Chapter 7
The Biosecurity Continuum and Trade: Tools for Post-border Biosecurity

Shashi Sharma, Simon McKirdy, and Fiona Macbeth

7.1 Introduction

The increase in rapid transport systems and movement of people and goods, accompanied by climate change has enhanced the potential for pests to disperse to new regions, find new vectors, new hosts, new environments, and new opportunities to evolve into damaging species and strains (Sharma 2012). In this era of globalisation, nations are perpetually exposed to the high likelihood of invasion by exotic pests unless strict biosecurity risk management measures are implemented across the biosecurity continuum of pre-border, border and post-border.

About 70,000 pest species damage agricultural crops worldwide (Pimentel 2009). The primary function of National Plant Protection Organisations (NPPOs) in every country is to prevent introduction, establishment and spread of exotic pests, minimise spread of endemic pests and provide information to other countries about the status of different pests in the country. The NPPO provides evidence that a pest is absent from a defined area, region or country. This information is required to claim, gain and maintain access to export markets.

Options for managing exotic pest risks pre-border and at the border include quarantine, treatments, inspection to a range of other phytosanitary measures. However, despite implementation of biosecurity risk management measures pre-border and at the border, some pests manage to invade and establish in new regions. This includes introduction of pest species and strains that are recognised by

S. Sharma
Centre for Biosecurity and Food Security, Murdoch University, 90 South Street, Murdoch, WA 6150, Australia
e-mail: s.sharma@murdoch.edu.au

S. McKirdy (✉)
Chevron Australia, QV1 Building, 250 St Georges Tce, Perth, WA 6000, Australia
e-mail: SMcKirdy@chevron.com

F. Macbeth
Blackwood and Kemp Pty Ltd, Canberra, ACT 2611, Australia

G. Gordh and S. McKirdy (eds.), *The Handbook of Plant Biosecurity*, DOI 10.1007/978-94-007-7365-3_7,

biosecurity agencies as significant threats to the plant sector, the community, the economy and the environment. The old saying "an ounce of prevention is worth a pound of cure" holds true for biosecurity. Preventing introduction[1] (i.e. the entry and establishment of a new or exotic pest) is more efficient and effective than attempting to "cure" a pest problem post border after a pest has established.

Post-border biosecurity is an integral component of the biosecurity continuum. It keeps a vigilant eye on any new biological threat and utilises best practice pest monitoring procedures and tools for early detection of new or exotic pests to achieve cost effective eradication, containment or control outcomes. It includes the use of sub-national boundaries to monitor and restrict the movement of biosecurity risk materials, surveillance and monitoring activities for pest detection and maintenance of pest free areas, and incursion response planning. Monitoring and surveillance for pest incursions, pest spread and establishment in new regions are some of the key activities of post-border biosecurity programmes (McKirdy et al. in press).

Post-border biosecurity actions are vital to claim pest freedom status for a region or country. They are necessary to demonstrate area freedom in order to meet trading partner requirements, as well as to demonstrate successful pest eradication.

Pest surveillance programmes include targeted active surveillance, generally undertaken by pest specialists, and passive surveillance often relying on growers and the general community to report any suspect pest to the relevant biosecurity institutions. The efficiency of passive surveillance depends on the awareness and interest of growers and general public in reporting any unusual sightings of pests and their symptoms. Successful post-border containment and eradication initiatives can be difficult and careful planning and preparedness is required.

This chapter discusses various post-border biosecurity tools that enhance preparedness of the NPPO and assist in responding in a timely manner to pest incursions as well as maintaining pest area freedoms. The tools ranging from standards of the International Plant Protection Convention (IPPC) to local communication are presented in different sections that correspond to various activities in post-border biosecurity.

7.2 Standards of the International Plant Protection Convention

The IPPC is an international agreement on plant health with 178 current signatories.[1] It aims to protect cultivated and wild plants by preventing the introduction and spread of pests. The IPPC defines plant pests as "any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products". Introduction of any biological species that meets the definition of 'plant pest' causes anxiety and apprehension that

[1] Terminology in this chapter is consistent with the International Plant Protection Convention's Glossary of Phytosanitary Terms (ISPM No. 5, IPPC, 2010) available online at http://www.ippc.int.

the introduced species may cause economic damage. The economic impact analysis of such pests is predictive and in most instances based on results of research and development and impact analyses from countries where the pest is endemic.

The IPPC provides International Standards for Phytosanitary Measures (ISPMs). These are the standards, guidelines and recommendations recognised as the basis for phytosanitary measures applied by members of the World Trade Organization (WTO) under the Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement). Some of these ISPMs are applicable to post-border biosecurity in building the operational framework and guiding the establishment of post-border biosecurity programmes. These ISPMs provide necessary guidance for post-border activities particularly when a pest is introduced to a new area (more information about ISPMs are in Chap. 2):

- ISPM No. 3: Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms
- SPM No. 4: Guidelines for pest free areas
- ISPM No. 6: Guidelines for surveillance
- ISPM No. 8: Determination of pest status in an area
- ISPM No. 9: Guidelines for pest eradication programmes
- ISPM No. 17: Pest reporting
- ISPM No. 29: Recognition of pest free areas and areas of low pest prevalence

Pest Risk Analysis is an important component of post-border biosecurity and the IPPC has at least two standards to guide national and regional pest risk analyses:

- ISPM No 2: Framework for pest risk analysis
- ISPM No 11: Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms

In addition to the IPPC, other organizations such as the International Atomic Energy Agency (IAEA) and the Regional Plant Protection Organisations (RPPOs) produce documents that provide standard protocol and guidance for post border pest management. An RPPO is an inter-governmental organization functioning as a coordinating body for NPPOs on a regional level. Information on RPPO can be found on the IPPC website: http://www.ippc.int.

