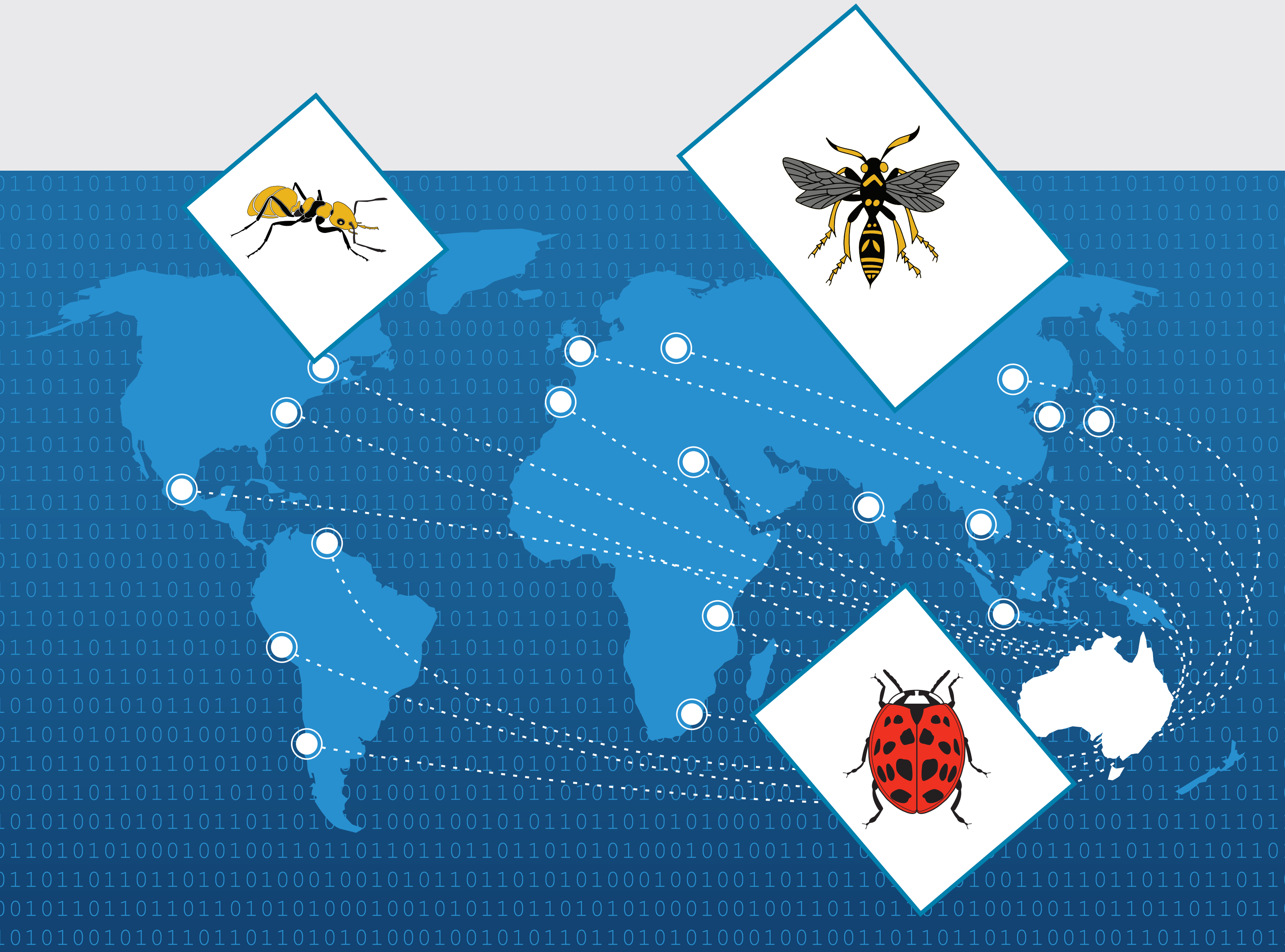
INVASIVE INSECTS

Risks and Pathways Project

Preliminary results and biosecurity implications, October 2019



MONASH University

invasive species council

Invasive Insects: Risks and Pathways Project

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Acknowledgements

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The research was conducted by the McGeoch Research Group of Monash University, led by Professor Melodie McGeoch, with contributions from:

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- International: Professor Helen Roy, Dr Sabrina Kumschick, Professor Andrew Liebold, Shyama Pagad.

The Invasive Species Council project leaders were Andrew Cox and Dr Carol Booth, with contributions from Tim Low.

The research benefited from the advice of a reference panel whose members were Dr David Yeates (Director, Australian National Insect Collection, CSIRO), Dr Suzy Perry (Principal Scientist in Plant Biosecurity, Biosecurity Queensland), Julie Quinn (Assistant Director, Environmental Biosecurity Section, Department of the Environment), Ian Thompson (Chief Environmental Biosecurity Officer, Department of Agriculture) and Dr Sally Troy (Assistant Secretary, Plant Health Policy, Department of Agriculture).

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About the Invasive Species Council

The Invasive Species Council was formed in 2002 to seek stronger laws, policies and programs to keep Australian biodiversity safe from invasive plants, animals, diseases and parasites.

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Introduction

Australia can't afford to allow in any more insect colonists like red imported fire ants, electric ants, browsing ants, yellow crazy ants, Argentine ants, African big-headed ants, Asian honey bees, large earth bumblebees and German wasps. These invaders are costing both the Australian environment and economy dearly. Hundreds of millions of dollars are being spent on Australia-wide eradications of red fire ants, electric ants and browsing ants because of their potential for devastating harm to wildlife and impacts on people. The others have spread too far to remove, so are here in perpetuity as a threat to biodiversity, human amenity and the economy, and a burden for future generations to manage.

Given the difficulties and costliness of eradicating or controlling invasive insects, one over-riding priority for Australian biosecurity must be to prevent more harmful species arriving and establishing. To do this, biosecurity authorities need to know which insects overseas (an estimated 4–6 million species) represent the greatest invasive risks for our country and how they are likely to arrive here. Biosecurity authorities already know which insects are the prevention priorities for agriculture, but there is no such list covering insects that could harm the Australian environment.

In 2017, with funding from the Ian Potter Foundation, the Invasive Species Council and the McGeoch Research Group of Monash University embarked on a project to fill that gap (Box 1). Additional funding came from the Australian and Queensland governments.

BOX 1

A community-based partnership contribution to biosecurity

This project represents a major community contribution to national biosecurity, led by a not-for-profit environmental organisation in collaboration with Australian and international researchers – an exemplar of the new 'partnerships' approach to biosecurity advocated by Australian governments.

It is the first systematic, comprehensive assessment of insects that cause environmental harm globally and the pathways by which they are transported – these are the species and pathways that need to be assessed for their specific risks to Australia. It is also the first dedicated, comprehensive assessment of the mechanisms by which invasive alien insects impact the environment, including horizon scans for elucidating the likely impacts of certain species in Australia should they invade. Internationally, the project makes a contribution by testing on insects the application of the *Environmental Impact Classification for Alien Taxa* scheme – a standard protocol being developed by the International Union for the Conservation of Nature.

