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Semi-quantitative model for ranking exotic invertebrate pest threats to Western Australia

Robert N. Emery,[1] *Marc C. Poole, John H. Botha and Darryl C. Hardie*
Department of Agriculture, Government of Western Australia, Locked Bag 4, Bentley, WA 6983

Abstract. Western Australian agriculture is free of many serious plant pests because of its geographical isolation, however the potential exotic pest threats to Western Australia are large. Consequently, various lists, based largely on 'gut feeling', have been created to highlight the top/priority pests for specific industries. Due to the variation in individual opinions, these lists vary greatly and contain many subjective and/or unsubstantiated assumptions regarding threat status.

There was a clear need for a semi-quantitative model to identify and consistently and objectively analyse top threats based on substantiated data from various authorities.

The model described here was developed using Microsoft Access 97®. Thirteen questions (contained in a pest threat questionnaire—PTQ) were developed, allowing for discrete answers carefully weighted in order to arrive at a realistic threat value or 'score' to be calculated for each pest analysed. The questions cover the various stages of a pest incursion, including importation and distribution (probability of entry), as well as probability of establishment and spread, and also addresses economic consequences (industry impact). The total threat value or measure of risk posed (expected loss) to the agricultural crops of Western Australia is then determined by a summation of the likelihood/probability of entry, establishment and spread weightings with the (economic) consequences weightings.

Introduction

Western Australia is free of many serious plant pests because of its geographical isolation. In recent times the risk of incursion of exotic plant pests has increased substantially as transport times between points of production and markets are reduced.

The list of potential exotic pest threats for Western Australia (WA) is large. Over time, various lists have been created that, for instance, list the 'top 10' pests, but these have largely been based on 'gut feeling'. These lists have been used to determine priorities for those diseases for which contingency plans should be developed. As resources are limited, it is important that the decision is based on more than just expert opinion.

As the need arises, the Department of Agriculture conducts full risk analyses (as state import risk analyses—SIRAs). However, these are resource-intensive and cannot realistically be made on each exotic plant pest. To counter this, the pest threat questionnaire (PTQ) was designed to address the requirements for the pest risk assessment component of a pest risk analysis as outlined by the Food and Agriculture Organization of the United Nations (FAO 2001). Concepts similar to the pest threat questionnaire for pest risk assessments are in use with the United States Department of Agriculture (USDA 2000) and European and Mediterranean Plant Protection Organization (EPPO 2001).

The PTQ is a semi-quantitative model developed as a rapid and economical means of decreasing the number of potential quarantine pests to a more manageable list on which more detailed analysis could be made.

Methods

The model described here was developed using Microsoft Access 97®. Thirteen questions (contained in a PTQ) were developed, allowing for discrete answers carefully weighted in order to arrive at a realistic threat value or 'score' to be calculated for each pest analysed.

Before beginning a questionnaire, users must determine the specific industry they wish to consider the pest is threatening. The size of the industry will have an important impact on the outcome. Users can choose 'non-specific industry' if they wish to analyse the threat posed to all industries combined.

Table 1 illustrates how the 13 PTQ questions address the requirements for the pest risk assessment component of a pest risk analysis as outlined by the FAO (FAO 2001). In the table, the FAO category in column 1 corresponds to the PTQ questions as indicated in column 2. The question weightings (column 3) and maximum response weightings (column 4) for the PTQ as well as the maximum risk

[1] Corresponding author: <remery@wa.gov.au>

weighting (column 5 = column 3 × column 4) are also given in Table 1.

The *total threat value* or measure of unrestricted risk posed (expected loss) to the agricultural crops of WA is determined by considering the *likelihood/probability of introduction, establishment and spread weighting* and the *economic consequences weighting*. The *total threat value is a combined threat value* of which 62% (1120/1800 × 100) of the weighting refers to the predicted (mainly economic) impact in the event of a foreign species (or resistant strain of an endemic or naturalised species) becoming naturalised.

To highlight variations in respondent assessments, the model was designed to provide maximum, minimum and average scores for each pest analysed by multiple users. The average weighting is used to determine the final ranking.

Western Australian Department of Agriculture entomologists were asked to list the top 10 grain pest threats for WA. These have been processed through the model to support the 'gut feeling' assessment (Table 2). Each pest was assessed using the model by at least four entomologists.

Each pest evaluated by the questionnaire is linked to an independent database that records known hosts, validated national and international pest distribution, common names, and literature references.

The Plant Health Branch of the Department of Agriculture, WA has drawn up a number of prophylactic 'threat data sheets' (TDSs) for those pests considered to be the top threats to specific grain and horticulture industries. The processes used are relatively complex and are demonstrated below using khapra beetle as an example.

