS publishes articles, research notes, and book reviews pertinent to the Caribbean region. Traditional emphasis is on botany, zoology, ecology, archaeology, geology, and paleontology. E-downloads from the last 5 years free, now 3 issues per year.
- E-Journals.org (http://www.e-journals.org/): World-wide web virtual library website providing links to numerous scientific (and other) journals. Also provides lists of journals with free internet access.
- Pubmed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi): A service of the U.S. National Library of Medicine, provides access to over 11 million MEDLINE citations back to the mid-1960's and additional life science journals. PubMed includes links to many sites providing full text articles and other related resources.
- Science Direct (http://www.sciencedirect.com/): A service which provides almost 2.5 million journal articles online, FOR A FEE.
- Scirus (http://www.scirus.com/): Scirus, launched by Elsevier Science, is a comprehensive science-specific search engine designed to chart and pinpoint data, locate university sites and find reports and articles.
- Entomological journals on the web (http://www.medbioworld.com/bio/journals/insect.html): E-journals covering entomological topics also has journal lists for arachnology, acarology, and nematology. Includes many free journals.

Early Warning, Pest Alerts and Archives:

- Agriculture Network Information Center (AGNIC), Plant Diseases Announcements (http://www.agnic.org/pmp/)
- Center for Invasive Plant Management (http://www.weedcenter.org/)

- Cooperative Agriculture Pest Survey program (CAPS) Pest Alerts, Authorization Required (http://ceris.purdue.edu/caps/pests/pest-alerts/index.html)
- EPPO Pest Alerts (http://www.eppo.org/QUARANTINE/Alert_List/alert_list.htm): The pests on the Alert List are selected by the European Plant Protection Organization Secretariat, mainly from the literature but also from suggestions of NPPOs of member countries.
- Invasive Species Emerging Issues (http://www.invasivespecies.gov/new/emerge.shtml)
- NAPPO Phytosanitary Alert System (http://www.pestalert.org/): North American Plant Protection Organization archived pest alerts, news stories and official reports of emerging pest situations threatening North America.
- National Agricultural Pest Information System (NAPIS) (http://ceris.purdue.edu/napis/)
- National Plant Board (NPB) Plant Pest Issues (http://nationalplantboard.org/issues.html)
- New Disease Reports (http://www.bspp.org.uk/ndr/): From the British Society of Plant Pathology, a rapid e-publication format for new reports encompassing fungi, bacteria, phytoplasmas, viruses and viroids.
- Pestnet (http://www.pestnet.org/)
- ProMed (http://www.fas.org/promed/): ProMed is the Federation of American Scientists (FAS) policy initiative calling for global monitoring of emerging diseases. ProMed mail is available online and by subscription, and the mail archives provide useful historical pathogen emergence data.
- The Nature Conservancy (TNC) Invasives on the Web (http://tncweeds.ucdavis.edu/index.html)
- University of Florida Pest Alert (http://pestalert.ifas.ufl.edu/)

General Resources:

General Resources - Online:

- APHIS Raleigh Plant Protection Center: (http://www.invasivespecies.org/)
- APHIS Regulated Pest List (PPQ website) (http://www.aphis.usda.gov/ppq/regpestlist/)
- Australian Quarantine and Inspection Service (http://www.daff.gov.au/aqis)
- Biosecurity New Zealand Risk Analysis Procedures Version 1, Biosecurity New Zealand, 2006. 103 pp (http://www.biosecurity.govt.nz/files/pests-diseases/surveillance-review/risk-analysis-procedures.pdf)
- Bureau of Land Management Weeds Website: (http://www.blm.gov/weeds/) (search by state)
- CAB International (CABI) Bioscience (http://www.cabi.org/)
- CABI Crop Protection Compendium (http://www.cabi.org/compendia/cpc/index.htm)