The results of this research will be peer-reviewed and made available as an open access resource for the Australian and international communities (including a database of the more than 2000 species considered and species-by-pathways data). Publications will include information on the Environmental Impact Classification for Alien Taxa process and its application to insects, a list of 100 species ranked by their impact severity, pathway results and structured horizon scan.

The glassy-winged sharpshooter has invaded parts of the Americas and a few islands. It is a vector for a very serious plant pathogen, *Xylella fastidiosa*, which infects a wide range of tree crops as well as native plants. In high densities the bug can also weaken plants by consuming xylem sap.
Photo: Alex Wild

One insect order – that of ants, bees and wasps (Hymenoptera) – accounts for a major proportion of environmentally harmful insect invasions around the world. They are habitual and versatile world travellers and many are social. The most harmful of them – typically ants – tend to live in extremely large societies. This is the tawny crazy ant, which has invaded North and South America.
Photo: Michael Bentley | Flickr | CC BY-NC-ND 2.0

In Brazil, matings between African honey bees and European honey bees in the 1950s produced a hybrid called the Africanised honey bee, which has spread widely in the Americas.More aggressive than the European honey bee, it attacks and kills people. It competes with native pollinators for flowers and with birds for nest holes. Photo: Jeffrey W Lotz, Florida Department of Agriculture and Consumer Services | Bugwood.org | CC BY 3.0 US

1. About the project

BOX 2

Environmental Impact Classification of Alien Taxa (EICAT)

The EICAT scheme has been developed by the IUCN as an effective, transparent and standardised way to prioritise invasive species based on their impacts[2]. It can be applied to plants and animals and makes use of different types of evidence of variable quality. Assessed species are classified according to the mechanisms by which they cause impacts – for example, competition, predation, hybridisation with native species, disease transmission – and assigned to one of six impact categories, ranging from minimal to massive (and including data deficient), based on the maximum impact documented for the species anywhere in the world. The categories are based on the invasive species' impacts on native species populations (declines or extinctions), and community structure or ecosystem composition (reversible or irreversible changes). For example, 'massive' impacts involve the local extinction of native species and irreversible changes in community structure or ecosystem composition. The assessment for each species is also associated with a measure of confidence. In this project, each species was independently assessed by two expert reviewers. It was the first time this method has been applied to insects.

Our first objective was to identify high-priority potential insect invaders to Australia that could harm the natural environment, and their likely impacts and pathways of arrival. A second objective was to establish a best-practice process – comprehensive, robust, transparent, repeatable, updateable – for identifying environmental biosecurity priorities (high-risk species and pathways) that can be used for all species groups.

The first steps were to design an information platform and synthesise the scientific knowledge of invasive insect species causing environmental harm anywhere in the world. Evidence of harm elsewhere is the most reliable way to scope and delimit potential invasion risks. There are undoubtedly many other potentially harmful insects not yet invasive or not yet studied, but we cannot predict from traits alone which species will become invasive[1].

For each of the invasive insects for which there are multiple lines of evidence in the scientific literature of negative environmental impacts, we rated the severity of these impacts based on a scheme developed by the International Union for the Conservation of Nature (IUCN) – the Environmental Impact Classification of Alien Taxa (Box 2) – and also identified the pathways by which they have spread using the Convention on Biological Diversity's Categories of Introduction Pathways[2]. This detailed literature review and assessment work was carried out by a dozen insect and biosecurity risk experts from Monash University and other research institutions.

The results will be published as peer-reviewed scientific papers and in an open source information platform that enables updates as more information becomes available.

The tawny crazy ant has invaded North and South America. In areas colonised in Texas, this ant has within one year reached densities up to two orders of magnitude greater than the combined abundance of all other ants.

Photo: Alex Wild and Ed Le Brun

The tawny crazy ant dominates ecosystems, eating invertebrates, displacing other ants, attacking mammals and birds, tending sap-sucking bugs that harm plants, and spreading plant diseases. Invades homes and gardens, causes electrical malfunctions in businesses and homes, spreads pathogens in hospitals, harms livestock and crops.”

Invasion Watch Species Profile

2. Invasive insects causing environmental harm

Insects are the world's most diverse class of animals and have a profound ecological influence (whether as native or non-native species), including as predators, plant-eaters, pollinators, parasites and disease carriers (Box 3). Their abundance and functional and biological diversity, as well as small size, rapid reproduction, multiple life stages and often-cryptic habitats, make them a very important but very challenging group of animals for biosecurity (Box 4).

For insect invaders of agricultural systems, it is usually straightforward to predict their impacts because the same plants and animals are typically farmed all over the world and there is often only one type of interaction responsible for the economic impact of an invasive species. However, predicting the impacts of environmental insect invaders is more difficult, because the ecology of natural systems is much more complex and differs from country to country. Australia's long isolation from other continents means that most of our terrestrial species are unique[3] and, as is typically the case for islands, many are likely to be susceptible to the impacts of invasive species due to their 'ecological naivete' (when native species have not previously been exposed to certain traits of invasive species)[4].

In contrast to the mountain of studies on the agricultural impacts of invasive insects, there was until recently very little work on their ecological impacts[5]. Of the world's estimated 4 to 6 million insect species – of which only 1 million

The European fire ant has invaded North American and Japan. It can reach extremely high densities, displacing nearly all other ants and reducing other insects, including in intact forest habitats. It attacks small mammals and kills nestling birds.

Photo: Kjetil Fjellheim | Flickr | CC BY-NC 2.

have been described – more than 2800 have been reported as having an environmental impact outside their native range (Figure 1). There is published evidence of negative environmental impacts for more than 500 species, and sufficient weight of evidence from multiple sources for about half of these (247 species) to allocate them to a high priority assessment pool for further consideration. There are likely to be many more invasive insects having environmental impacts that haven't been studied[6].

The assessment pool of 247 species includes 17 already established in Australia (excluding external territories) for which there is evidence of environmental harm here (Table 1). There are other exotic insect species in Australia but their environmental impacts are mostly not studied. It is important to include already-established species in the assessments to help set priorities and because new introductions could result in them establishing in new areas, introducing new diseases or becoming more genetically diverse, boosting their potential for causing harm[17,19]. So far, we have assessed about 100 of the priority species for their global environmental impacts (by the EICAT method).

Of the 100 species assessed so far about three-quarters have concerning impacts on biodiversity somewhere in the world:

- 29% are 'of substantial concern' (based on being rated as 'massive' or 'major' in the EICAT assessment).

BOX 3

How invasive insects can harm native biodiversity

The variety of impact mechanisms of invasive species are encompassed within the following Environmental Impact Classification of Alien Taxa categories, with examples from the species EICAT-assessed in this project[7].

