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Pest risk analysis - organisms or pathways?†

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Abstract

Pest risk analysis is central to determining both country risks from potential biotic threats and identifying the nature and scale of measures the country puts in place to address the identified threat. International Plant Protection Convention procedures, described in International Standards for Phytosanitary Measures No. 11, are the basis for pest risk analysis and recognise three elements; initiation, pest risk assessment and pest risk management. Among the components of the initiation phase, the decision on whether to base the pest risk analysis on a pest or a pathway for movement of a pest is fundamental. However, it must be recognised that the two are inextricably linked, although the tendency to concentrate on the pest is dominant. A pest-based approach has the advantage of focus on a named organism but, increasingly, there is recognition that other pest organisms that might be associated with the same pathway will tend to be missed. Such a 'list-based' approach has been valuable in raising awareness and in tackling recognised threats, but it is probably true to state that most pest-based pest risk analyses have been retrospective and only initiated when a pest has actually been found in a new geographic area. It is, therefore, important to recognise that a range of organisms in addition to those on a phytosanitary list can move along a given pathway. This suggests the need for a more generic approach to risk mitigation of high-risk pathways so that organisms not on current phytosanitary lists are accounted for. In this context, live plants for planting pose the greatest threats and the greatest challenge in development of effective phytosanitary measures. In attempting to manage multiple threats on a given pathway, a philosophy of "manage once remove many" needs to be developed as a component of pest risk analysis aimed at maximum pest risk reduction.

Keywords: biosecurity; pest risk analysis; pathway; phytosanitary; quarantine; risk mitigation; global trade; wood packaging; plants for planting

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Introduction and background

Global trade, both in terms of volume and speed of transport, is one of the key factors contributing to movement of pests[1], including forest pests, around the world. The role of traded goods and, indeed, other less obvious pathways in facilitating 'delivery' of pests to new locations is not always understood since not all pathways provide an obvious association with a given pest. This is also true for forest pests which, depending on life stage, may be associated with wood (in whatever form), live plants and with other commodities with no link to the original host of the pest.

Statistics on volumes of global trade serve to emphasise the increasing scale and range of potential pathways. For example, Figure 1 illustrates the rate of change in trade of goods of different categories from 1950 to 2007 inclusive (FAO, 2008). What is most striking about these statistics is the logarithmic scale of the increase. In summary, the quantities of traded goods have increased by up to 7000 fold since 1950, with an annual rate of increase of around 6% across all traded goods for the whole period.

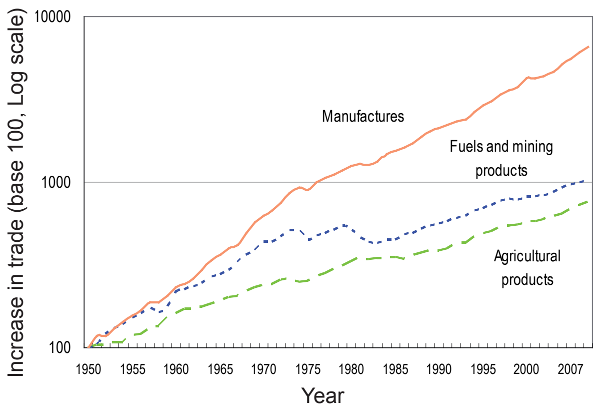

FIGURE 1: Trade in goods over time relative to base value of 100 in 1950 (FAO, 2008).

The commodities moved in trade provide a number of potential pathways for national and international movement of forest pests and it is, therefore, not surprising that the incidences of new pest incursions are also increasing despite phytosanitary rules that have been in place since the International Plant Protection Convention (IPPC) was formed in 1952. For example, more than 2000 species of exotic insect species have established in the USA, a total that includes over 400 species that feed on trees and shrubs (Mattson et al., 1994).

A further factor in the provision of opportunities for establishment of pests in new locations is climate change, which enables some organisms that would have been climate-limited to survive under a changed climate (Liebhold & Tobin, 2008). Range expansion of forest pests under changing climate also adds to the evidence base that opportunities for survival and population growth are increasing for some of the most damaging pests globally. For example, the current massive outbreaks of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in the Pacific Northwest of North America are being linked to a combination of factors including climate change (Aukema et al., 2008). The northward expansion of pine processionary moth (*Thaumetopoea pityocampa* (Den. &Schiff.)) in Europe is also linked directly to improved late winter survival of larvae as a result of increased temperatures arising from climate change (Robinet et al., 2007).