- California Agriculture Magazine (http://calag.ucop.edu/)
- California Department of Food and Agriculture (CDFA) (http://www.cdfa.ca.gov/phpps/pdep/)
- California Exotic Pest Plant Council (http://www.caleppc.org/)
- Canadian Forest Service (http://www.nrcan-rncan.gc.ca/cfs-scf/index_e.html)
- CFIA Plant Pest Information (http://www.inspection.gc.ca/english/sci/surv/pesrave.shtml): The Canadian Food Inspection Agency's plant pest fact sheets.
- COSAVE (http://www.cosave.org): The South Cone Plant Protection Committee (IPPC Regional Plant Protection Organization; Argentina, Brazil, Chile, Paraguay, Uruguay) includes frames for quarantine pests and data sheets.
- Crop Knowledge Master (http://www.extento.hawaii.edu/kbase/crop/crop.htm): University of Hawaii Integrated Pest Management website
- Department of Agriculture- Western Australia (http://www.agric.wa.gov.au/)
- Ecoport (http://www.ecoport.org/ep): A public service partnership between UFL, FAO, and the Smithsonian Institution. A useful biodiversity index that is gathering content.
- Featured Creatures (http://creatures.ifas.ufl.edu/): This site provides in-depth profiles of insects, mites, nematodes, and other organisms that are of interest to Florida's residents. Jointly sponsored by UFL and FL DOACS.
- FL DOACS (http://www.doacs.state.fl.us/pi/enpp/triology.html): The Florida Dept of Agriculture and Consumer Services has indexed circulars (data sheets) compiled since the 1960's. Scope includes botany, nematology, entomology, and plant pathology. They are in the process of scanning the archives, and many are available as pdf files. Files not available electronically can be requested online.
- Florida Exotic Pest Plant Council (http://www.fleppc.org/)
- Great Lakes Information Network (http://www.great-lakes.net/)
- HYPPZ (http://www.inra.fr/Internet/Produits/HYPPZ/pests.htm): French Institut National de la Recherche Agonomique Pest Data Sheets.
- International Association for the Plant Protection Sciences (http://www.plantprotection.org/)
- International Survey of Herbicide Resistant Weeds (http://www.weedscience.org/in.asp)
- Invasive Alien Plant Species of Virginia (http://www.dcr.state.va.us/dnh/invproj.htm)
- IPPC 2006. International Plant Health Risk Analysis Workshop 24 - 28 October 2005, Niagara Falls, Canada (https://www.ippc.int)
- IPPC Procedural Manual, 2006. Website: www.ippc.int/id/159891?language=en
- Israel Journal of Plant Protection Sciences (http://www.phytoparasitica.org)
- Ministry of Agriculture and Forestry, New Zealand (http://www.maf.govt.nz/MAFnet/index.htm)
- NAPIS (http://ceris.purdue.edu/napis/index.html): The National Agricultural Pest Information System (U.S.), homepage for the database of the Cooperative

Agriculture Pest Survey (CAPS) Program. Database access requires a password, but useful links exist.

- National Association of State Departments of Agriculture (http://www.nasda-hq.org/)
- New Pest Advisory Group (NPAG) (http://www.cphst.org/NPAG/)
- North American Exotic Forest Pest Information System (http://www.exoticforestpests.org/): identifies exotic insects, mites and pathogens with potential to cause significant damage to North American forest resources. Sponsored by the North American Forest Commission.
- PPQ Intranet, Need Access (http://inside.aphis.usda.gov/ppq/)
- PPQ Plant Protection and Management Programs (PDMP) (http://www.aphis.usda.gov/plant_health/plant_pest_info/biosecurity/index.shtml)
- Queensland Government (http://www.nrm.qld.gov.au/)
- RiskWorld (http://www.riskworld.com/): Daily risk analysis in the news covering various areas, includes training opportunities.
- ScaleNet (http://www.sel.barc.usda.gov/scalenet/scalenet.htm)
- Secretariat of the Pacific Community Plant Protection Service (http://www.spc.int/pps/Default.htm)
- Southeast Exotic Pest Plant Council (http://www.se-eppc.org/)
- Systematic Botany and Mycology Laboratory (http://www.ars.usda.gov/main/site_main.htm?modecode=12-75-39-00)
- Systematic Entomology Laboratory (http://www.sel.barc.usda.gov/selhome/selhome.htm)
- Texas Department of Agriculture-Alerts: (http://www.agr.state.tx.us/agr/program_render/0,1987,1848_5411_0_0,00.html?channelId=5411)
- Texas Parks and Wildlife (http://www.tpwd.state.tx.us/)
- The World Conservation Union Invasive Species Specialist Group (http://www.issg.org/)
- U.S. Department of State (http://www.state.gov/)
- United States Department of Agriculture (USDA) Forest Service (http://www.fs.fed.us/)
- United States Fish and Wildlife Services (http://www.fws.gov/)
- United States Geological Survey (USGS) Nonindigenous Aquatic Species (NAS) (http://nas.er.usgs.gov/)
- USDA Crop Profiles (http://cipm.ncsu.edu/cropprofiles/): This site is part of the effort by the USDA Pest Management Centers to provide information critical to pest management needs in the United States; subject focus is pesticide oriented
- USDA Identifiers Website, Need Access (http://inside.aphis.usda.gov/ppq/identifiers/INDEX.HTM)
- USDA PRA's (http://www.aphis.usda.gov/ppq/pra/): Provides guidelines, status of requests, and completed pest risk assessments.