The IAEA documents are useful for the application of sterile insect technique and management options for fruit flies. Pest management information from the IAEA is available at http://www-naweb.iaea.org/nafa/ipc/public/manuals-ipc.html.

7.3 Biosecurity Legislation

Modern and robust biosecurity legislation is a vital part of any nation's biosecurity system to meet the increasing demands of movement of people and goods and to ensure that the biosecurity system is effective in dealing with rising pest incidents and in maintaining freedom from exotic pests.

Table 7.1 Examples of biosecurity legislation relevant to the management of pest threats

Country	Name of legislation	Scope
Australia	Quarantine Act (under revision)	In this Act, quarantine includes, but is not limited to, measures for the prevention or control of the introduction, establishment or spread of diseases or pests that will or could cause significant damage to human beings, animals, plants, other aspects of the environment or economic activities
Canada	Plant Protection Act	To protect plant life and the agricultural and forestry sectors of the Canadian economy by preventing the importation, exportation and spread of pests and by controlling or eradicating pests in Canada
New Zealand	Biosecurity Act (part 5 Pest management)	To provide for the effective management or eradication of pests and unwanted organisms
United States of America	Plant Protection Act	Detection, control, eradication, suppression, prevention, or retardation of the spread of plant pests or noxious weeds for the protection of the agriculture, environment, and economy of the United States

Biosecurity legislation provides enabling powers to the NPPOs to reduce the likelihood of introduction of biosecurity threats and enhance the level of preparedness to respond to biosecurity emergencies and safeguard the industry, the environment and the community. Biosecurity legislation implemented at the national level is referred to as first tier legislation. In some countries, the states and territories implement additional second-tier legislation. Considerable understanding is required to ensure alignment of operations of first and second-tier biosecurity programmes. In Australia, the Federal (first-tier responsibility) and most of the state and territory governments (second-tier responsibility) have signed an Intergovernmental Agreement on Biosecurity to strengthen the collaborative approach between the federal and state and territory governments (IGAB 2012).

Biosecurity legislation and regulation of a nation must be consistent with international requirements described in the WTO's SPS Agreement and the IPPC. The regulatory actions can be diverse and relate to treatments that facilitate trade, movement controls that lower risk of entry of a pest in an area and surveillance of areas for regulated pests. Regulations are developed and amended to facilitate "biosecure" movement of people and goods that are potential carriers of pests. For example, regulations can specify restricted entry for commodities that pose an unacceptable level of risk of entry of regulated pests or specify standard operating procedures for testing, inspection and surveillance. These actions are described in Chap. 3. Some examples of biosecurity legislation are given in Table 7.1.

7.4 Tools That Guide Organisational Response to Detection of New or Exotic Pests

Responses to detection of new or exotic pests generally require significant commitment of resources (time, money, staff, technology, etc.). The biology of the pest and characteristics of the environment are important in determining the success of an eradication response and other contributory factors such as costs, benefits and stakeholder support are crucial for successful eradication. The NPPO often adopts standard operating procedures (SOPs) or protocols used in different national or regional emergencies such as wildfire, flood, cyclone, volcanic eruption and earthquake. The approach to managing risks and emergencies and organisational structures needed for implementation of incident responses to pest incursions are similar across sectors and involve the following (from Murray and Koob 2004):

- **Emergency planning** – emergency management related policies, strategies, plans and procedures to enable a high level of readiness.
- **Prevention and mitigation** – regulatory and physical measures to ensure that risks are minimised, emergencies are prevented, or their effects mitigated, by working with neighbouring countries, conducting import risk analyses, and border and quarantine measures.
- **Assessment and training** – personnel are able to perform their assigned tasks to accredited national competencies standards.
- **Surveillance, warning and alerting** – systems for predicting, detecting, warning and alerting of potential emergencies.
- **Co-ordination** – mechanism to ensure the integration of national whole-of-the-government and industry (affected crop growers) decision-making.
- **Emergency response** – actions are rapidly taken in anticipation of, during, and immediately after an emergency to ensure that its effects are minimised.
- **Communication** – timely information exchange before, during and after emergencies, between governments and government agencies, with industry and with the community.
- **Risk assessment** – systematic identification and analysis of hazards, exposures and vulnerabilities.
- **Knowledge management** – gathered, stored, accessible and applied information.
- **Legislation** – supporting laws and regulations.
- **Resourcing** – adequately trained people, appropriate equipment and facilities, and necessary financial arrangements.
- **Emergency recovery** – the co-ordinated process of supporting emergency affected communities in the reconstruction of the physical infrastructure and restoration of emotional, social, economical and physical well-being.
- **Continuous improvement** – enhancement of existing systems through exercising, auditing against performance standards, bench marking and debriefing following emergencies.