Predation: The yellow crazy ant (*Anoplolepis gracilipes*) on Christmas Island has killed more than 10 million red land crabs, a keystone species, resulting in irreversible changes to the structure of the rainforest[7].

Competition: The harlequin ladybird (*Harmonia axyridis*) outcompetes several other aphid-eating species and preys on them as well, leading to major declines in several native ladybird species in Europe and North America[8].

Herbivory: The cycad aulacaspis scale (*Aulacaspis yasumatsui*) feeds on the sap of cycads, depleting carbohydrates and often killing the plant[9,10]. One affected species, *Cycas micronesica*, was once the most common tree on Guam and is now listed as endangered[9].

Parasitism: The fly *Bessa remota* is a moth parasite. Introduced to Fiji as a biological control agent against moths attacking coconut palms, it may have caused the extinction of native zygaenid moths[11].

Transmission of disease: The glassy-winged sharpshooter (*Homalodisca vitripennis*) is a vector for a very serious plant pathogen, *Xylella fastidiosa*, which infects plants from many different families, including Australian plants grown overseas[12, 13].

Interaction with other exotic species: The European fire ant (*Myrmica rubra*) causes harm in part by benefiting other invasive species. It increased the recruitment of the North American weed greater celandine (Chelidonium majus) more than eight-fold by dispersing its seeds more effectively than native ants, and may help the harlequin ladybird (*Harmonia axyridis*) by attacking its competitors[14, 15].

Facilitation of native species: The seedhead fly *Urophora affinis*, introduced as a biological control agent to North America, has become super-abundant, elevating populations of a native predator, the deer mouse (*Peromyscus maniculatus*), potentially disrupting food webs and increasing the prevalence of a deadly disease[16].

Hybridisation: A parisitoid of gall wasps, *Torymus sinensis*, introduced into Japan to control the invasive Asian chestnut gall wasp (*Dryocosmus kuriphilus*), is displacing a native parasitoid by hybridising with it[18].

Table 1: Invasive insect species for which there is evidence of environmental harm in Australia					
Order	**Family**	**Species**	**Common name**	**Year of first detection or mention**	**First state or territory record**
Hymenoptera	Apidae	*Apis mellifera*	European honey bee	1820	Queensland
Hymenoptera	Formicidae	*Solenopsis geminata*	Tropical fire ant	1863	?
Hymenoptera	Formicidae	*Paratrechina longicornis*	Black crazy ant	1886	Queensland
Hymenoptera	Formicidae	*Monomorium floricola*	Floral ant	1910	Queensland
Hymenoptera	Formicidae	*Monomorium destructor*	Singapore ant	1910	Queensland
Hymenoptera	Formicidae	*Pheidole megacephala*	African big-headed ant	1911	Queensland
Coleoptera	Scarabaeidae	*Heteronychus arator*	African black beetle	1920	South Australia
Hymenoptera	Formicidae	*Linepithema humile*	Argentine ant	1939	Victoria
Hymenoptera	Vespidae	*Vespula vulgaris*	Common wasp	1959	Victoria
Hymenoptera	Vespidae	*Vespula germanica*	European wasp	1959	Tasmania
Hymenoptera	Formicidae	*Anoplolepis gracilipes*	Yellow crazy ant	1975	Northern Territory
Hymenoptera	Vespidae	*Polistes chinensis*	Asian paper wasp	1979	New South Wales
Hymenoptera	Megachilinae	*Megachile rotundata*	Leafcutting bee	1987	New South Wales
Hymenoptera	Apidae	*Bombus terrestris*	Large earth bumblebee	1992	Tasmania
Hymenoptera	Formicidae	*Solenopsis invicta*	Red imported fire ant	2001	Queensland
Hymenoptera	Formicidae	*Wasmannia auropunctata*	Electric ant	2006	Queensland
Hymenoptera	Apidae	*Apis cerana*	Asian honey bee	2007	Queensland

Note: This list excludes external territories.

- 47% are 'of concern' (based on being rated as 'moderate' or 'minor' in the EICAT assessment).
- 11% are 'of minimal concern' (based on being rated as 'minimal' in the EICAT assessment).
- 13% are 'data deficient'.

The most common mechanisms by which these invasive insects are having an environmental impact are competition, herbivory, predation and transmission of disease.

The next step is to assess the Australia-specific risks of all 'of substantial concern' and 'of concern' species. Not all the species assessed as having impacts overseas will be a risk for Australia – for example, if their food sources do not occur here or the climate is not suitable – and, conversely, the risks of some species will be greater for Australia than indicated by impacts elsewhere.

Some clear patterns have emerged from the assessments with relevance for Australian biosecurity. One is that a very few insect groups dominate the assessment pool of 247 harmful insect invaders. Of the world's 24 orders of insects, only 10 are represented in this pool and only 6 are represented by more than one species (Figure 2). By far the most dominant group are the ants, bees and wasps (order Hymenoptera), accounting for half of the pool species. They also account for all but one of the exotic insect species in Australia for which there is evidence of environmental harm (Table 1). Most invasive Hymenoptera are sociable, living in colonies, and their sociality – often extreme in invasive ants – helps explain their invasion success and the immense harm they can cause (see reference 21 for an overview).

BOX 4

The western yellowjacket has invaded Hawaii, where it is having dramatic ecological impacts. With hives that can contain half a million wasps, it exerts very high predation pressure on insects and spiders. In two national parks, it depressed spider densities by 36% and caterpillar densities by 86%. It is an aggressive 'nectar thief', reducing seed production by Hawaii's dominant tree, ohia, by taking its nectar without spreading the pollen, and displacing native bees and wasps. Photo: Ken Schneider Flickr CC BY-NC 2.0

Features of insects and their implications for biosecurity

Features of insects that make them particularly challenging for biosecurity (20) include:

- **Small body size and cryptic habits**
  ⟶ difficult to detect and identify during inspections; may require specialised equipment or methods.
- **Highly diverse and many undescribed species**
  ⟶ identification is often difficult and uncertain; requires several different taxonomic experts; creates uncertainty about how to respond to interceptions and incursions.
- **Several life stages**
  ⟶ increases the difficulty of identification; identification keys are usually not available for larvae and eggs.
- **Many cryptic species**
  ⟶ creates uncertainty about identification and about which species are native or exotic.
- **Carry diseases**
  ⟶ creates uncertainty in how to respond to new detections of species already established in a country; new arrivals may carry new diseases.
- **Some reproduce asexually or parthenogenetically**
  ⟶ increases biosecurity risks by potentially enabling one individual to establish a new population.
- **Able to survive adverse conditions**
  ⟶ allows live individuals to travel with imported goods or on vessels, even under adverse conditions.
- **Mobile (able to fly or be carried by the wind)**
  ⟶ allows some species to easily escape port areas.