- USDA/APHIS/PPQ Manuals Unit (http://www.aphis.usda.gov/ppq/manuals/online_manuals.html)
- USDA-ARS Germplasm Resources Information Network (GRIN) (http://www.ars-grin.gov/npgs/tax/)
- Wisconsin Department of Agriculture, Trade, and Consumer Protection (http://datcp.state.wi.us/)
- World Trade Organization: www.wto.org
- WTO on-line training course: www.wto.org/English/res_e/d_learn_e/d_learn_e.htm#sps
- WTO-SPS Agreement: www.wto.org/english/tratop_e/sps_e/sps_e.htm

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Organisms: Arthropods

Organisms: Arthropods - Online

- Bugwood Network (http://www.bugwood.caes.uga.edu/entomology.html)
- Catalog of the Lepidoptera of the French Antilles (http://www.inra.fr/Internet/Produits/PAPILLON/indexeng.htm): This catalogue presents all species of macrolepidoptera found in Martinique, Guadeloupe and their dependencies. It is mainly based on collections made by J. le Duchat d'Aubigny and B. Lalanne-Cassou during their six years stay in Guadeloupe. Hosted by the French Institut National de la Recherche Agonomique.
- CBIF. 2003. Butterflies of Canada. Canadian Biodiversity Information Facility; http://www.cbif.gc.ca/spp_pages/butterflies/index_e.php
- Cerambycidae (http://www.uochb.cas.cz/~natur/cerambyx/cerambyx.htm): Contains a photogallery of over 400 West Palaearctic species, with details on the biology and host plants of many. Includes useful literature citations.
- Coleoptera (http://www.coleoptera.org/): It's not clear who runs this website, but a lot of useful Coleopteran information is accessible here, including links to numerous databases.
- Electronic Resources on Coleoptera (http://www.chebucto.ns.ca/Environment/NHR/coleoptera.html)
- Entomological Society of America (http://www.entsoc.org)
- Entomology Circulars (http://www.doacs.state.fl.us/pi/enpp/ento/entocirc-no.htm): Florida Dept. of Agriculture and Consumer Services
- Entomology Index of Internet Resources (http://www.ent.iastate.edu/List/): A very comprehensive list of entomological links from Iowa State University. The database link is particularly useful (http://www.ent.iastate.edu/List/databases.html).
- Entomotropica (http://www.entomotropica.org/presentacion.php?LNG=2): Free e-journal with particular relevance to the Caribbean. Three issues per year.
- Florida Entomologist (http://www.fcla.edu/FlaEnt/)
- Florida Entomologist (http://www.flaentsoc.org/fe.html): Free e-journal with particular relevance to the Caribbean. Four issues per year.
- Hosts (http://www.nhm.ac.uk/entomology/hostplants/): A database of the host plants of the world's Lepidoptera, hosted by the Natural History Museum, UK. This site offers a synoptic data set drawn from about 180,000 records comprising taxonomically "cleaned" host plant data for about 22,000 Lepidoptera species drawn from about 1600 published and manuscript sources. It is not (and cannot be) exhaustive, but it is probably the best and most comprehensive compilation of host plant data available.
- HYPP Zoology (HYPPZ) Home Page (http://www.inra.fr/Internet/Produits/HYPPZ/pests.htm)
- Index of Pages of Butterflies and Moths of Australia (http://www-staff.it.uts.edu.au/~don/larvae/larvae.html)