In Australia, this approach has been adopted for responding to incursions of exotic plant pests, and developed into national manuals approved by the industry,

government and other relevant stakeholders. Plant industry bodies and the Australian and state and territory governments have established Plant Health Australia as a public company in April 2000 with the challenge of taking a partnership approach to key plant health issues and enhancing Australia's ability to respond to incidents of plant pests (Donovan 2004).

Plant Health Australia has established a 'world first' Emergency Plant Pest Response Deed (DEED) which enables equal involvement of government and plant industry members in decision making when responding to pest incidents. The DEED is underpinned by PLANTPLAN (www.planthealthaustralia.com.au/plantplan), a national emergency preparedness and response plan for plant industries (Donovan 2004). PLANTPLAN describes four phases of incident response:

1. **Investigation** – presence of a suspect new pest is reported to the Chief Plant Health Manager of the State/Territory agriculture department. The process of confirmation of identity by diagnostic experts is initiated. Additional trace back analysis defines the nature of the incident. Relevant contacts in stakeholder organisations are notified.
2. **Alert** – Pest identity is confirmed by diagnosis using local and independent experts, and the outbreak declared. A management committee comprising representative stakeholders is convened. Pending a decision that confirms the pest meets the criteria of an Emergency Plant Pest[2] the committee then evaluates feasibility of eradication. If this is also confirmed the issue is referred to a high-level management committee, consisting of representatives from Industry and Government. Its responsibility is to consider the facts and recommend an action. It has the power to authorise eradication and associated resources.

   Development of a specific response plan based on PLANTPLAN is usually referred to the "affected" jurisdiction. This includes estimates of technical and economic resource requirements. This is subject to consideration by the high level committee and, if satisfied, eradication action is approved. The lead agency and the formula for national cost sharing arrangements are confirmed.
3. **Operational** – The lead agency implements and manages the response plan and reports to a Consultative Committee on Emergency Plant Pests that provides

[2] An Emergency Plant Pest is defined as:

(a) It is a known exotic plant pest the economic consequences of an occurrence of which would be economically or otherwise harmful for Australia, and for which it is considered to be in the regional and national interest to be free of the plant pest.
(b) It is a variant form of an established plant pest that can be distinguished by appropriate investigative and diagnostic methods and which, if established in Australia, would have a regional and national impact.
(c) It is a serious plant pest of unknown or uncertain origin which may, on the evidence available at the time, be an entirely new Plant Pest and which if established in Australia is considered likely to have an adverse economic impact regionally and nationally.
(d) It is a plant pest of potential economic importance to the area endangered thereby and not yet present there or widely distributed and being officially controlled, but is occurring in such a fulminant outbreak form, that an emergency response is required to ensure that there is not either a large scale epidemic of regional and national significance or serious loss of market access.

Table 7.2 Factors to consider in deciding whether to implement a full-scale pest eradication programme

Factors favouring eradication	Factors favouring alternate action
Cost/benefit analysis shows significant economic loss to industry or the community if the organism establishes	Cost/benefit analysis shows relatively low economic or environmental impact if the organism establishes
Physical barriers and/or discontinuity of hosts between production districts	Major areas of continuous production of host plants
Cost effective control difficult to achieve (e.g. limited availability of protectant or curative treatments)	Cost effective control strategies available
The generation time, population dynamics and dispersal of the organism favour more restricted spread and distribution	Short generation times, potential for rapid population growth and long distance dispersal lead to rapid establishment and spread
Pest biocontrol agents not known or recorded in Australia	Widespread populations of known pest biocontrol agents present in Australia
Vectors discontinuous and can be effectively controlled	Vectors unknown, continuous or difficult to control
Outbreak(s) few and confined	Outbreaks numerous and widely dispersed
Trace back information indicates few opportunities for secondary spread	Trace back information indicates extensive opportunities for secondary spread
Weather records show unfavourable conditions for pest development	Weather records show optimum conditions for pest development
Ease of access to outbreak site and location of alternate hosts	Terrain difficult and/or problems accessing and locating host plants

regular reports to the high level management committee. If required, a Scientific Advisory Panel may evaluate technical effectiveness of the response and an independent auditor may assess the financial accountability of the programme.

4. **Stand Down** – This occurs when eradication is completed or when review determines that eradication is no longer feasible. Records of expenditure and technical reports are provided so that cost shares can be calculated. Activities are formally reported that summarise outputs and impact of incursion response action. This is communicated to stakeholders including appropriate international agencies and markets.

Biosecurity emergencies in urban and peri-urban areas are generally more complex than that in the rural areas due to higher population density, diversity, small land parcels, opposition to application of chemicals in urban landscapes, and the need to revisit properties during eradication.