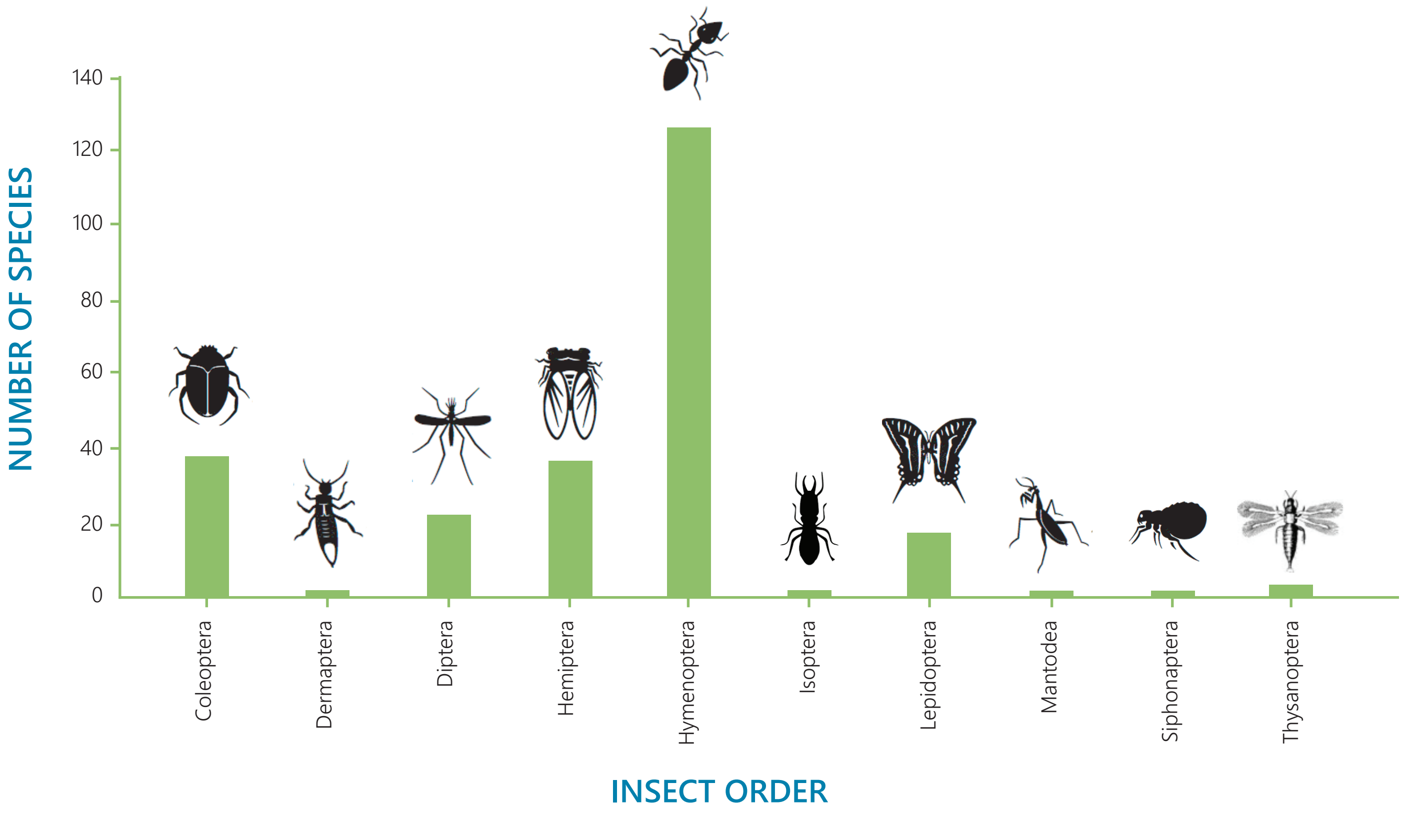


Figure 2: The insect orders with the highest numbers of environmentally harmful invasive insect species worldwide.

The next most prevalent invaders are beetles (order Coleoptera), making up about one-sixth of the assessment pool, and sap-sucking insects (order Hemiptera), about one-seventh of the pool. Besides ants, bees and wasps (order Hymentoptera), insect families in other orders that are prevalent among the harmful invaders are aphids (family Aphididae) and true weevils (family Curculionidae).

One likely reason for the prevalence of these groups of insects is their association with particular pathways of spread around the world that enable large numbers to be introduced (exerting high 'propagule pressure')[1]. Also, the Hymenoptera may have an invasive advantage because they nest in materials that are often transported[22].

Although there are overlaps, the insect group priorities for environmental biosecurity differ from those for agricultural biosecurity. While ants, bees and wasps dominate the environmental invaders, beetles, bugs, moths and flies are most common among plant-based agricultural invaders[23]. A priority for further research is an examination of the overlap between species causing environmental and agricultural harm and a comparison of their pathways of introduction and spread.

The world’s insects: About 1 million species have been described of an estimated 4–6 million species in total.