The khapra beetle, *Trogoderma granarium* Everts, is one of the most feared pests of stored products, especially when stored under hot, dry conditions (Shea et al. 2000). As with the warehouse beetle (*Trogoderma variabile* Ballion), khapra beetle is brown–black, oval shaped and 2–3 mm long. Khapra and warehouse beetles are similar in many ways and can only be distinguished by specialist taxonomists. Khapra beetle thus ended up high (highest of all true exotics) on the final threat list (Table 2). Based on this high rating, the GrainGuard® initiative published a TDS regarding khapra beetle as a threat to the Western Australian grain industry. The categories as used by the GrainGuard® initiative were applied in the ranking with the following result.

Economic impact was considered to be 'high'. Supporting evidence was that khapra beetle, depending upon existing conditions, may cause losses to stored grain

Table 1. Comparison of the Food and Agriculture Organization of the United Nations (FAO) categorisation (FAO 2001) with the questions in the pest threat questionnaire (PTQ), with indication of the weightings as used in the PTQ.

Pest risk assessment				
FAO category	PTQ question	Question weighting	Maximum response weighting	Maximum risk weighting
Assessment of the probability of introduction and spread				
Probability of entry of a pest	Ability to enter Western Australia (WA)	50	4	200
	Ability to invade (spatial and temporal distribution history)	30	2	60
	Pest distribution	30	3.5	105
Probability of establishment	Number of individuals required to establish breeding population	10	3	30
	Demographics of host	30	3	90
	Species' climatic requirements	30	3	90
Probability of spread after establishment	Ability to spread once established (pathway and independent spread)	30	3.5	105
				Maximum score 680
Assessment of potential economic consequences				
Pest effects	Impact on the industry	40	6	240
	Pest status in other countries	30	4	120
	Insect species a vector of a plant or animal disease/parasite	10	4	40
Analysis of economic consequences	Gross value of WA industry affected	40	8	320
	Cost of control or eradication following pest establishment calculated for a 30-year period	30	12	360
	Expected long-term pest status in WA	20	2	40
				Maximum score 1120
				Maximum possible combined score 1800

of 5–30% and losses have been known to reach as high as 74%. The most favourable conditions for multiplication and damage are in bulk grain under extended storage. The economic impact is increased through the significant marketing and quarantine problems that would arise if WA was found to be infected. When Australia was erroneously listed as 'khapra beetle country' in the late 1940s, it took over 15 years of lobbying and publication to have this stigma removed (Emery 1999). Many Australian export markets will disappear immediately if khapra beetle is found to be present.

Entry potential was considered to be 'extreme', since the larvae can survive for several years without food. Khapra beetles have a very wide host range and since they may hide in such diverse items as hessian cloth, crude rubber, wool, vermiculite, timber and cotton waste, the chance of an undetected incursion substantially increases. Asia, the Middle East and African countries are high-risk regions and considered to be endemic for khapra beetle.

Establishment (= distribution) potential is considered to be 'high', since detection may go unnoticed—for example, where the continuous identification in the presence of warehouse beetle is not practised. Existing surveillance strategies in use by the Department probably significantly lower the likelihood of establishment, but here we refer to unrestricted potential of no additional phytosanitary measure, such as surveillance strategies. Khapra beetle is typically a pest of hot, dry climates or of commodities stored elsewhere in hot, dry conditions. Given the localities where it has established elsewhere, it is highly likely that khapra beetle would get a foothold in WA, especially in areas such as Dalwallinu, Mullewa and Southern Cross. Banks (1977) showed that much of the interior of Australia, including several grain-growing areas, provide suitable conditions for this pest. Coastal population centres appear unsuitable, with the exception of Adelaide. While bulk grain is usually unloaded and inspected at a few coastal ports at probably relatively low risk, container lots could end up just about anywhere. Observations on environmental suitability are based on ambient weather conditions. Actual conditions in a grain bulk or store may be quite different. The spread and rapid establishment of khapra beetle in south-western USA provides a warning about the potential of the pest and the cost and difficulty of getting rid of it (Rees and Banks 1999). Larvae tend to be gregarious and large numbers together can cause the commodity to heat, further assisting their rate of development (Lindgren et al. 1955). Regarding WA, studies by Howe (1958) indicated how interspecific competition may lead to (for example) khapra beetle and the lesser grain borer (*Rhyzopertha dominica* F.) being the dominant species in a climatic region such as Merredin, whilst the granary weevil (*Sitophilus granarius* L.) may dominate in Fremantle.