The process of assessing phytosanitary risk: Pest Risk Analysis (PRA)

The combination of increased frequency of opportunity and the geographic expansion in climatic suitability for many forest pests requires a systematic approach to recognising and managing phytosanitary risks. This process is achieved through Pest Risk Analysis (PRA), which is almost universally employed by countries receiving goods and, consequently, the possible arrival of forest pests.

Pest Risk Analysis is a structured procedure to assess the risks from pests and to develop mitigation measures to manage any identified threats. Most countries use the IPPC generic guidelines, summarised through two main International Standards for Phytosanitary Measures (ISPMs):

- ISPM 2 – Framework for pest risk analysis (International Plant Protection Convention, 2007); and
- ISPM 11 – Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms (International Plant Protection Convention, 2004).

[1] *International Plant Protection Convention definition of a Pest is any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products.*

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Most Regional Plant Protection Organisations (RPPOs) and National Plant Protection Organisations (NPPOs) adapt these basic IPPC standards in carrying out their PRAs. In Europe, the European & Mediterranean Plant Protection Organisation (EPPO) members tend to use a common template for PRA and, in the light of experience, this has been modified regularly in recent years (EPPO, 2009).

The PRA process involves three stages: (i) initiation; (ii) pest risk assessment; and (iii) pest risk management. If a decision is made to apply measures to prevent or to manage incursions, there should be evidence to support the conclusion. Failure to provide this structured evidence base could lead to challenges to the procedures under World Trade Organisation (WTO) Sanitary and Phytosanitary measures (WTO-SPS).

To provide context for later discussion in this paper, the PRA process is described in outline in the remainder of this section.

Stage 1: initiation

In determining the need for a PRA, criteria for initiation can be based on one or a combination of pest, pathway or policy drivers. In reality, most PRAs are driven by either the need to consider named pests or, through a commodity-based approach, i.e. a determination of which traded goods provide pathways for the named pests. An initial evaluation of whether pests that could pose a phytosanitary threat are likely to arrive in the PRA area is carried out at this stage. If a decision is made that a potential threat exists, the process moves on to the second stage - Pest Risk Assessment. In some cases, there may be sufficient evidence to rule out further evaluation and no further action is taken.

Stage 2: pest risk assessment

This stage is critical to the whole PRA process because it assesses and provides the supporting evidence for whether criteria for quarantine pest status are satisfied, defined by 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, 2008). The area itself needs to be defined but could be wide (all or part of several countries) or narrow (officially defined part of a country). Within the area being considered, the assessment process focuses on the endangered area, as defined by ecological conditions that would be suitable for establishment of a pest leading to economic losses. All assessments take into account pest characteristics, including geographic distribution, biology and economic impact. Such an approach employs expert judgement but with verifiable supporting evidence for the facts and conclusions presented. Having assessed the potential threat, the process considers whether introduction of the pest to the PRA area is possible. Clearly, since the process is initiated by either a potential or demonstrated arrival of a pest in a new area, the scientific evidence on establishment and damage potential will depend on interaction with scientists and regulators in the area of origin of the pest.

Stage 3: pest risk management

The final stage of the PRA is often the most difficult to implement because it considers and recommends procedures for eliminating or mitigating the risks from the identified pest (or commodity). Central to this is assessment of the level of risk and evaluation of the technical information that has led to the quantification of the risk. In essence, it requires a decision on the scale of the identified risk and on the magnitude of measures to be applied to reduce the risk to acceptable levels. Thus, the information from the Pest Risk Assessment phase is used to make justifiable risk management decisions that are proportionate to the risk. For example, debarking of wood can be a risk reduction measure that is applied to reduce the risks from bark beetles and other phloem-feeding pests.