Table 7.2 shows a description of factors considered by the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) in determining whether to pursue an eradication programme for a new or exotic pest. The NPPO may elect to not manage a given pest if no effective, affordable or feasible options are available. This can include cases where the pest is not expected to have a significant impact. In between eradication at one end and "do nothing" at the other end is a spectrum of other measures and options including surveillance, control, suppression, containment and area wide pest management.

7.4.1 How to Prioritise Resources and Assess Risk of Pest Incursion

Uncertainty can be common in dealing with pest incursions when there are insufficient resources, data and time to make well-informed decisions. Prioritisation tools when operating in uncertain and resource-constrained environments are becoming increasingly important. These tools assist the NPPO in decisions on how best to use diminishing resources when faced with new pest challenges.

Multi-Criteria Decision Making tools are promising in that they offer diverse views to enter the decision making process and for the negotiation of consensus positions (Liu et al. 2011). Decision makers invariably face complex situations when responding to pest incursions with potential for their decisions to have positive consequences for some stakeholders and negative for other stakeholders. These tools assist in working out best possible decisions based on available information using qualitative and/or quantitative information. Each decision alternative is represented by its performance in multiple criteria and assists in finding the best alternative or finding a set of good alternatives. For instance, pests can be prioritised and ranked as high or low impact using multi-criteria analysis. The advantage of using a designated prioritisation process is that the evaluation is more objective and comparisons are possible because the same evaluation methods and criteria are used for different pests. Properly documented process increases transparency for communicating with stakeholders.

The Analytical Hierarchy Process (AHP) is a specific type of multi criteria analysis that weights evaluation criteria in order of importance, and then uses them to evaluate a problem (Saaty 2008). The US Department of Agriculture uses the AHP to prioritise exotic pests in the Cooperative Agricultural Pest Survey programme (CAPS), which is designed to detect new pests that have been ranked as important and high risk to US agriculture and the environment. This prioritisation identifies which pests warrant the greatest expenditure of resources for detection (USDA APHIS 2003). The AHP has been used to prioritise introduced pests and make decisions on resource allocation; the Department of Primary Industries, Victoria (Australia) has used this process to rank weeds that are candidates for control programmes (Weiss and McLaren 2002).

Risk analysis and threat prioritisation are the tools used to assess and manage the risk and likely consequences of entry, establishment and spread of pests. Exotic or new pests are usually detected as a result of surveillance. In many cases, there are pests for which the NPPO conduct regular surveillance based on pre-existing knowledge and there is clear understanding of the actions that would be taken if those pests were detected. In Australia, industry biosecurity plans summarise surveillance and monitoring for the high impact threats, and include incident response in the event of a pest incursion, containment, eradication and other management measures, research and development priorities and biosecurity communication and training needs.

There is distinction between exotic pests for which there is little experience and exotic pests for which responses have already been mapped prior to introduction.

Often exotic pests are detected by chance via passive surveillance (e.g. reported by member of community or a grower) and there is no specific preparedness for exotic pests that are not identified as high impact pests. Depending on the pest and its likely impact, the NPPO may decide to:

- Do nothing;
- Undertake surveillance;
- Suppress or contain the pest;
- Manage the pest;
- Eradicate the pest.

For example, fruit flies are a taxonomic group of pests that are considered to be economically important by many NPPOs (Chap. 15). When incursion of a fruit fly species is detected, there is usually an understanding of its importance because an analysis has already been done and a response plan is usually ready to commence eradication action. For pests that are well understood, the level of uncertainty is usually much lower as there is broad understanding of potential impacts, management strategies, costs and benefits of taking different types of actions.

For poorly understood pests there is uncertainty whether the pest will establish and spread to new areas and express significant impacts. An example is a new species of wood-boring beetle whose complete host-range and other important biological information are not known. Consequently a much higher level of uncertainty exists, and decision-making becomes more difficult. Decisions relating to ongoing progress and success of a programme invariably must be made in the absence of complete information. These situations are often described as 'damned if you do and damned if you don't scenarios', and they fall within the "choice under uncertainty" category of classical decision theory.

More importantly, by understanding the principles of decision theory, the risks of poor decisions can be mitigated. In the absence of data, desired outcomes may be achieved using several treatments or restrictions whose cumulative effects become equivalent to the preferred measure that would be applied in the presence of data. These measures may gain the desired level of confidence to ensure that eradication remains feasible. Decisions made on this basis should be well documented and recorded. Furthermore, decisions made without complete data should involve the widest possible consultation. Stakeholders not directly involved in that process should be provided with the full rationale on which the decision was made. Good practice recommends recording decisions made in a sub-optimal environment and to fully explain the logic followed in the absence of empirical evidence.

7.5 Tools for Pest Diagnostics and Surveillance

Two critical operations needed for dealing with exotic pests involve diagnosis and surveillance. They go hand in hand and are used to generate contemporary data for decision makers throughout the incursion response.

7.5.1 Types of Diagnostic Tools

In this section, types of diagnostic tools are presented rather than the specific detail of the methods for diagnosis of strains and species of pests in entomology, bacteriology, mycology, nematology and virology. (See Chap. 13 for details on Molecular Diagnostics.)