- Index of the Species of Florida Lepidoptera (http://fsca-dpi.org/Lepidoptera/FloridaSpeciesIndex.htm): From the Museum of Entomology, Florida State Collection of Arthropods.
- Insect Pests of Micronesia (http://www.crees.org/plantprotection/AubWeb/bugweb/bugroot.htm)
- Iowa State University Entomology Index of Internet Resources (http://www.ent.iastate.edu/list/)
- Lepidopteran Web Links (http://facweb.furman.edu/~snyderjohn/lepsoc/lepidop.htm)
- Nomina Insecta Nearctica (http://www.nearctica.com/nomina/main.htm): A checklist of the insects of North America. Nomina Insecta Nearctica is a complete synonymical checklist of the approximately 90,000 species of insects of North America north of Mexico published by Entomological Information Services in 1996 and 1997 in four volumes and a CD-ROM. Caveats: the web version omits synonyms; doesn't distinguish between presence in CA, US, or MX; and doesn't include references.
- North American Non-indigenous Arthropod Database (NANIAD) (http://www.invasivespecies.org/NANIAD.html)
- Pest Fruit Flies of the World (http://www.sel.barc.usda.gov/Diptera/tephriti/tephriti.htm): Descriptions, Illustrations, Identification, and Information Retrieval.
- ScaleNet (http://www.sel.barc.usda.gov/scalenet/scalenet.htm): A scale insect (Coccoidea) database which provides comprehensive information on the scale insects of the world, including queriable information on their classification, nomenclatural history, distribution, hosts, and literature. Cooperatively hosted by governmental agricultural research agencies in US, CA, and IL.
- Tephritidae (Fruit Flies) (http://www.sel.barc.usda.gov/Diptera/tephriti/tephriti.htm)
- The Beetles of the Virgin Islands (http://IRIS.biosci.ohio-state.edu:80/vi_beetles/): The V.I. beetle fauna project was started in 1978 by Michael A. Ivie of Montana State University, now includes many taxonomic and collecting cooperators. Currently contains 489 species (34,698 specimens), and can be queried by island, family, or specimen.
- University of Florida and FDOACS Featured Creatures (http://creatures.ifas.ufl.edu/)
- University of Florida Woodybug (http://woodypest.ifas.ufl.edu/)

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Organisms: Pathogens (bacteria, viruses, fungi, etc) - Online

- All the Virology on the WWW (http://www.tulane.edu/~dmsander/garryfavweb.html)
- Berkley Xylella fastidiosa Web Site (http://www.cnr.berkeley.edu/xylella/index.html)
- Common Names of Plant Diseases (http://www.apsnet.org/online/common/) from the American Phytopathological Society website
- Institute for Plant Diseases Plant Pathology Internet Guide Book (http://www.pk.uni-bonn.de/ppigb/ppigb.htm)
- List of Widely Prevalent Plant Pathogenic Fungi (http://www.aphis.usda.gov/ppq/permits/fungibyfungus.pdf): from the US, a pdf file from APHIS, 2001.
- Plant Virus Server/Information (http://www.virology.net/garryfavwebplant.html): Hotlinks to numerous plant virus resources.
- Plant Viruses Online (http://image.fs.uidaho.edu/vide/): Excellent database from the University of Idaho covering multiple plant virus aspects.
- Soybean Disease Atlas (http://cipm.ncsu.edu/ent/SSDW/soyatlas.htm): From the Southern Soybean Disease Workers (SSDW), an organization involved with soybean production and research in the southern U.S.
- The American Phytopathological Society (APS): Plant Pathology/Disease Online (http://www.apsnet.org/)
- The Plant Pathology Internet Guidebook (http://www.pk.uni-bonn.de/ppigb/ppigb.htm): This multi-disciplinary German website is a subject oriented internet resource guide for plant pathology, applied entomology, and all related fields.
- University of California Cooperative Extension (UCCE) in Marin County Sudden Oak Death (http://nature.berkeley.edu/comtf/)
- USDA Systematic Botany and Mycology Lab (http://www.ars.usda.gov/main/site_main.htm?modecode=12-75-39-00): includes vascular plant and fungal databases
- Viruses of Plants (http://image.fs.uidaho.edu/vide/refs.htm#authors): Descriptions and Lists from the VIDE Database, CAB International

