Defending national and internal borders against invasive insects

Symposium at XXIII International Congress of Entomology

Co-organised by Craig Phillips (Better Border Biosecurity, New Zealand) and
James Ridsdill-Smith (Cooperative Research Centre for National Plant Biosecurity, Australia)

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Foreward

Craig Phillips
Better Border Biosecurity, New Zealand

The abstracts given here make up the talks for a symposium on *Defending National and Internal Borders against Invasive Insects* held at the 2008 International Congress of Entomology in Durban, South Africa.

The all day symposium described trade-quarantine and incursion-response measures, which have traditionally had to look to pest management research for support, and are now benefiting from a more direct focus of research on border biosecurity. Indeed, knowledge from border biosecurity research is beginning to flow back the other way, and is providing valuable spin-off benefits for pest management; this was particularly apparent in the sessions on *Detection and Diagnostics* and *Incursion Response*.

A second feature of border biosecurity research that was clearly evident at the symposium was the diversity of scientific disciplines and technological approaches required to help limit the spread of unwanted species into new regions. The presentations included new approaches to computation and modelling, electronic data capture, risk assessment, host range testing, diagnostics, surveillance and eradication.

Most threats from invading species are pests in another country, and this symposium showed the importance of greater international cooperation. As David Nowell reinforced in his keynote address, preventing the spread of unwanted species demands the implementation of management measures that are integrated across regional, national and international scales. The authors of the presentations were from ten countries, including representatives of both hemispheres. The coordinators hope that this symposium will encourage stronger awareness and better collaboration between countries in the future.

Abstracts of papers given at Symposium 16.5, held as part of the XXIII International Congress of Entomology 2008

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Thursday 10 July 2008, Durban South Africa

Co-organisers:

Craig Phillips (Better Border Biosecurity, New Zealand), and James Ridsdill-Smith (Cooperative Research Centre for National Plant Biosecurity, Australia).

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Keynote address

Plant biosecurity capacity to protect national and internal borders against invasive insects

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Invasive insects have had, and still have, a very significant negative economic, social and/or environmental impact. Such impacts in agriculture are usually quantifiable as loss of production or financial losses (incursions can have a major economic impact on market access and trade), many other impacts such as environmental and social impacts are less easily quantified. It is economically and ecologically far more cost effective to prevent pest entry into a country, than trying to manage or eradicate the pest after it has established.

Although national legislative and institutional frameworks, based on the *International Plant Protection Convention* (IPPC), are necessary for a biosecurity system to function, science provides the foundation for this process. However, the biology, ecology or impacts of many invasive insects are often not completely understood making the accurate assessment of risk and the development of mitigation options difficult. Management tools to support this process are often limited or poorly developed. Anticipated climate changes will ensure that we have to revise all current risk assessments and mitigation measures as the environment changes. Pivotal to managing increasing challenges by invasive insects are international cooperative approaches. The IPPC is developing standards for countries to use in trade, as well as building the capacity to implement these on a worldwide basis.

We need to find new ways of working more efficiently (e.g. risk assessment and emergency response), greater integration and coordination (e.g. public, academic and private research), improved communication and transparency, increased cooperation (e.g. surveillance, diagnostics and reporting), and develop new tools (e.g. diagnostics and treatments).

Theme 1 – Risk analysis and preparedness

Being prepared: ecological informatics and computational intelligence methods applied to invasive insect risk assessment

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As increasing numbers of species are moved around the world and as ranges alter in response to climate change, risk assessment of potential alien invasive species becomes increasingly important. Risk assessment and analysis are required to make decisions concerning which species are likely to cause economic or environmental damage and to allocate resources to prevent or control an incursion. Risk assessments are usually qualitative and reactive and often focused on individual species. Yet, when large numbers of insect species have potential for harmful impact in regions where they are not normally found, conventional risk assessment does little to help prioritise the risk. New approaches based on neural networks, machine learning and spatially explicit models are described that allow pre-emergent species to be identified, potential establishment to be predicted with high accuracy, and spread over a detailed heterogeneous landscape to be simulated. Prioritisation of potential invasive insect species with respect to risk adds a new tool to the risk analysis framework. A multi-model ensemble approach to prediction of potential non-native species establishment, allows sources of uncertainty to be identified. Additionally, prediction of potential establishment and simulation of spread over topographic, climatic and land-cover features, results in realistic dispersal patterns and identification of potential 'hotspots'. Given appropriate data, a spatially explicit model such as that described here not only allows sampling programs for detection to be tested, eradication strategies to be evaluated, but also bio-economic models of impact to be refined before an incursion occurs. These quantitative approaches allow uncertainty to be evaluated and utilised for a more informed approach to the threat of non-native insect incursion.