Refinements to the PRA process are constantly being sought both at IPPC level and through variation delivered at RPPO or NPPO levels. The latest versions of PRA templates, often accompanied by completed PRAs, can usually be found on the websites of RPPOs, e.g. the EPPO website has the EPPO PRA template and examples of PRAs completed by its expert panels. To date, the PRA process has been the cornerstone in development of phytosanitary measures to enable trade in goods to continue without undue restriction. However, this dependence also has its weaknesses, which will be discussed below.

Pest risk analysis in practice: drawbacks

While the process underpinning PRA is fundamentally sound and is an essential basis for development of acceptable phytosanitary rules and measures, there are a number of drawbacks to the process that are becoming increasingly apparent. This is particularly the case in relation to the combination of increased trade in goods and links to climate change summarised earlier.

As the name implies, Pest Risk Analysis has a high dependence on named pest organisms. While providing focus, particularly during mitigation and inspection regimes, this inevitably results in missing new pest organisms that were not already listed. Indeed, it is arguably the case that the great majority of PRAs carried out are retrospective and are carried out only after a pest has been located or has established in a new location. For example, within Europe the PRA for the platypodid beetle *Megaplatypus mutatus*

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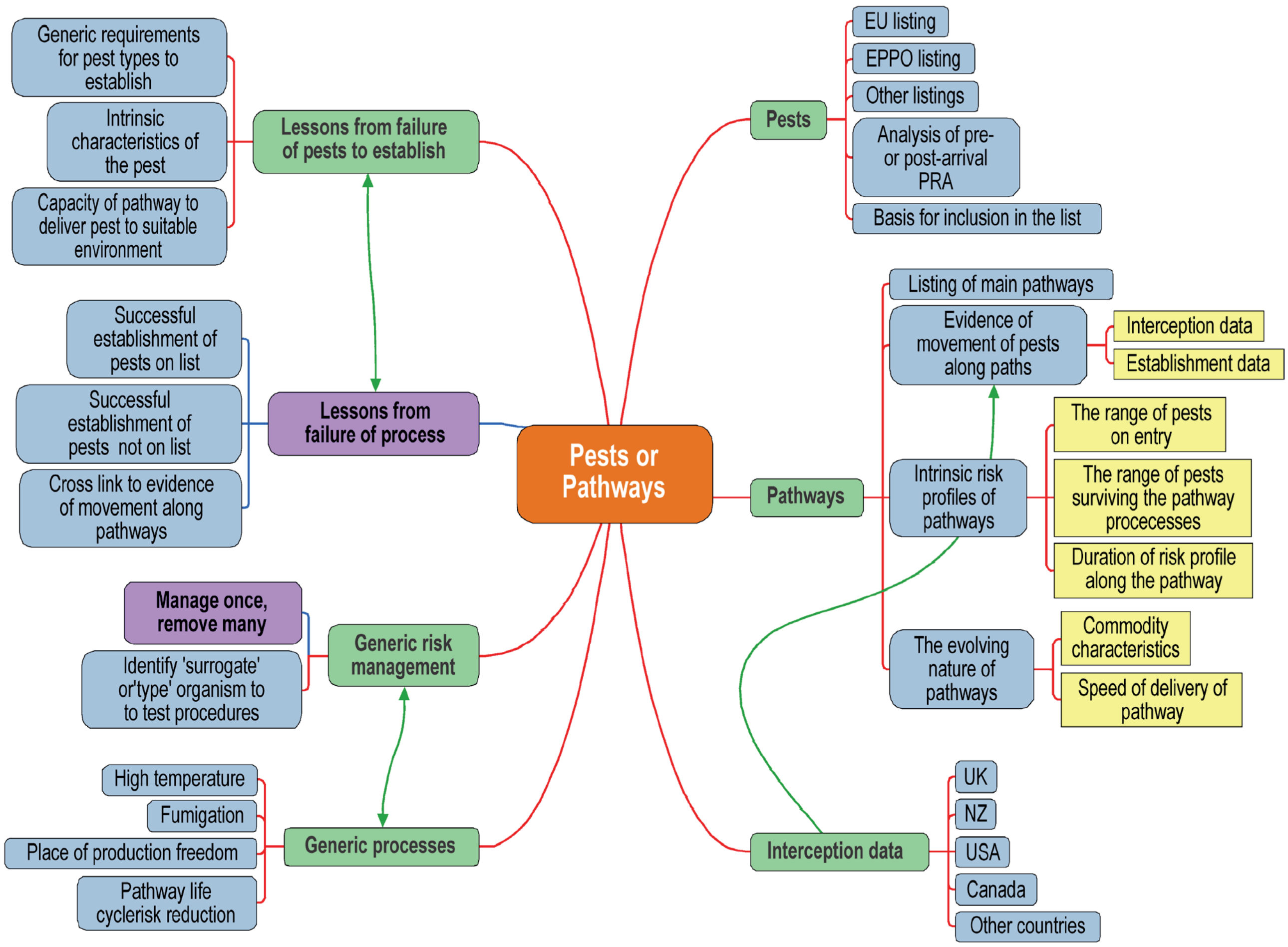