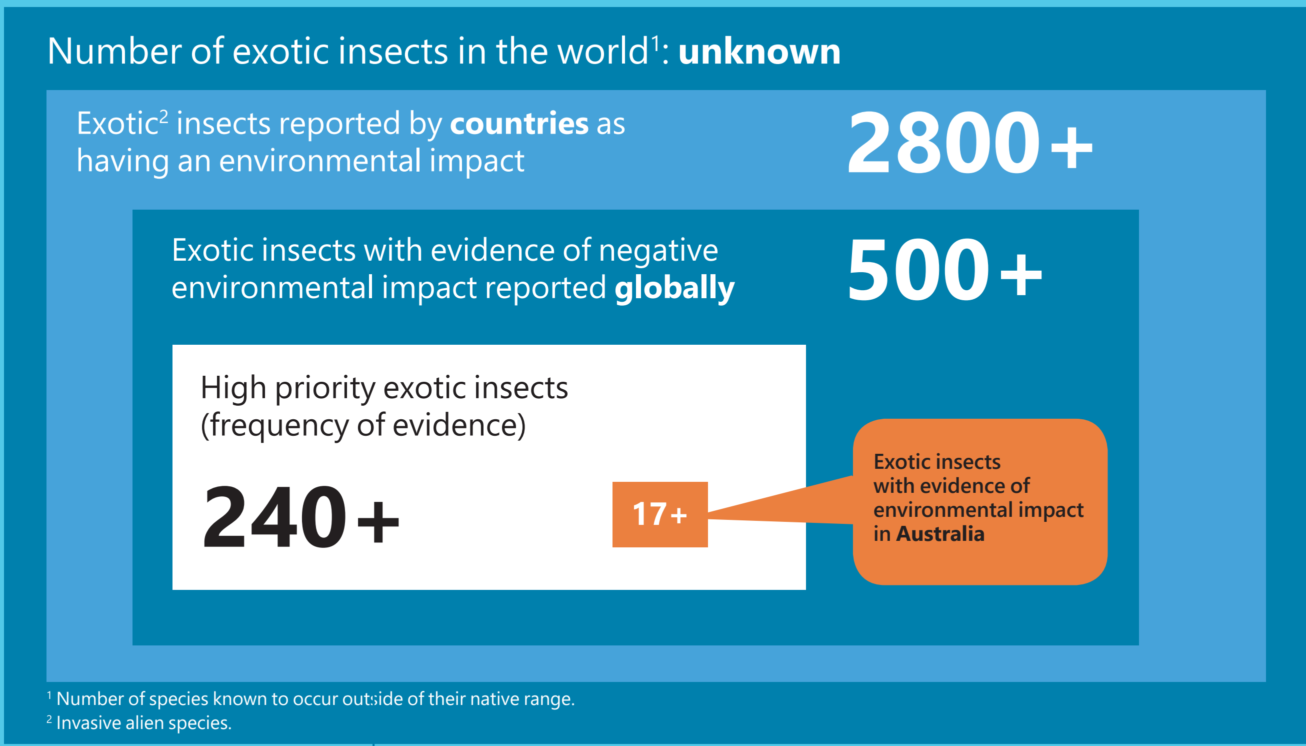


Figure 1: The process for refining the species pool of invasive insect species. The ‘high priority exotic insects’ (white square) are those species for which there is evidence from multiple sources that they have negative environmental impacts. They are a high priority for EICAT assessment and referred to in the text as the ‘assessment pool’. (‘Reported globally’ means that there is literature evidence from at least one place in the world of the species causing negative environmental impact).

3. The pathways by which invasive insects travel

In this age of globalisation, with more than 50,000 merchant ships plying the seas[24] carrying some 10 billion tonnes of goods a year[25, 26] and some 10,000 planes plying the air at any one time[27], there are many ways for insects to travel to new countries. They can be introduced intentionally (for biological control, for example), unintentionally as contaminants of traded goods (such as flowers or timber) or stowaways on ships or planes, or by natural dispersal from another invaded country.

In this project we recorded all the pathways by which the assessment pool of 247 invasive insects have spread around the world, using a hierarchical scheme adopted by the Convention on Biological Diversity that encompasses 44 different pathways. Again, clear patterns have emerged from this assessment with relevance for Australian biosecurity. Most (85%) of the harmful insect invaders for which there is information about pathways have been introduced unintentionally. This is the opposite of the situation for invasive plants and vertebrate animals, the vast majority of which have been introduced intentionally[28-30]. However, the pathways for close to half the harmful insect invaders are unknown.

Because most invasive insects are introduced unintentionally across a large number of pathways – making it difficult to predict which species will arrive – there should be a strong biosecurity focus on identifying high-risk pathways and minimising their risks[2]. This offers the potential to prevent a large number of new species arriving, including those whose invasion risks are unknown.

Our assessment found that 10 of the 21 unintentional pathways are commonly used by invasive insects (Figure 3). The ants, wasps and bees, in particular, and the beetles as well, use all 12 of the most prevalent pathways, indicating that flexible travel habits (through their association with a wide range of traded products and ability to endure adverse conditions during travel) are a major reason for their high level of invasiveness (see Figure 3). There is of course variation within insect orders (family level and below) in which pathways are used.

The top three pathways are contamination of imported plants, nursery material and the timber trade. The first two of these highlight the importance of a biosecurity focus on imports of cut flowers and foliage (see Box 5), with more than 70 environmentally harmful invasive insect species (mostly bugs, beetles and ants) known to have been introduced around the world as contaminants of plants and nursery material. From 2007 to 2017, more than half the consignments of cut flowers and foliage arriving at the Australian border were found to contain live arthropods (31). To help determine the highest-risk pathways to Australia, this assessment of pathways used globally needs to be supplemented with Australian-specific information about which insect groups are most commonly detected on which pathways at the national border.

BOX 5

Cut flower and foliage imports as a high-risk pathway for the introduction of invasive insect species

This project found that more than 70 invasive insect species with documented environmental impacts somewhere in the world have been transported on pathways likely to be associated with the international trade in cut flowers and foliage as contaminants on nursery material or plants or as parasites on plants. More than three-quarters are bugs (32%), beetles (21%), ants (18%) or moths (10%).

The Australian government is conducting pest risk analyses for cut flower and foliage imports. Part 1, focused on aphids, thrips and mites, was published in 2018[31]; part 2 will focus on other arthropods.

The risk analysis explains the high risks of this pathway. Almost a quarter (23%) of arthropods detected on imported goods have arrived with imported cut flowers and foliage. Over the decade to 2017, imports of cut flowers and foliage increased more than three-fold and detections of live arthropods at the Australian border increased dramatically from 13% to 58% of consignments. Of 241 species of aphids,