The Plant Biosecurity Toolbox (PBT) (www.padil.gov.au/pbt) is an example of a diagnostic tool site developed by the Australian Cooperative Research Centre for National Plant Biosecurity. The PBT provides detailed, web-based diagnostic information to assist with the rapid identification of exotic plant pests in the event of an incursion. It centralizes diagnostic information in recognition of the need for diagnosticians and plant health workers to have quick and easy access to accurate diagnostic resources that have been endorsed by the NPPO.

The comprehensive PBT resources include:

- Information on biology and taxonomy of the pest;
- Diagnostic morphological, biochemical and molecular tests;
- Images of the pest, host symptoms and damage.

Diagnostic science is an important tool for post-border biosecurity because it must specify methods for recognition of damage and symptoms and identification of new or exotic pests. The goal for the NPPO is to ensure laboratories adopt best practice standard operating procedures to minimise the risk of misdiagnosis. The diagnostic labs engaged in biosecurity programmes utilise accepted protocols for diagnosis of pests. The protocols include two components: (1) Recognition of symptoms and pest damage, and (2) Isolation and identification of the pest. (See Chap. 11 for a discussion of digital identification tools.)

Recognition of pest damage or disease symptoms sometimes can be surprisingly difficult. This is due to variation in symptom production on plant parts, cultivars and between plant species. High-quality imaging of diseased or damaged plants is helpful. Locating quality images that illustrate differences can be difficult and diagnostic tools such as PBT, Pest and Disease Image Library (PaDIL) (www.padil.gov.au) and Bugwood (www.bugwood.org) have been developed to provide diagnosticians with access to these valuable resources (See Sect. 12.3.6). Field-survey teams need prior training to identify the affected host plants, and recognise various types of damage on plant parts, varieties and species. Tools such as printed images of pest symptoms or mobile digital technologies with access to image libraries are essential for field based teams responding to new detections.

Lab-based diagnosis of exotic or new pests requires access to robust, reliable and accurate methodologies. Molecular approaches are increasingly being evaluated to find unique sequences of DNA or RNA that can be used to identify pests (Chap. 13). While molecular protocols are readily utilised, many traditional methods are still valuable tools for diagnosing exotic or new pests. Molecular approaches enable diagnosticians to ensure an accurate and repeatable result is obtained that can be used by the decision makers in determining and justifying actions to be undertaken.

The use of molecular (Chap. 13) and morphological (Chap. 12) protocols in tandem helps to achieve reliable diagnosis of suspect pest.

Confirmatory diagnosis is important to verify the identity of a new or exotic pest. Internationally recognised and approved methods are used to confirm pest identity and avoid false positive or false negative results. It is generally advisable to involve at least two independent national labs in pest identification and, if required, consideration should be given to involve a third independent lab based at a location where the pest is endemic. Routine diagnosis is often a shortened version of confirmatory diagnosis with emphasis on selection of robust tests with quick turnaround time.

7.5.2 Tools for Pest Surveillance

Pest surveillance is one of the most critical functions that all the NPPOs perform at the domestic level and one of the first steps in any post- border biosecurity plan. (See Chap. 11 for a detailed discussion of surveillance and ISPM No. 8.) It enables detection of new pests and pest incursions, determination of the extent of pest spread, monitoring programmes for eradication, official containment, control, maintenance of pest free areas and areas of low pest prevalence and confirmation of pest freedom after eradication.

Surveillance provides the basis for domestic phytosanitary measures including justification for quarantine regulation of plant products from foreign sources. The presentation of contemporary surveillance data enables countries, states and territories to specify pest status either 'known or known not to occur' or as 'not known to occur'. The distribution of a pest is defined by delimiting surveys, which identify the extent of spread and account for climatic, host and ecological influences. Surveillance tools range from passive to targeted surveillance. These tools enhance the ability to detect an organism when it is present. Failure to detect or the false positive detection of high impact threats may pose significant and unacceptable risks.

Post-border surveillance (Chap. 11) includes structured surveys, passive surveillance, qualitative assessment of data from various sources and passive surveillance assisted by mathematical tools ranging from formulae to assist in survey design to stochastic scenario trees and Bayesian belief networks. Self-organising maps are a type of neural network that have been used to identify species that are likely to establish, if introduced (Worner and Gevrey 2006; Paini et al. 2010). These maps compare pest assemblages from different regions around the world. When high similarity exists between two regions, pest species known to have established in one region are predicted to have a high likelihood of establishing if introduced to the other region.

Results from sentinel site surveys can be important in supporting claims of pest area freedom status (Boland 2005; McMaugh 2005). Sentinel sites are selected in locations where there is a high likelihood of a pest incursion.

Pest distribution data provide essential information to assess feasibility of intervention and there is usually a requirement for delimiting surveillance to monitor progress of containment or eradication programmes (See ISPM No. 8 "Determination of pest status in an area" for more information.) When selecting sites for pest surveys, random sampling, stratified random sampling, systematic sampling and flying insect trapping are all appropriate methods (McMaugh 2005).

Surveillance is required to confirm that the pest has been eradicated and that eradication is endorsed internationally. Incursion response activities tend to focus on areas of pest presence, but there is an equally important issue of confirming pest absence or "freedom" in unaffected areas. This information is required by industry for national and international trade.