FIGURE 2: A conceptual framework to assess the roles of organisms or pathways in phytosanitary risk assessment.

(Chapuis), a native of South America, was only carried out because the pest had already established in Italy (EPPO, 2007). Similarly, the appearance of both Asian longhorn beetle (*Anoplophora glabripennis* (Motschulsky)) and emerald ash borer (*Agrilus planipennis* Fairmaire) in North America triggered PRAs and the passing of phytosanitary regulations in the European Union (EU). Neither species was on the EU list of quarantine pests, even though both were increasing their pest status in China and the far East, their region of origin.

It is not surprising that PRAs tend to be retrospective because there are many organisms that are of pest status in their native ranges that have no ‘track record’ of invasiveness and, consequently, tend not to be listed under phytosanitary regulations elsewhere in the world. Even more problematic are those organisms that pose little or no threat in their native regions, presumably arising from their existance in a co-evolved situation that is in balance with resources, natural enemies, etc, but which have become pests when translocated to new regions (Liu & Stiling, 2006).

Difficulties both in obtaining information to set up a PRA and in validating PRA conclusions compound the problem, especially in less developed countries that have limited resources. Nevertheless, the fact that PRAs tend to be retrospective is a major weakness because the emphasis is on named organisms and their associated commodity pathways when populating the lists of quarantine pests globally.

Organisms or pathways?

Issues arising from the weaknesses of the pest-dominated PRA process, therefore, pose the question of whether phytosanitary threats should be addressed by emphasis on the organisms or on the pathways on which they are carried. Since the two elements of the question are closely linked (i.e. the organisms generally cannot move without a pathway), the question needs to be approached in a structured way to identify key components of the risk matrix. An example approach is shown in Figure 2, which uses knowledge sources to assess the relative contributions

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of organisms (pests), pathways and the influences of existing phytosanitary procedures on incidences of movement or establishment of pests. It highlights two elements that provide insights and potential emphases in process-based management of future phytosanitary threats; ‘failure of process’ and ‘manage once, remove many’.

Thus, lessons can be learned from failures of phytosanitary process and, from them, how generic risk management procedures can be derived that place emphasis on the concept of ‘*manage once, remove many*’ to address a wider spectrum of pests rather than concentrate on a low number of named organisms. Such a procedure would account for unknown pests that may already be moving along a pathway, but which may not yet be identified or recognised.

Data on invasive organisms from global databases, i.e. which species feature in phytosanitary listings, provide a measure of the very small coverage in current lists of potential phytosanitary threats. Taking Invasive Alien Species (IAS) as a whole, the Convention on Biological Diversity estimates that >480000 IAS have established outside their home ranges (Convention on Biological Diversity, 2004). Of these species, up to 30% (i.e. 144 000 species) are regarded as pests although clearly these are not all of phytosanitary concern. Thus, the number of new organisms establishing in new locations globally is clearly very large and many contribute to the pool of phytosanitary pests being moved around the world. The EU recognises proliferation of IAS as an emerging issue, noting IAS as one of the main recorded causes of biodiversity loss and serious damage to economy and health (European Council (Environment), 2002).

A more detailed examination of phytosanitary lists internationally emphasises the contrast between those species that are listed and recognised as threats and the very much larger numbers of IAS listed by the Convention on Biological Diversity. Some examples of data on phytosanitary threats are illustrated in Table 1 where lists from the European Union and Canada are summarised.