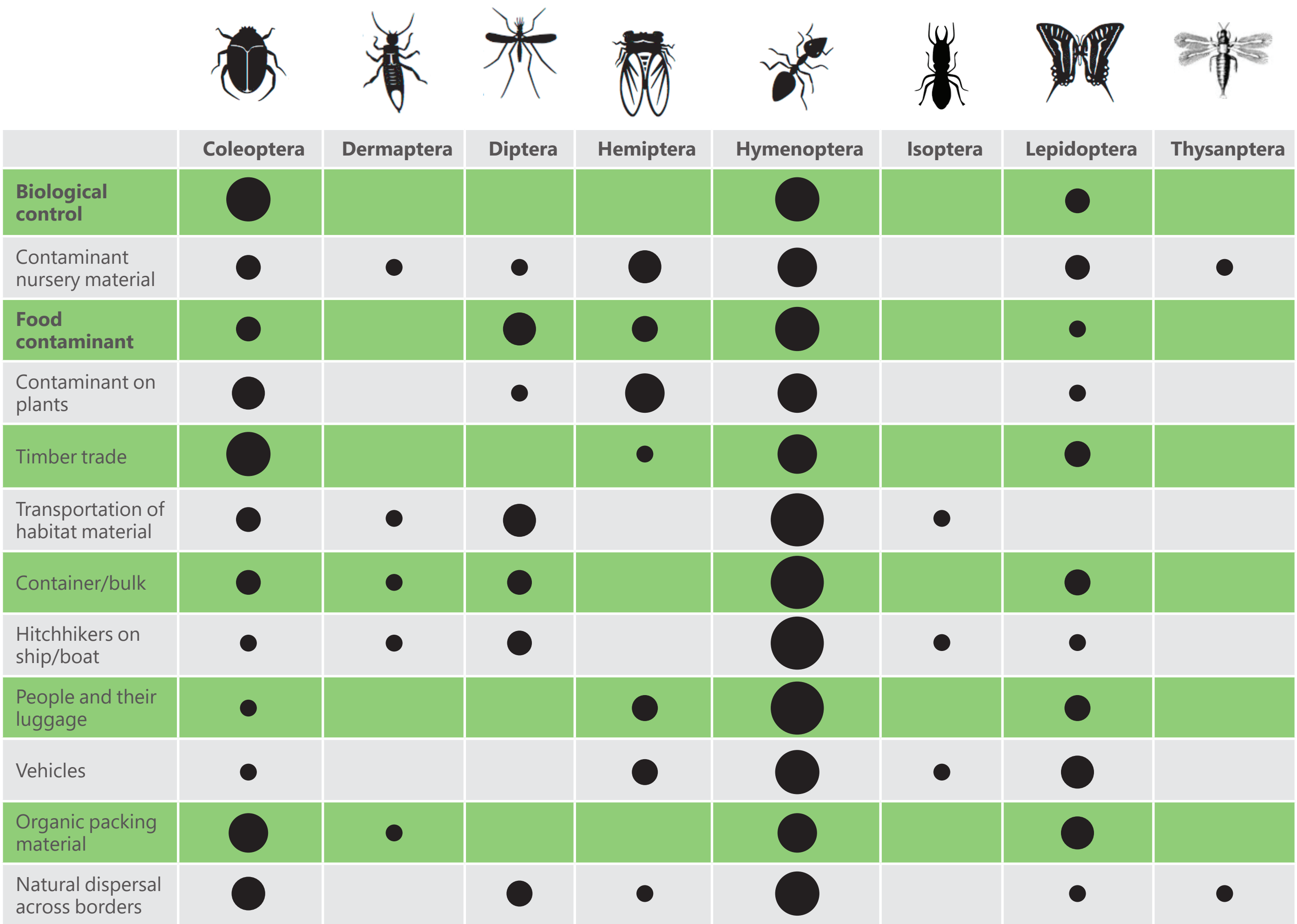


Figure 3: The use of introduction pathways by invasive insects. Only the most prevalent pathways and insect orders are shown. Circles and their sizes represent the relative contribution (%) of each insect order to the number of species using a particular pathway. For example, an insect on the food contaminant pathway is more likely to be a Hymenopteran than a Dipteran. Circle sizes (from smallest to largest) represent 1–10%, 11–20%, and so on up to 60%. Note that the figure does not provide information on the relative importance of pathways per se.

thrips and mites identified by the government as being of potential concern on this pathway, they assessed 35 mite, 40 aphid and 82 thrips species, and determined that risks for all three groups were too high. Some import conditions were amended in 2018 and 2019 to reduce the risks.

The risk analysis focused mainly on economic risks. Environmental consequences were considered as a subset of economic consequences and mostly lacked detail. The risk assessments noted 'the potential for negative consequences such as environmental impact' for 14 mite species, but not for any of the insect species (aphids and thrips). None of the seven aphid species for which the Insect Impacts and Pathways project found evidence of environmental impacts are specified as environmental risks in the analysis;.

The lack of environmental focus in the assessments is partly due to the scarcity of information on environmentally harmful species, but at the very least environmental consequences should be assessed separately from economic consequences and in as much detail as permitted by the available evidence. Examination of the potential environmental risks of aphids as disease vectors should be a priority.

4. Predicting how invasive insects could harm the Australian environment

For insect invaders of agricultural systems, it is usually straightforward to predict their impacts because the same plants and animals are typically farmed all over the world and there is often only one type of interaction responsible for the economic impact of an invasive species. However, predicting the impacts of environmental insect invaders is more difficult because the ecology of natural systems is much more complex and differs from country to country. Because of Australia's long isolation from other continents, most of our terrestrial species are unique[3] and, as is typically the case for islands, many are likely to be susceptible to the impacts of invasive species due to their 'ecological naivete' - when native species have not previously been exposed to certain traits of invasive species[4].

Structured horizon scans are one way of explicating the likely Australian-specific ecological consequences of invasive insect species[23,24]. Horizon scans combine expert judgement with scientific evidence to describe likely invasion scenarios by identifying sensitive and susceptible areas, the mechanisms of impact (and their likelihood) and the potential ecological consequences (see Figure 4). We conducted nine such scans to assess the potential of this approach for helping biosecurity decision-makers understand and assess risks and prepare responses for incursions.

Across the nine scans, competition, predation and herbivory were the most common impact mechanisms. Most invaders are likely to have multiple types of impact in the Australian environment – with competition, predation and herbivory often co-occurring – and therefore have multiple ecological consequences, highlighting the complexity of environmental invasions, as shown by the structured horizon scan for the yellow crazy ant (Figure 4). In another example, for a species not yet in Australia, the scan for the common eastern bumblebee (*Bombus impatiens*) identified four impact mechanisms and eight ecological consequences for Australia. The potential interactions with many other species, both native and invasive, make the outcomes hard to predict. They could significantly alter plant communities due to the expansion of sleeper weeds, increased reproduction in native or invasive plant species, and competition for flowers with other insects[32-34].

We found that horizon scans are useful for explicating potential invasion scenarios and recommend they be conducted by ecological experts for all priority potential insect invaders.