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Organisms: Botany

- A Global Compendium of Weeds (http://www.hear.org/gcw/): A collaborative website from Agriculture Western Australia and USGS' Hawaii Ecosystems at Risk (HEAR) project. It contains references to approximately 20,000 taxa of plants, citing information about "weedy" characteristics of each, based on information in nearly 300 references.
- Agricultural Research Service (ARS) (http://www.ars.usda.gov/)
- Agriculture Research Service (ARS) Exotic and Invasive Weeds Research Unit (http://www.nps.gov/plants/alien/list/a.htm)

- APHIS Federal Noxious Weed List (http://www.aphis.usda.gov/ppq/permits/fnwsbycat-e.PDF)
- Aquatic Plants (Life of Amazonia, Plants) (http://www.amazonian-fish.co.uk/)
- ARS Magazine (http://www.ars.usda.gov/is/AR/)
- Atlas of Florida Vascular Plants online Database (http://www.plantatlas.usf.edu)
- BONAP (http://www.bonap.org/): Biota Of North America Project (BONAP) includes data for all vascular plants and vertebrate species (native, naturalized, and adventive) of North America, north of Mexico.
- Center for Aquatic and Invasive Plants: (http://plants.ifas.ufl.edu/)
- Center for Invasive Plant Management (CIPM) (http://www.weedcenter.org/index.html)
- Croplife America (http://www.croplifeamerica.org/)
- CropMAP (http://www.hort.purdue.edu/newcrop/cropmap/): U.S. crop distributions and hardiness zones by county.
- Database of IPM Resources (DIR) (http://www.ippc.orst.edu/cicp/gateway/weed.htm)
- Flora Europaea (http://rbg-web2.rbge.org.uk/FE/fe.html): From the Royal Botanic Garden in Edinburgh, the flora of Europe as extracted from the digital version of the Flora Europaea.
- FloraBase (http://florabase.calm.wa.gov.au/): Information on the flora of Western Australia
- Food and Agriculture Organization of the United Nations (http://www.fao.org/)
- Fundecitrus- Fund for Citrus Plant Protection (http://www.fundecitrus.com.br/)
- GRIN Taxonomy (http://www.ars-grin.gov/cgi-bin/npgs/html/index.pl): USDA Germplasm Resources Information Network (GRIN) taxonomic data provide the structure and nomenclature for the accessions of the National Plant Germplasm System (NPGS). Many plants (37,000 taxa, 14,000 genera) are included in GRIN taxonomy, especially economic plants.
- HEAR, a Global Compendium of Weeds and the Hawaii/Pacific Islands Ecosystems at Risk Websites (http://www.hear.org/index.html; http://www.hear.org/pier/index.html)
- Internet Directory for Botany (http://www.botany.net/IDB/): A compendium for plant related websites, it comes highly recommended.
- Invaders Database System (http://invader.dbs.umt.edu/)
- Missouri Botanical Garden (http://www.mobot.org/)
- National Agricultural Statistics Service (http://www.nass.usda.gov/index.asp)
- NewCROP Homepage (http://newcrop.hort.purdue.edu/newcrop/default.html)
- North Carolina Botanical Garden (http://www.ncbg.unc.edu/)
- North Carolina State University (NCSU) Department of Botany Herbarium (http://www.cals.ncsu.edu/botany/ncsc/)
- Plant Conservation Alliance's (PCA) Alien Plant Working Group (APWG) Alien Plant Invaders of Natural Areas (http://www.nps.gov/plants/alien/list/a.htm)