Among the listed pests, a relatively small proportion are forest pests, indicating strongly that very few of the potential pests of trees from around the world are yet recognised as threats. By implication, this indicates that most of the potential threats to our trees are not being managed, even though they could be moved in international trade. Evidence of this failure of process is becoming increasingly apparent.

Failure of process

There are currently a number of serious pests of forestry that provide evidence of failure of phytosanitary processes, both for pests on current listings and, more significantly, for those not listed. Among the listed pests, the establishment of citrus longhorn beetle (*Anoplophora chinensis* (Forster), which originated in China, Japan, Korea and Russia), in various European countries illustrates that rules governing its main pathways (wood packaging and plants for planting)

TABLE 1: Examples of listed pests of phytosanitary concern: European Union and Canada.

Location	Pest Category	Named Pests		
		Forest	Other	Total
European Union[1]	Insects & nematodes	17	88	105
	Bacteria	0	8	8
	Fungi	16	21	37
	Viruses	1	47	48
	TOTAL	*34*	*164*	*198*
Canada	Bacteria	1	7	8
	Fungi	7	31	38
	Insects & mites	14	46	60
	Molluscs	0	11	11
	Nematodes	0	9	9
	Phytoplasmas	0	10	10
	Viruses	0	62	62
	TOTAL	*22*	*176*	*198*

[1] *Directive 2000/29EC*

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have proved inadequate to prevent movement and subsequent establishment. Other examples include pine shoot beetle (*Tomicus piniperda* L.) listed by Canada but now established there and pine wood nematode (*Bursaphelenchus xylophilus* ((Steiner & Buhrer) Nickle)), listed by EU and EPPO but established in Portugal. In all cases, rules to reduce the likelihood of movement along particular pathways were in place, but these were clearly not sufficiently robust to prevent introduction.

A recent in-depth analysis of invasive invertebrate pests that have established in Europe arising from the Delivering Alien Invasive Species Inventories for Europe (DAISIE) project and database provides well-documented evidence that more pests are moving internationally than are on phytosanitary lists (Roques et al., 2008). Table 2, from Roques et al. (2008) shows both the origins of pests established in Europe (as percentages of the total) and the total number of pests. As a contrast, the EPPO A1 and A2 lists combined have approximately 135 invertebrate pests.

Pests that have established and which were not on lists include some that are now causing serious problems in the countries in which they have established. Notable among these are Asian longhorn beetle (*Anoplophora glabripennis*), established in the USA and several European countries and emerald ash borer (*A. planipennis*), established in Canada, the USA and Russia. Both these tree-killing pests originated from China and the far East.

There is little doubt that further incursions of the many pests that are not on current phytosanitary lists will take place and, based on previous experiences, will only be noted after they have established and started to cause noticeable economic and environmental damage.

Potential solutions

The current measures to prevent pests from moving internationally have a sound basis but are clearly not 'capturing' all the organisms that move internationally. Solutions to increase the prevention rate will not be simple but a general principle should be applied to attempts to improve the success rate. As indicated in Figure 2, a central tenet to any phytosanitary measure is that it should not be too species focussed but, instead, should aim to *manage once, remove many*. A shift from individual organisms to the pathways on which they are carried should now be the focus for management of quarantine pests. Each pathway has a generic carrying potential for a range of pests and any processes applied to the pathway should be evaluated for their potential to remove a range of pests with similar characteristics – a generic, rather than a specific, approach.

Clearly, this is not a simple solution to the problem of unknown organisms moving along pathways. Development of a generic approach will inevitably be a compromise between:

- *efficacy/cost of the generic process*. The efficacy and cost components of a pathway management process have to take into account the scale of the pathway so that both the direct efficacy of the process and how quickly it can be applied need to be taken into account;

- *feasibility of the generic process*. This is an extension of the efficacy/cost constraint and needs to assess whether the process has an adverse effect on the pathway commodity

TABLE 2: Invasive invertebrate species established in Europe as a percentage of their countries of origin (based on Roques et al., 2008).