Many tools available for biosecurity surveillance and field teams normally require tools such as:

- Images for recognition of host plants, disease symptoms, pest damage and life stages (Chap. 12).
- Survey strategies that provide information on how to survey in rural, peri-urban and urban environments, and modified strategies for targeted survey (Chap. 11).
- Vehicles, survey clothing and equipment including identification tags and geo-positioning system (GPS) for accurate location.
- Data recording methods that facilitate direct information technology input i.e. digital maps that include GPS points.
- Methods of communication with property owners/managers by survey team leader (Sect. 8.3).
- Hygiene protocols for moving on and off properties (Sects. 18.3 and 18.4).

The Department of Agriculture and Food in Western Australia (DAFWA) runs targeted and community surveillance programmes; the targeted programmes document the absence, presence or level of containment in the State of key exotic pests. The community programmes include general surveillance where specimens are actively solicited from the public and identified free-of-charge. Information gained is used to confirm the state's area-freedom of targeted pests of quarantine significance. Surveillance also monitors the status of pests that are under eradication or containment programmes. DAFWA has increased public awareness and engagement of the community in surveillance via the provision of the Pest and Disease Information Service (PaDIS) that offers a free service to identify specimens and handles any unusual sightings. Cities are 'transport end-points' for road, rail, air and sea freight, through which most exotic pests enter the State. Therefore it is important to engage the public as a resource in the detection of exotic pests.

7.6 Tools for Pest Risk and Economic Analyses

Pest Risk Analysis (PRA) is addressed in more detail in Chap. 9. PRA consider the biological and associated factors that determine options for intervention activities against a new pest in the area where it has become established. It is frequently

integrated with economic analysis. Both are needed and used to make informed decisions. PRA provides the biological and technical information that guides decisions on what steps are taken after a pest is introduced. PRA normally assesses likelihood of entry and magnitude of consequences. However, in the case of new pest detection, the likelihood of entry is redundant because entry has already occurred. For example, a new organism may be detected in a light trap at a port of entry. If the PRA demonstrates that the pest is likely to be a negligible risk because the climate of the country does not favour pest survival, then the NPPO may decide not to take further action against that pest. On the other hand, if a new pest is detected in an orchard and the risk analysis shows that the pest has a high likelihood of establishment based on ability to survive and potential economic impacts then the NPPO is likely to implement a response plan. Consideration of the following factors helps to develop and implement a sound response plan:

- Potential distribution and abundance;
- Length of time present;
- Host range;
- Distribution of potential hosts;
- Biology of the pest including length of life cycle and viability;
- Potential for spread;
- Influence of climate;
- Vectoring capacity, presence/absence of vector;
- Ease of identification both in the field and in the lab;
- Legislation to enable an adequate response;
- Effectiveness of proposed treatments.

Economic analyses are important components of any decision-making framework for newly introduced pests. An economic analysis of a pest may be a "stand-alone" document, or may be integrated with PRA. The types of impacts of pest introductions include direct impacts on agricultural production, impacts on exports (e.g. loss of export markets), environmental impacts and brief reference to social, aesthetic and political impacts. Tangible monetary impacts are generally easy to assess and quantify than the non-tangible impacts which are equally, if not more, important on lifestyle, biodiversity, etc.

The NPPOs determine the economic impacts associated with either managing or eradicating a new pest and this determination includes the relative costs and benefits of different actions to be taken. The Cost Benefit Analyses help to provide economic assessment and useful information in determining whether the costs of a programme (e.g. eradication or containment or maintenance of low pest prevalence programmes) outweigh its potential benefits. In some instances eradication is technically feasible but the costs of eradication may exceed long-term benefits. In such cases, the NPPO may decide that an alternative to eradication (such as the use of existing Integrated Pest Management system or planting of resistant varieties) is preferable.

For export-oriented industries, the economic analyses include costs of potential loss of export markets and the need for additional phytosanitary treatment and

certification. Pest free places of production are sometimes considered as an alternative to eradication (ISPM 10) and the recurrent costs of their establishment and maintenance should be considered.

Additional information is provided in ISPM No. 2 "Framework for Pest Risk Analysis", ISPM No. 11 "Pest Risk Analysis for quarantine pests including analysis of environmental risks and living modified organisms" and ISPM No. 5 "Glossary of phytosanitary terms". This in-depth analysis provides more information on the types of economic consequences that may be considered in a risk analysis.

7.7 Tools for Eradication and Pest Management

Differences exist in tools and processes for eradication and management. Management tools usually aim to reduce the population of a pest to levels that minimise its economic damage on hosts. By contrast, eradication tools aim to completely eliminate the pest population. Surveillance and diagnosis are required to check that the pest is absent and no longer detectable by best practice survey and diagnosis.

The success of eradication recommended by pest and economic analyses frequently depends on depriving the pest of susceptible hosts on which it can survive and reproduce. This involves planned programmes and tools to remove and destroy the hosts that surround the infested area. Additional survey and pest management tools are used to check and treat (i) the area where host plants have been removed, (ii) the host free buffer area that surrounds the infested area, and (iii) the nearest locations of host plants. A range of strategies is selected including hygiene management and pesticide treatments.