Spread potential following establishment is rated as 'high'. The reason is that khapra beetle is readily transported with agricultural products in packaging, shipping containers, vessels, or vehicles carrying agricultural produce. Some larvae may hitch a lift on birds, rodents or farm animals, but it is transportation by humans (also on clothing) that allows them to cover long distances quickly (Rees and Banks 1999). The natural, and especially the managed, environment is reasonably suitable for the natural (short distance) spread of this pest. Adults are short-lived and do not fly. Small larvae, being light and hairy, may be blown about in the wind. Both adults and larvae can walk limited distances (Rees and Banks 1999).

Based on the above values, the *unrestricted risk* for khapra beetle is determined as being 'high'. By filling in the PTQ, one arrives at a percentage value of 70, indicated in Table 2.

Table 2. Ranking based on semi-quantitative analysis of the top 10 grain pest threats to Western Australia. Both postharvest (primary and secondary) and field pests are given. An 'R' following the common name indicates resistant species as present in other countries (or states of Australia).

Rank	Common name	Species	Weighting (%)[a]
1	Lesser grain borer R	*Rhyzopertha dominica* (F.)	76.0
2	Granary weevil R	*Sitophilus granarius* (L.)	75.0
3	Saw toothed grain beetle R	*Oryzaephilus surinamensis* (L.)	75.0
4	Rust red flower beetle R	*Tribolium castaneum* (Herbst)	75.0
5	Confused flower beetle R	*Tribolium confusum* Jacquelin du Val	75.0
6	Khapra beetle	*Trogoderma granarium* Everts	70.0
7	Russian wheat aphid	*Diuraphis noxia* (Kurdj.)	68.0
8	Hessian fly	*Mayetiola destructor* Say	66.0
9	English wheat aphid	*Sitobion avenae* (F.)	64.0
10	Wheat stink bug	*Aelia rostrata* Boh.	54.0

[a] All completed questionnaire weightings can be between 0% and 100%—pests with every response of lowest impact will come out with a weighting of 0%, while pests with all high responses will be 100%.

Table 3. Plant threat questions and responses for each question and the response weighting.

Question	Question weighting	Response	Response weighting
1. Pest status in other countries	30	1. Not a pest in any country/state 2. Requires some management practice to control it in another country/state 3. Requires management practices to control it in most countries/states where present 4. A pest of national importance in one country/state 5. A pest of national importance wherever it is established	0 1 1.2 2 4
2. Expected long-term pest status in Western Australia (WA)	20	1. The pest status of this species will decline within 5 years of establishment 2. The pest status of this species will decline after 10 or more years 3. The pest status of this species generally remains unchanged over time 4. The pest status of this species will increase 10 years after establishment 5. The pest status of this species will increase with 5 years of establishment	1 1.2 1.4 1.6 2
3. Ability to invade	30	1. The species is not known to have spread beyond its native range 2. The last major species demographic change occurred more than 50 years ago 3. The last major species demographic change occurred 10–50 years ago 4. The last major species demographic change occurred 5–10 years ago 5. The last major species demographic change occurred in the last 5 years	1.1 1.3 1.5 1.7 2
4. Pest distribution	30	1. Species not established in neighbouring country or one sending host commodities or tourists to Australia 2. Pest established in a country with direct tourist flights to Australia 3. Pest long established in neighbouring country or one exporting host commodities to Australia 4. Pest recently (last 2 years) established in neighbouring country or one exporting host commodities to Australia 5. Pest present in another Australian state/territory 6. Pest present in another Australian state/territory exporting host commodities to WA 7. Pest already in WA	1.1 1.6 2.2 3 3.2 3.5 3.5
5. Ability to enter WA	50	1. Species never intercepted coming into Australia 2. Species never intercepted coming into WA 3. Species has been intercepted coming into Australia 4. Species has been intercepted coming into WA 5. Species frequently intercepted (more than twice a year) coming into WA	1.1 1.2 1.5 2 4
6. Ability to spread once established	30	1. Species will not spread from site of introduction 2. Species will have limited spread and only when associated with host material 3. Species will spread widely in association with host material 4. Species will spread widely independent of host material 5. Species will spread widely independently and with host material	1 1.2 1.5 2.5 3.5
7. Demographics of host	30	1. No host(s) present in WA 2. Host(s) distribution discontinuous across a small area of WA 3. Host(s) distribution continuous across a small area of WA 4. Host(s) distribution discontinuous across a large area of WA 5. Host(s) distribution continuous across a large area of WA	0 1.1 1.5 2 3
8. Species' climatic requirements	30	1. Species' climatic requirements not present within WA 2. Species restricted to narrow niche, e.g. specific glasshouse condition 3. Species' climatic range and economic host(s) distribution would have limited overlap in WA 4. Species' climatic range and economic host(s) distribution would overlap considerably in WA 5. Species unrestricted by climatic types present within WA	1.1 1.5 2 2.5 3
9. Impact on industry	40	1. None 2. Minor financial impacts on industry in short term 3. Major financial impact on industry in short term 4. Major financial impact on industry in long term 5. Industry not profitable in long term	0 1 2 4 6