	Invertebrate Species established in Europe (%)		
	Total Invertebrates	**Arthropods**	**Non-arthropods**
Africa	12.3	12.9	3.2
North America	19.8	19.6	22.6
C & S America	10.8	10.9	9.7
Asia	29.4	29.3	32.3
Australasia	6.5	6.6	4.3
Tropics	6.7	7.1	1.1
Cryptogenic	14.5	13.7	26.9
TOTAL NUMBER	*1517**	*1424*	*93*

** 135 species are on EPPO lists*

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itself. For example, a fumigant is not likely to be practical for plants for planting because of risks of phytotoxicity, even though associated pests could be killed;

- *acceptance of managed risk.* The aim of 100% removal of risk should remain, but many processes will not be capable of killing all organisms associated with a particular pathway. Managed risk, therefore, implies that some pests might still move along a pathway but at a level that is regarded as acceptable rather than impose a complete ban on a particular commodity; and

- *the need to allow trade along the pathway to continue.* This is an outcome of managed risk which takes account of the need to continue trading but does so in the knowledge that any processes applied to the pathway remove most of the risk, but not necessarily all.

Generic pathway management

Generic pathway management should take account of the likely range and biological characteristics of organisms that could move along a named pathway. Commodities moved in international trade can often be lumped into given pathways and, within the wider pathway category, the generic phytosanitary risks can be linked to sub-sets of the pathway. This can be illustrated by reference to two key pathways for forest pests, namely Wood (not in the living plant) and Plants for Planting (Roques, 2010).

Wood as a pathway

Figure 3 shows the risk triangle for wood in relation to how much processing of the wood is carried out prior to being traded as a commodity and how each category acts as a potential pathway for movement of pests, (Evans, 2008).

Even without additional measures, the risk profile of untreated wood can be reduced to virtually negligible when it is fully converted into a high quality manufactured product, such as medium density fibreboard, etc. In relation to *manage once remove many*, the fact that wood can be treated aggressively using a range of techniques (e.g. heat treatment, microwaving, fumigation, etc.) indicates that generic pathway management is feasible and practical. The introduction of ISPM15 dealing with treatments for wood packaging is an excellent example of a process-based generic solution to a previously highly dangerous pathway. As with all solutions that rely on direct application of a phytosanitary treatment, the likelihood of pests surviving to the end of a pathway depends both on the efficacy of the treatment itself and on the quality of its application. This is under regular review and, for example, the 2009 revision includes reference to use of debarked wood as a baseline measure, irrespective of further treatment.

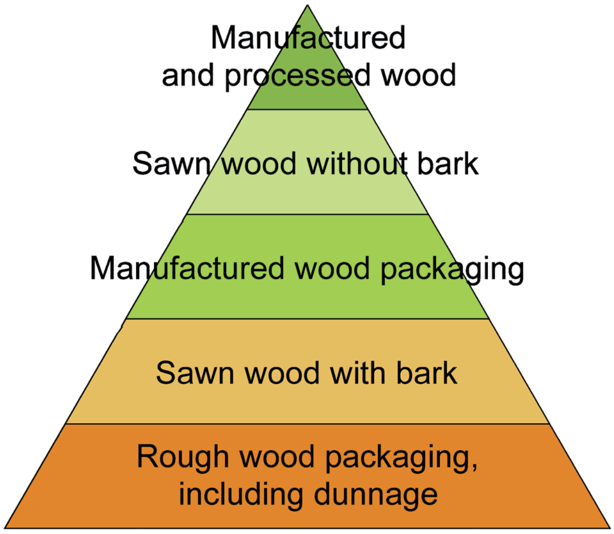

FIGURE 3: Risk triangle for wood (not as a living plant) as a pathway for invasive pests.

Plants for planting as a pathway

Global trade in relation to capacity and speed of transport has increased the feasibility of transport of living plants from country to country, including inter-continental transfers. This is reflected in the great increase in plants for planting, including woody plants, hardy ornamentals and miniature trees (bonsai and penjing) in recent years. For example, the value of imports in nursery products recorded by the US Department of Agriculture (http://www.fas.usda.gov/ustrdscripts) has increased from \$0.6 billion in 1993 to \$1.55 billion in 2007, although it fell in 2008 and 2009. The percentage increase in this trade value, with a baseline of 1993 is shown in Figure 4, illustrating clearly that, for the USA alone, imports in plants for planting from the rest of the world in total has increased approximately 1.5 times in 16 years.