In some instances less drastic eradication strategies are used especially for organisms that are slow growing (e.g. wood infecting pests) and where the host is accessible to management practice such as pruning. It is possible to remove infected (infested) wood to a point where the pest cannot survive. Careful removal and destruction of affected plant material and use of selected pest management tools can result in success. The benefit of this approach is that the host plant is retained. This strategy is particularly appropriate for perennial crops that represent considerable investment for farmers.

When eradication is not recommended, alternative strategies are available either for containment or control. These options can be similar to those used for endemic pests. Containment recognises that eradication is not possible in the short term and tools are applied to effectively contain the pest to a defined area and the remaining part of the country can be considered to be "pest free". For export industries, the markets will decide on levels of surveillance and control to justify "pest free" status. Surveillance, diagnostic and regulatory tools are used to confirm the pest infested and free areas.

In some cases, a pest management programme may be applied over wide areas and may involve multiple agencies and stakeholder groups. Such programmes are

often referred to as "area-wide pest management". Such programmes are typically applied for serious pests, such as certain species of fruit flies, or pests that are important for public health (e.g. mosquitoes). Establishment of a new pest can mean adjustment to existing pest management programmes because of the likely need to introduce new chemistries whose effects on other pests and biocontrol agents are not fully understood.

Regulatory tools are frequently used to secure either infested or pest free areas. Usually these specify movement controls of people and produce that minimise risk of inadvertent transfer of the pest. Also specific quarantine that controls movement can be applied to infested areas to limit pest spread. For instance, if a fruit fly is introduced into an area, then restriction could be imposed on any host material moving out of the area where the pest was found. A buffer zone could be delimited around that area to prevent spread through movement of infested host material (e.g. Sect. 18.4). The intensity and duration of measures applied are determined by analysis of the type of pest, the likelihood of success of pest treatments and the available resources.

A simple post-border measure implemented by farmers to maintain freedom from pests is the "farm biosecurity approach", which emphasises farm hygiene necessary to prevent introduction of exotic pests into the farm from anywhere. Farmers can have a major impact on the future of their own farm output and also at a wider level by implementing biosecurity measures on their farms. Farm biosecurity measures include simple actions to minimise the entry and spread of pests. These include:

- Display a sign to inform farm visitors that all machinery, vehicles, boots, hand tools, bins and boxes must be clean before coming onto the farm.
- Establish a wash-down area near the main entrance with a sump that can be readily inspected for signs of weeds and pests.
- Check the cleanliness and quality of any seed or grain before it comes onto the farm.
- Prevent livestock coming to property from spreading infections, soil-borne diseases and weeds.
- Ensure that agricultural machinery, plants and equipment are cleaned of plant material and most soil before they are moved to a new work site.
- Consider washing footwear and hand equipment before entering and leaving high-risk work sites when working in nurseries and seed-crop areas.
- Make it easy for visitors to clean machinery, equipment and boots before they leave the property.

7.8 Tools for Communication

Communication strategies are vitally important tools for post-border biosecurity (Chap. 8). Incursions of new pests can affect a range of stakeholders both on-shore (post-border) and off-shore (pre-border). This diversity of stakeholders and

associated complexity demands carefully planned communication strategies to ensure everyone involved has a shared understanding of the emerging situation. The impact of new pest detections can have economic, social and environmental consequences. The communication tools that are used include dedicated phone lines, radio, television, Internet, print and news media.

Important stakeholders include offshore markets, exporters, public, governments, consumers, industry leaders, farmers, environment agencies, regulators, technical groups and media. All stakeholders are interested in progress but each has different information requirements. Communication planning ensures that the communicator has time to interpret and summarise complex technical issues for different audiences. For example, pest incursions can threaten export trade. Communication is needed by exporters and by off shore representatives in countries that are recipient markets. Both stakeholders need relevant information on how the regulated pest affects trade, disinfestation options and (if eradication is approved), when trade can be restored.

Incursions in urban areas bring unique challenges for communicators and these include but are not limited to the use of pesticides, specific demands of different property owners in the affected area, removal of host plants and associated movement controls. The key to successful communication is to develop clear and concise messages (see Chap. 18 for citrus examples). The incursion response plan should include checklists that outline information needs for specific audiences during different phases of the response plan.

Two examples are presented here that illustrate the complexity of the problem and the difficulty of achieving shared understanding by stakeholders.

A decision by the NPPO to destroy trees on private properties for control of Asian Longhorn Beetle has been met with resistance (cf. Sect. 16.5). Frequently this raises complex issues of compensation for loss. Effective communication strategies are vital to ensure stakeholders, including affected owners, have a shared understanding of the problem that frequently extends well beyond the boundaries of their properties.

Cooperation and support are essential features of communication strategies or tools. Often stakeholders have a central and active role in pest management programmes that requires almost everything from field pest management practices to observing specific quarantines such as restricting the movement of host material in infested areas. In these cases, the NPPOs communicate and work with stakeholders to ensure that the purpose of the programme, the objective of specific actions and the respective roles of the NPPO and stakeholders are clearly identified.