Using artificial neural networks to predict and quantify risk of invasion by insect pests

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Introduction: Predicting which species are most likely to invade a particular region presents significant challenges to researchers and government agencies. In order to rank the potential list of invasive species, experts and stakeholders are often consulted for their opinion. This method, while valuable, can bring a level of subjectivity to the process. Artificial neural networks, specifically self organising maps (SOMs), present the possibility of objectively identifying and quantifying the risk of invasion by insect pests.

Methods: We used presence/absence data of insect pests from the CABI Crop Pest Compendium. We tested the effect of errors in this data set on risk list stability. The data set was altered and we generated SOMs of different sizes to determine the resilience of these risk lists.

Results: We found that the lists generated from smaller maps were more sensitive to these errors than the larger maps. However, the lists generated showed significant resilience to these errors no matter what map size was used.

Conclusions: SOMs offer a novel method to identifying and ranking the risk of pest species invading a particular region.

Invasive pest information systems

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International trade is rapidly expanding; the relevance of international borders is diminishing. With that expansion comes the risk of the spread of exotic plant pests. Invasive pest information systems require a secure, structured, risk-focused process designed to collect, synthesise/analyse, communicate and utilise relevant offshore pest information to be used by phytosanitary officials in the US and elsewhere.

Inspectors at ports of entry need to be aware of pest situations abroad on a daily basis in order to focus their inspection activities. Local plant regulatory agencies also need similar information for their pest surveys. Federal risk assessors and trade managers need to know what pest threats exist offshore as they evaluate potential trade opportunities with countries that may harbor pests of concern to the USA. Producers and importers need current pest incidence information before they negotiate sale contracts to ensure that the products they purchase from offshore will not be infested with plant pests and suffer quality loss or seizure upon arrival due to infestation/infection.

The timely collection, synthesis and communication of offshore pest information provides US safeguarding personnel with the tools necessary to focus their activities based on commodity and origin-based risk posed in a dynamically changing world.

This paper describes the technical aspects of such reporting systems, including how reporting is handled electronically, data sources, linkages with other database systems, and security issues involved.

Monitoring phytosanitary insect pests and sharing pest information in tropical areas

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Introduction: Fruit flies, whiteflies, and the cocoa pod borer (CPB) (*Conopomorpha cramerella* Snellen), are among some of the worst agricultural insect pests. It is critical to share pest information and monitor pest distribution and populations on regional, and global basis.

Methods and Results: This collaborative effort involves three tropical regions: Southeast Asia (SA), the Caribbean Basin (CB), and West Africa (WA).

SA Project. This study focuses on sharing pest information of CPB. CPB is a destructive cocoa pest in Southeast Asia only. It would be devastating to world cocoa production if this pest spreads to other cocoa production areas. Our efforts involve five areas: a) creating a knowledgebase of CPB; b) collecting and distributing CPB pest management technology; c) developing databases such as a Global CPB Expert Database, d) mapping of CPB worldwide; e) databasing general pest management information.

WA Project. Study scope includes a) developing a knowledge base of whitefly biology and dynamics, including alternative host plants, b) a pesticide residue and safety training website, c) developing an online mapping tool to provide dynamic descriptions of whitefly distribution in the region.

CB Project. This study is to develop an online fruit fly surveillance system for monitoring five species of tephrid fruit flies in the region. An online data reporting and mapping system has been developed. Training sessions on sampling procedures and methods have been conducted and data collection is in progress. The current effort is focused on sampling and data reporting.

Harmonising approaches to pest risk assessment in Europe: The EFSA Plant Health Panel

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The Plant Health (PLH) Panel of the European Food Safety Authority provides independent scientific advice on the risks posed by plant pests which threaten the safety and security of the food chain and the wider environment in the EU. The aim of the panel is to contribute to development of a harmonised approach for pest risk assessment in the EU, in cooperation with EU Member States and international organisations. The Panel, which started its activity in June 2006, is composed of 21 Members with expertise in various fields of risk analysis and plant health. It operates with the support of the EFSA PLH secretariat and includes a permanent working group on arthropods. Since its start, it has published six scientific opinions on the risk posed by invasive plants, weeds, a citrus bacterial disease and a citrus insect pest. Most recently, it evaluated thirty pest risk assessments, for the French overseas departments of Martinique, Guadeloupe, French Guiana and Réunion, with the aim of harmonising their phytosanitary rules with EU plant health legislation. Seven of these opinions relate to insect pests of banana and citrus.