In the UK, imports of living plants more than doubled from £370 million in 1993 to reach £860 million in 2005 (Brasier, 2005). These trends provide clear evidence that the numbers of living plants moving internationally is enormous and increasing.

A risk triangle for plants for planting is shown in Figure 5, which illustrates that virtually no sub-categories of this pathway can be regarded as intrinsically safe from the risk of carrying pests, (Evans, 2008).

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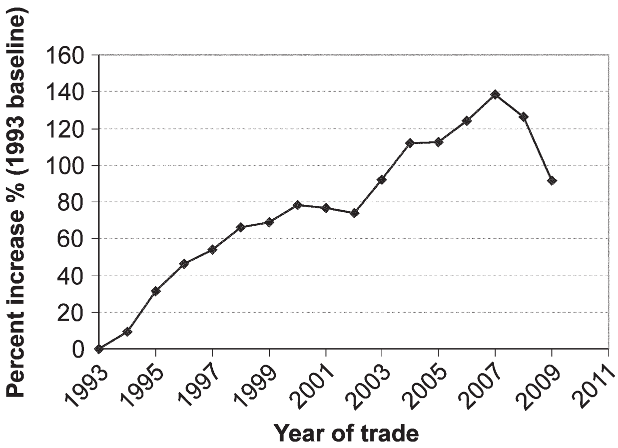

FIGURE 4: Percentage increase over time in trade value of plants for planting into the USA from a 1993 baseline.

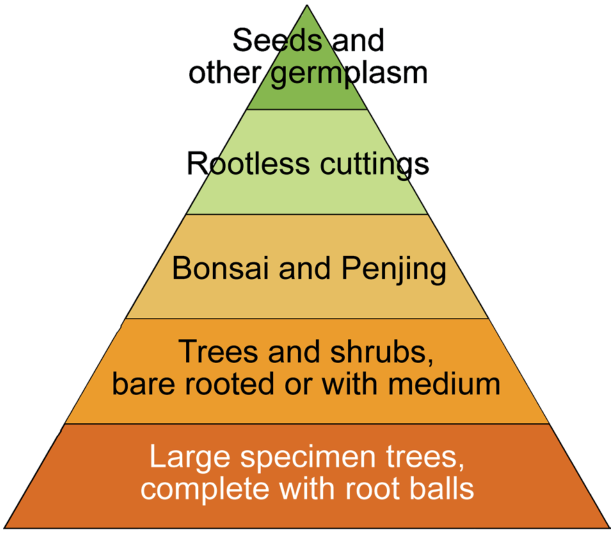

FIGURE 5: Risk triangle for "Plants for Planting" pathway.

The likelihood of pests being present increases dramatically if soil remains associated with the plant, particularly for potted plants and, especially, large root-balled specimens. It is no exaggeration to describe the latter category as being 'an ecosystem in a pot', with most of the associated organisms being hidden and of unknown identity. Brasier (2005) addressed the risks from the plants for planting pathway with particular reference to pathogens and concluded that biological weaknesses in current phytosanitary procedures leave importing countries open to constant arrival of unknown pathogens. Threats from pathogens are particularly acute, where evolutionary change and hybridisation are rapid and outpace our capacity to identify or recognise the organisms and their environmental consequences.

Can the *manage once, remove many* concept be applied to plants for planting? For most of the categories in the risk triangle in Figure 5, it appears clear that a single solution approach is likely to be difficult or impossible to develop or apply. Direct treatments to remove all phytosanitary threats are either not efficacious or not practical, especially with increasing sizes of planting material. Some options are offered within existing phytosanitary procedures under IPPC and are potentially part of the pathway management solution. For example, the application of 'Place of Production Freedom' from pests could be employed to ensure clean plants for export (International Plant Protection Convention, 1999). However, this begs the question of which organisms should be added to a phytosanitary certificate to indicate 'place of production freedom', again indicating the drawbacks of a list-based system that is reliant on knowing which organisms are present at the origin of a pathway.