Another example assumes a new species of fruit fly has been detected in a citrus grove, reported by the grower to be damaging the citrus fruit. The local department of agriculture was consulted and the detection reported to the NPPO. In this example it is assumed that the detection occurs at the peak of harvest time and that the citrus fruits from the area of the initial detection are intended for domestic markets (both as fresh fruit and for processing facilities for making juice) and export markets.

Early after detection, the first steps the NPPO takes (in cooperation with local governments) are to delimit the infestation through surveys and to quarantine any materials associated with the pest moving from infested areas. The quarantine would affect the commercial growers in that area, other property owners (e.g. homeowners

with backyard trees), and other industries involved in handling citrus fruit (e.g. packinghouses, juicing facilities, local markets and transportation for moving host material such as trucks or trains). All of this would take place before a full control or eradication programme has been implemented. Growers may later comply with specific requirements such as field sanitation or pre- or post-harvest treatment programmes if they wish to move their produce out of the quarantine area (Sects. 18.3 and 18.4). Other stakeholders (juicing facilities, packinghouses, local markets, transportation) might be asked to ensure waste material (e.g. rotten fruit) is disposed of in specific ways.

This example shows a relatively simple scenario in which a single pest introduction might affect many different stakeholders. Many other individuals, industries or organisations can be impacted as well.

7.9 Conclusions

In a rapidly changing global operating environment, modern biosecurity risk management approaches, ongoing vigilance and modernisation are essential. The preservation of the biosecurity status of a nation represents a moving target. The impacts of pest invasion vary depending on factors such as virulence of the pest, host range, the nature of damage, and the rapidity of spread and climate. The NPPOs are usually expected to provide leadership in technical, policy and regulatory matters that pertain to the specific incursion but justifiable responses to the new pest would be difficult without use of tools that usually generate data and help with interpretation and management of risk.

This chapter identifies the important tools commonly used by the NPPOs to assess the biological and economic implications of pest invasions and maintenance of pest area freedoms. There is general agreement by the NPPOs to apply a standardised set of procedures that are used to guide interpretation of pest risks. It is important to recognise that tools currently in use in post-border biosecurity are under continual revision and changes can occur if and when more effective and efficient tools become available.

On-going needs to develop innovative tools will ensure that post-border biosecurity risk management planning and implementation is timely, professional, effective and will ensure business excellence and continuous improvement. Post-border biosecurity issues require adequate attention from all stakeholders otherwise the cost of living with the introduced pests would be unaffordable and the loss to economy, environment, agriculture and biodiversity would be unsustainable.

References

Boland P (2005) A review of the National Sentinel Hive Programme in Queensland, New South Wales, Victoria, Western Australia and the Northern Territory. Biosecurity Australia, Canberra, Australia

Donovan G (2004) Emergency plant pest response deed. Aust J Emerg Manage 19:32–35
IGAB (Intergovernmental Agreement on Biosecurity) (2012) Australian Government – Department of Agriculture. Fisheries and Forestry, Canberra
Liu S, Sheppard A, Kriticos D, Cook D (2011) Incorporating uncertainty and social values in managing invasive alien species: a deliberative multi-criteria evaluation approach. Biol Invasions 13:2323–2337
McKirdy SJ, Sharma SB, Bayliss KL (in press) Quarantine and biosecurity. Encyclopaedia of agriculture and food systems. Amsterdam, Netherlands
McMaugh T (2005) Guidelines for surveillance for plant pests in Asia and the Pacific, vol 119, ACIAR monograph. ACIAR, Canberra
Murray G, Koob P (2004) Biosecurity in Australian agriculture. Aust J Emerg Manage 19:5–8
Paini DR, Worner SP, Cook DC, De Barro PJ, Thomas MB (2010) Using a self-organizing map to predict invasive species: sensitivity to data errors and a comparison with expert opinion. J Appl Ecol. doi: 10.111/j/1365-2664.2010.01782.x
Pimentel D (2009) Pesticides and pest control. In: Peshin R, Dhawan AK (eds) Integrated pest management: innovation-development process. Springer Science+Business Media B.V, Dordrecht, pp 83–87
Saaty TL (2008) Decision making with the analytic hierarchy process. Int J Serv Sci 1:83–98
Sharma, S (2012) Global food security issues. In: Khan MR, Jha S, Sen C, Banerjee H, Biswas T (eds) Proceedings of international symposium on food security dilemma: plant health and climate change issues, pp 3–4. Association for Advancement in Plant Protection, Plant Health Clinic Laboratory, Directorate of Research, Bidhan Chandra Krishi Vishwavidyalaya, Kalyani, 741235, India: West Bengal
USDA APHIS (2003) CAPS program guidebook. United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection Quarantine, Riverdale
Weiss J, McLaren D (2002) Victoria's pest plant prioritisation process. In: Spafford Jacob H, Dodd J, Moore JH (eds) Proceedings of the 13th Australian weeds conference. Plant Protection Society of Western Australia, Perth, pp 509–512
Worner SP, Gevrey M (2006) Modelling global insect pest species assemblages to determine risk of invasion. J Appl Ecol 43:858–867