Table 3. (cont'd) Plant threat questions and responses for each question and the response weighting.

Question	Question weighting	Response	Response weighting
10. Gross value of WA industry affected	40	1. No commercial value 2. Less than $1 million 3. $1–10 million 4. $10–100 million 5. $100 million – $1 billion ($1000 million) 6. More than $1 billion	0 1 2 4 6 8
11. Cost of control or eradication following pest establishment for a 30-year period	30	1. Net present value (NPV) less than $10,000 per annum 2. NPV between $10,000 and $100,000 per annum 3. NPV between $100,000 and $1 million per annum 4. NPV between $1 million and $10 million per annum 5. NPV greater than $10 million per annum	1.1 2 4 8 12
12. Insect species a vector of a plant or animal disease/ parasite	10	6. No record of being a vector 2. Potential vector 3. Vector of a minor disease/parasite 4. Vector of a significant disease/parasite 5 Vector of three or more significant diseases/parasites	1 1.3 2 3 4
13. Number of individuals required to establish breeding population	10	1. Enough individuals to establish a breeding population given favourable conditions 2. 4–10 males/females 3. 1 unmated female and 2 or 3 males 4. 1 mated female 5. 1 parthenogenetic individual	1 1.3 1.5 2 3

One can then compare this *total threat value* for khapra beetle (70) with the value of 'high' as arrived at by using methods used in the TDS. Please note that there are also a number of primary and secondary grain pests of which although relatively susceptible strains of the species are present in WA, we do not have the resistant strains as occurring in other parts of the country and the world. As shown in Table 2, these resistant strains are ranked as posing a very high risk to the Western Australian grain industry because of the exchange of infested material across state borders. All of these would end up as 'high' in using the TDS method, which is in contrast to the PTQ approach which enables finer grading and more sensitive ranking of these 'high' threats.

Results

Initial validation of the model was completed by processing common endemic pests such as Mediterranean fruit fly and blue–green aphid. This validation allowed question and response weightings (Table 3) to be assessed.

The average rankings of both exotic pests as well as resistant strains of the same but susceptible species occurring here (and which attack grain pre and postharvest) as assessed by the entomologists are listed in Table 2. Of the 10 pests, resistant strains of the lesser grain borer (see Table 2) were ranked as the top pest threat.

The model has also been used to rank pests identified as threats on threat summary tables compiled as part of the HortGuard® and GrainGuard® initiatives of the Department of Agriculture.

Reporting functions allow for ranking to be obtained for threats within an industry or across industries. For example, we have found that the khapra beetle presents a greater threat to the cereal industry alone than the Russian wheat aphid poses to all industries combined.

Researchers familiar with particular pests and the potential economic consequences can complete the questionnaire and obtain a ranking in under 10 minutes. The database comes pre-loaded with 4500 validated invertebrate species to avoid confusion over scientific and common names. The questions have been made available over the Internet so that opinions of international experts can also be solicited.

Discussion

The model has been well received by entomologists at the Department of Agriculture, Fisheries and Forestry – Australia and it will continue to be developed and adapted for national use. It has proven to be a very useful and quick means of semi-quantitatively assessing and ranking exotic pests. It allows a defined score to be used to justify the importance of a pest rather than relying on educated guesses or 'gut feelings'. This has become a valuable tool for the industry protection plans being developed as part of the HortGuard® and GrainGuard® initiatives (Landos et al. 2000). A refined version of the model may prove a useful tool in assessing exotic pests as part of the import risk assessment process being undertaken at the national level.

This state-based tool has been further developed and adapted to analyse national pest threats. The database is fully Internet-enabled and collaborators can now contribute their expertise online. Collaborator reporting is restricted to only those questionnaires completed by the user allowing personal rankings to be obtained. However, project administrators will be able to analyse reports of all completed responses, distilling a vast pool of collaborator expertise. More information on this project is available on the Internet at <http://www.agric.wa.gov.au/ento/threat.htm>.

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