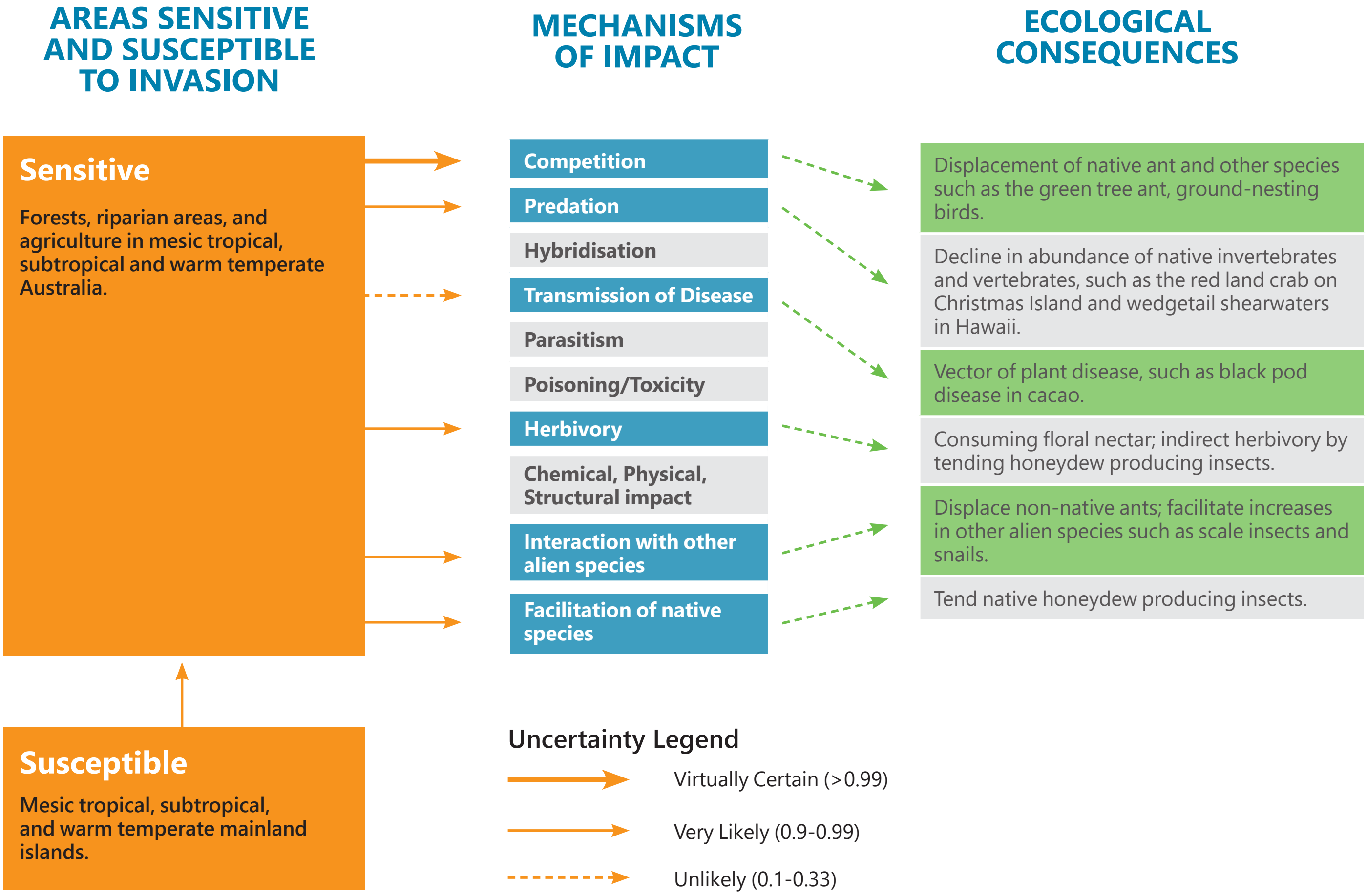


Figure 4: Horizon scan for the yellow crazy ant (*Anoplolepis gracilipes*) conducted by Associate Professor Lori Lach (James Cook University). This species is already in Australia and was used to exemplify this approach to better understand the potential ways in which a high risk invader could impact the Australian environment. Using a combination of published evidence and expert interpretation, the structured horizon scan examines areas susceptible (most likely to be invaded) and sensitive (most likely to experience greatest impacts) to invasion by the species[3], the mechanisms (or means) by which these impacts are realised (associated with an estimate of uncertainty), and the ecological consequences of these. The green arrow pointing to disease transmission is based on current evidence in agricultural settings only.

5. The way forward

The Invasive Insect Risks and Pathways Project has fulfilled two main purposes – identifying invasive insect species and pathways of concern for the natural environment and developing a best practice process for this that can be applied to all species groups. The assessment work is ongoing, including to complete all EICAT assessments and assess the potential ecological consequences for Australia of certain priority invasive insects.

The next steps, as outlined below, are to work with Australia's biosecurity agency and other stakeholders to:

(a) incorporate the results of the project into the national biosecurity system;

(b) apply the process to other species groups and

(c) establish a sustainable and publicly accessible data platform to maintain and regularly update information on potential invasion risks for the Australian environment.

The Invasive Species Council and Monash University are seeking funds to undertake a similar assessment for invasive fungi.

5.1 Preventing insect invasions into Australia

5.1.1 Priority species: Invasive insect species of environmental concern should be incorporated into Australia's biosecurity system. (The Australian government has taken a step towards this with the recent release of the 'Priority list of exotic environmental pests and diseases'; however, it only includes five priority insect species)[36].

- Initially, assess all 'of substantial concern' and 'of concern' insect taxa for their specific risks to the Australian environment.
- Prepare risk profiles for all high-risk invasive insect species.
- Review biosecurity protocols, including treatment, inspection and surveillance regimes, for their adequacy to kill or detect insect species, at different life stages, assessed as an environmental risk for Australia.
- Include a strong focus on the environmental risks of invasive insects in all relevant pest risk analyses.
- Develop contingency plans for all high-risk invasive insect species.
- Incorporate high-risk invasive insect species into the Department of Agriculture's Risk Return Resource Allocation model.
- Conduct research to fill information gaps for potential high-risk species where there is high uncertainty of impacts or other data deficiencies.
- Regularly update the invasive insects impacts and pathways database to identify new 'of concern' taxa and update ratings for previously assessed species, particularly those that are data deficient.

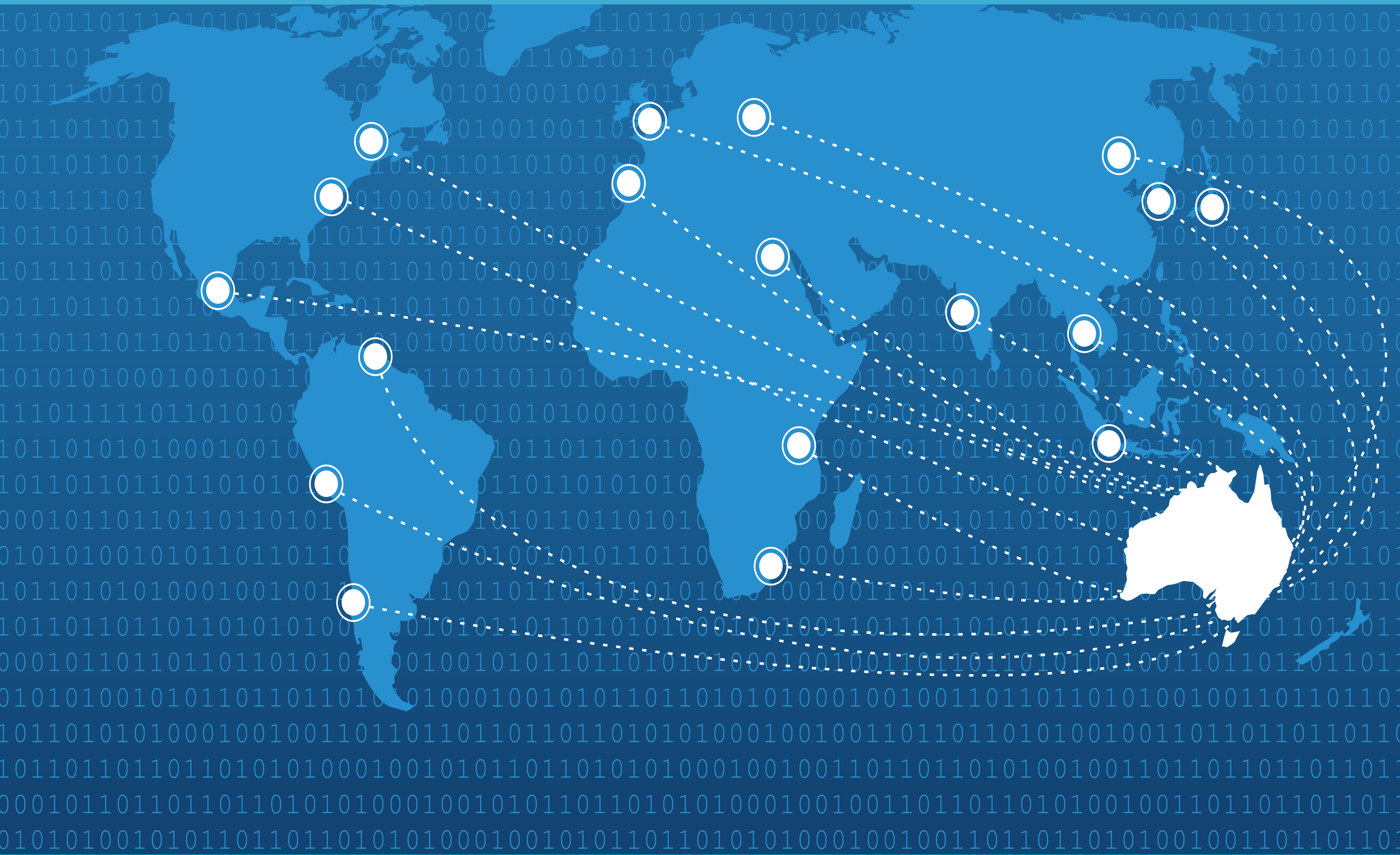
5.1.2 Introduction pathways: Recognising that most insect introductions are unintentional and that there are likely to be many more harmful insect invaders than are currently documented, there should be a strong focus on reducing the risks of insect spread via the most common pathways for unintentional introductions.