Management of the greater complexity and pest-carrying capacity of the plants for planting pathway, therefore, is difficult and, currently, not entirely tractable. Future approaches require a multi-component solution set rather than reliance on a 'single solution fits all' approach, as is the case for some measures targeting named pests on phytosanitary lists. Key to managing the pathway is improving our knowledge and understanding of its capacity to support pests with particular biological characteristics. Such a process-based approach would categorise the plant by the types of organisms that could be expected to be associated with the particular species and growth stage of the plant, prior to its entering the trade pathway. A generic description of this range of organisms would not be based on a simple list of pests but on identifying exemplar species that could act as surrogates for all other organisms with similar biological characteristics and likelihood of association with the host plant. The principle will be to apply prevention or pest reduction regimes targeted at exemplar organisms on the assumption that removal of the target also removes all other species of similar biological linkage to the host plant, thereby reducing overall risk. The concept of *manage once, remove many* remains central to this approach but would apply to each group of pests and may require either sequential or parallel applications of a number of risk reduction measures.

International concerns in relation to the plants for planting pathway are driving a number of debates and initiatives on this particularly difficult and high risk pathway. A number of RPPOs (EPPO, North American Plant Protection Organisation, etc) and quarantine groups (International Forestry Quarantine Research Group, International Union of Forest Research Organisations (IUFRO) Alien Invasive Species and

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International Trade Unit, etc.) are addressing this pathway and collaboration at a global scale will be needed to develop working solutions. Since the live plant pathway is driven by end-user demand (including commercial landscape management stakeholders) as well as the desires of the wider public, one of the potentially most effective solutions is to educate end-users and reduce the aspiration to have 'instant plants and landscapes'. Clearly, this fundamental approach would require delivery of alternative ways of obtaining the desired range of live plant species. Brasier (2005), in his thought-provoking analysis of the phytosanitary issues associated with plants for planting, offers solutions that reduce risks while still offering availability of plant species. These can be extended to address the exemplar organism pathway management approach:

- regulate plant introductions far more stringently, in a similar way to regulation of animal introductions, taking particular account of the high risk from unknown organisms not on current phytosanitary lists;
- import, under licence, only meristem cultures or seed for propagation, or, more rarely, import small, licensed quantities of rooted material for quarantine testing before release. Release would require freedom from a range of exemplar organisms covering key pest groupings; and
- encourage local commercial propagation of exotic forest trees, shrubs and ornamentals, using safe sources of propagative materials.

Clearly, such an approach would require a radical overhaul and re-think of current phytosanitary rules but, combined with improved scientific categorisation of risks, including the exemplar pest concept, does offer a potential solution to a dramatically increasing high risk pathway. This re-think on phytosanitary risks for forest pests is being accompanied by similar concerns in the agri-environment sector, indicating the need for a 'joined-up' approach. The suggestions put forward by Waage and Mumford (2008) certainly have resonance with the potential solutions being put forward in the current paper:

- an integration of plant and animal biosecurity around a common, proactive, risk-based approach;
- a greater focus on international cooperation to deal with threats at source; and
- a commitment to refocus biosecurity on building resilience to invasion into agroecosystems rather than building walls around them.

Conclusions

Pest Risk Analysis remains a central component in recognising phytosanitary threats and as a basis for developing risk management solutions. However, the value of a pest-based PRA culture is tempered by the increasing evidence of establishment of pests not on previous lists.

Thus, the approach advocated in the current paper is to recognise the difficulties inherent in managing pathways carrying both known and unknown pests. The new paradigm should build on the traditional PRA approach and move to Pathway Risk Analysis, with emphasis on Pathway Risk Mitigation. Generic approaches to pathway categorisation and management should now be based on biological characteristics of exemplar pests (in its IPPC definition to include all organisms of phytosanitary concern), with emphasis on a combination of measures addressing pest-plant associations rather than individual pests. Risk management should also involve education of end-users, including importers, to increase awareness of the consequences of expansion in trade in particular pathways and to work towards offering alternative ways of achieving the same ends. This is particularly the case for the plants for planting pathway where there appears to be low awareness of risks in the end-user community that is actually driving the trade itself through demand for exotic live plants.

Concerted international action based on scientifically based development of phytosanitary measures is essential in developing future solutions. However, as evidenced by the continuing expansion in trade, especially of plants for planting, combined with climate change, the need for tractable solutions is becoming increasingly urgent.

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