- Plant Protection and Quarantine (PPQ) Federal Noxious Weed Program (http://www.aphis.usda.gov/ppq/weeds/nwpolicy2001.html)
- Plants Database (http://plants.usda.gov/): The PLANTS Database (USDA) is a single source of standardized information about plants, focusing on vascular plants, mosses, liverworts, hornworts, and lichens of the U.S. and its territories. The database includes names, checklists, automated tools, identification information, species abstracts, distributional data, crop information, plant symbols, plant growth data, plant materials information, plant links, references, and other plant information.
- Radcliffe's IPM World Textbook (http://ipmworld.umn.edu/)
- Soybean Disease Atlas (http://cipm.ncsu.edu/ent/SSDW/soyatlas.htm)
- The National Agricultural Library (http://www.nal.usda.gov/)
- The National Center for Food and Agricultural Policy (NCFAP) (http://pestdata.ncsu.edu/ncfap/search.cfm)
- The New York Botanical Garden Vascular Plant Types Database (http://www.nybg.org/bsci/hcol/vasc/)
- Tropical Fruit Index (http://www.proscitech.com.au/trop/link.htm)
- U.S. Federal Noxious Weeds (http://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/index.shtml): USDA's published list of federally regulated (quarantine) weeds. Other related links are also available.
- University of Minnesota Plant Information Online, Password required (http://plantinfo.umn.edu/arboretum/default.asp)
- US Army Corps of Engineers Weed Database (http://www.saj.usace.army.mil/conops/apc/newtt/cat1maps/database.htm)
- USDA Economic Research Service (ERS)-State Fact Sheets (http://www.ers.usda.gov/statefacts/)
- USDA HomePage: (http://www.usda.gov/news/pubs/fbook98/content.htm)
- USDA Systematic Botany and Mycology Lab (http://www.ars.usda.gov/main/site_main.htm?modecode=12-75-39-00): includes vascular plant and fungal databases
- Weed Science Society of America (http://www.wssa.net/)
- Weeds Gone Wild (http://www.nps.gov/plants/alien/)

Organisms: Molluscs

<u>Organisms: Molluscs – Online</u>

- Bishop Museum (http://www.bishopmuseum.org/research/natsci/mala/): Contains Hawaiian checklists.
- The Malacological Society of London (http://www.malacsoc.org.uk/): Various Molluscan information.

- Malacology Collection Database (http://www.flmnh.ufl.edu/databases/mala/intro.htm): The Florida Museum of Natural History houses the major malacology collection in the southeastern USA. Presently the collection contains about 340,000 specimen-lots.
- Michigan State University Snail Laboratory (http://www.msu.edu/~atkinso9/)
- Molluscan Pictures (http://www.molluscan.com/)
- Giant African Land Snail Website (http://www.geocities.com/Heartland/Valley/6210/)
- American Malacological Society (http://erato.acnatsci.org/ams/)

<u>Organisms: Molluscs – Print</u>

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Barker, G.M. (ed.). 2002. Molluscs as Crop Pests. Wallingford, U.K.: CABI Publ.

Bishop Museum. Hawaiian Alien Snail Database. Honolulu: B.P. Bishop Museum; http://hbs.bishopmuseum.org/aliensnailsearch.html

Organisms: Nematodes

<u>Organisms: Nematodes – Online</u>

- Accueil Laboratory of Nematology (http://www.rennes.inra.fr/)
- Insect Parasitic Nematodes (http://www2.oardc.ohio-state.edu/nematodes/)
- Nematode Common Names (http://www.barc.usda.gov/psi/nem/common.htm): USDA database of common and scientific names of nematodes.
- ONTA (http://onta.ifas.ufl.edu/index.html): Organization of Nematologists of Tropical America.
- Pest List Project (http://nematode.unl.edu/pesttables.htm): The Society of Nematologists list of the top pest threats to North America, with very good data sheets.
- Phytoparasitic Nematodes Reported from Florida (http://www.doacs.state.fl.us/pi/enpp/nema/images/phyotnema.pdf): a pdf file from December 2002.
- Plant and Insect Parasitic Nematodes (http://nematode.unl.edu/): University of Nebraska- Lincoln website on nematodes.
- University of Nebraska-Lincoln- Nematodes of Quarantinable Concern (http://nematode.unl.edu/quaranem.htm)
- USDA Nematology Lab (http://www.barc.usda.gov/psi/nem/home-pg.html): Useful links, collection and database, and other nematological information.
- USDA Nematology Lab Home Page (http://www.barc.usda.gov/psi/nem/home-pg.html)

Organisms: Nematodes – Print

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USDA Plant Hardiness Zone Maps

- Africa: http://www.geocities.com/westcornersville/africazones.gif
- Australia: http://www.anbg.gov.au/hort.research/zones.html
- China: http://www.backyardgardener.com/zone/china.html
- Europe: http://www.backyardgardener.com/zone/europe1zone.html
- North America: http://www.usna.usda.gov/Hardzone/ushzmap.html
- South America: http://www.geocities.com/westcornersville/sazones.gif
- Turkey/Black Sea region: http://www.geocities.com/westcornersville/turzones.gif
- Ukraine: http://www.ars.usda.gov/Main/docs.htm?docid=9815&page=3

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