- Accord high priority to reducing the risks of insect introduction via the 10 most prevalent international pathways for unintentional introductions.
- Assess the Australian-specific environmental risks of these pathways, including by comparing pathway prevalence for priority insect species with Australian intercept data.
- Compare the highest-risk environmental pathways to those of highest risk for Australia's primary industries to identify and address any gaps for where additional environmental pathway-focused effort is needed.
- Impose import conditions to reduce the risks of new insect introductions via high-risk pathways.
- Regularly update pathway information based on the global literature and Australian interceptions.
- Evaluate the effectiveness of Australian biosecurity measures for high-risk pathways.

5.1.3 Social bees, wasps and ants: Because of the prevalence of social Hymenoptera, particularly ants, as invaders, their harmful impacts on biodiversity, and their wide and versatile use of introduction pathways, reducing the risks of hymenopteran introductions should be a top priority for biosecurity.

- Fully implement Australia's invasive ant biosecurity plan (35). One particularly important action (6.5), essential for coordination and motivation, is to establish a 'permanent national body to coordinate national actions on invasive ants'.
- Develop a biosecurity plan (or

BOX 6



The process used in this project to assess and prioritise invasive species potentially harmful for the Australian environment, and their pathways of introduction and spread

1. Design an information platform (contributing to work internationally to deliver an information system for invasive species).
2. Generate a candidate invasive species pool from global and national databases.
3. Systematically collate the scientific literature on the species group being assessed.
4. Determine which species are established in Australia.
5. Apply a structured decision-making method – here the Environmental Impact Classification of Alien Taxa – to identify and rate the primary impact mechanisms of each species.
6. Conduct a specialist workshop to fill gaps with expert knowledge.
7. Identify global pathways for each priority species (eg based on the 44 pathway categories endorsed for the Convention on Biological Diversity).
8. Integrate the species and pathways information.
9. Populate the open-source database.
10. Conduct Australian-specific risk assessments for each species rated as having impacts of concern somewhere in the world.
11. Conduct Australian-specific risk assessments for the most prevalent global pathways for introductions.

plans) for other high-risk social Hymenoptera.

- Strengthen Australia's preparedness to respond to new incursions of social Hymenoptera. This requires developing effective surveillance programs and being well prepared to eradicate new incursions. Surveillance of bees, wasps and ants in Australia can be boosted by citizen science programs with scientific support, including for confirming species identification.

5.1.4 Established invasive insects: Given the risks of boosting the invasiveness or impacts of exotic insect species already established in Australia by introducing new subspecies or genetic variants, there should be a biosecurity focus on preventing new arrivals that could exacerbate their harm.

- For those invasive insects already established in Australia that are known to cause environmental harm, assess the risks of introducing new subspecies and other genetic variants.
- Apply import conditions and manage pathways (consistent with Australia's legal obligations) to limit the risks of new potentially harmful introductions of existing insect invaders.

5.2 Applying best practice processes for prioritising potential environmental invaders

5.2.1 Other species groups: The methods used in this project to identify high-priority invasive insect species and pathways globally are robust, transparent and repeatable (available via the publications to emerge from this work). Inclusive rather than exclusive, the process provides a comprehensive base of information from which to assess Australian-specific biosecurity priorities. An additional benefit of the EICAT method (Environmental Impact Classification of Alien Taxa) is that it is endorsed by the IUCN, which will facilitate data-sharing worldwide and the development of compatible databases. The same is true of the Pathway Categories used in this project. The research and process requires an initial moderate financial investment and ongoing minor investments for regular updates.

- Apply a similar robust, transparent, repeatable and inclusive process to other species groups as the basis for determining priorities for Australian environmental biosecurity (see Box 6 for a summary of the steps).
- Invest in regular updates of the results database as the basis for maintaining up-to-date biosecurity priorities.

5.3 Sustaining the process with an accessible data platform

5.3.1 Database: A national public exotic and invasive species data platform is an essential tool for Australian biosecurity.

- Establish a national exotic and invasive species data platform that:
  - provides comprehensive, up-to-date information to support risk assessments, including information on impacts, pathways and potentially susceptible and sensitive sites;
  - is updateable, repeatable, with full references for all information and levels of confidence assigned for all assessments;
  - is accessible to all (except for restricted information such as trade-sensitive interception data);
  - is sustainable, with resources allocated for regularly updating the information and quality control.
- Develop a policy for information-sharing that specifies the process for making information accessible to researchers while protecting Australia's interests (to protect trade-sensitive information, for example). It is strongly in the public interest for researchers to have simple access to data so that they can conduct research that supports biosecurity.

The adult harlequin ladybird is one of the most variable-looking species in the world (hence the name 'harlequin'), making identification difficult. Some are red or orange with 0 to 21 black spots; others are all black or black with 2 or 4 orange or red spots. Most have white on the pronotum (the first segment behind the head) with black spots that usually form an 'M' or 'W' shape (the easiest way to identify them). The small head is mainly black and white. They range in size from 5.5 to 8.5 mm.

Photo: Gilles San Martin | Flickr |

"Should the harlequin ladybird establish in Australia, we must be concerned about the fate of native ladybirds and other insects that prey on the aphids and scale insects eaten by the harlequin as well as other prey species. Australia has about 500 species of ladybird, mostly endemic, with about half yet to be described."

Invasion Watch Species Profile

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