The particular challenges faced by the PLH Panel faces include dealing with uncertainties relating to entry pathways and impacts, and developing a harmonised approach to the evaluation of risk assessments in the EU.

Enhancing sugarcane biosecurity measures in Australia

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Introduction: Invasive pest and disease species pose an ongoing threat to agricultural industries world wide. In Australia, a sugarcane biosecurity scheme has been initiated, whereby Incursion Management Plans are developed for major exotic pests and diseases such as species of moth borers and sugarcane smut.

Methods: The plans detail steps to be taken following an incursion of a sugarcane pest or a disease into Australia, with specific information on the pest's biology, identification, geographical distribution, economic impact and control strategies. All plans are continuously updated in light of new information on changing pest status and recent expansions. The plans also provide information on the 'pest risk category', which places the pest into one of four categories depending on its economic status in its area of distribution, with predicted levels of damage that might be incurred in Australia in case of incursion. These categories assist in deciding on sharing eradication and compensation costs between the state government and the industry(s) concerned.

Results: Our preparedness has been tested when an unknown moth borer was found on Thursday Island north of the Australian mainland. The moth species was found to be *Chio crypsimetalla*, which is not a pest of sugarcane and unlikely to cause any economic damage. Conclusion: Our detection, quick diagnosis and response confirms our good level of preparedness for any possible exotic pest or disease introduction.

The role of habitat structure on disease-infected insects invading Australia

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Introduction: Ramu Stunt disease of sugarcane and its vector, *Eumetopina flavipes*, are present in Papua New Guinea (PNG). Disease-free *E. flavipes* populations occur on the Torres Strait Islands (TS) and northern peninsula area (NPA) of mainland Australia. Infected *E. flavipes* could disperse from PNG through the TS/NPA and introduce Ramu Stunt into commercial Australian sugarcane. No data exists on *E. flavipes* host use when it colonises new regions. The effect of host structure (abundance and spatial distribution) on *E. flavipes* population structure was used to assess the likelihood of its successful establishment and population growth, and so determine likely TS entry-points for Ramu Stunt infected *E. flavipes*.

Methods: The distribution of *E. flavipes* host species, their occupancy by and abundance of *E. flavipes* if present was assessed at key locations in PNG, TS and NPA.

Results: *E. flavipes* was detected on four main host types in PNG. *E. flavipes* occupation of the four host types varied significantly but once a host was occupied, *E. flavipes* abundance was not different between host types. Of the four host types present in PNG, only two were present and utilised by *E. flavipe*s throughout TS/NPA. In TS/NPA, less than half of the host plants sampled were occupied, compared to 100% occupation of similar host plants in PNG. Despite this, *E. flavipes* abundance on occupied host plants was not different between TS/NPA and PNG. In the TS/NPA, a number of locations were consistently negative for, or sustained very low infestations of *E. flavipes* over time. Ten 'stable' locations were identified, in that medium to heavy *E. flavipes* infestations were sustained over time.

Conclusion: Host structure may affect the persistence of *E. flavipes* populations in the TS/ NPA, in part because cultivation practices may frequently reduce the availability of host plants available for occupation by *E. flavipes*. In PNG, host structure appears to be continuous and stable in nature, and may thus be constantly available for re-colonisation by *E. flavipes*. All PNG and stable TS/ NPA locations may be sources from which dispersal of Ramu Stunt disease infected *E. flavipes* could occur.

An integrated approach to biosecurity threat identification and prioritisation

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Biosecurity prediction is notoriously uncertain, and in planning biosecurity investments agricultural industries need confidence in the process. Most pest risk prediction rely upon some form of regression-based analysis of the habitat preferences of the target species, and application of the inferred relationships to novel environments where the invasion risk is being assessed. Regression-based methods tend to give results that include spurious modelling artifacts. Process-oriented models overcome some of these problems, but require skilled modellers to produce reliable results, take time to develop and currently lack a means of generating meaningful goodness of fit metrics. The outputs generated by habitat modelling software vary in their meaning, and are not provided in terms that are directly usable by pest risk assessors. Our research aims to relate CLIMEX outputs to damage functions that can be applied in economic impact assessments.

To a large extent systems of pest prioritisation depend on expert opinion regarding a number of uncertainties. While valuable, these subjective opinions have a profound impact on threat perception. Objective economic analyses are rarely used to inform prioritisation decisions, and where they are used their scope is generally limited to market impacts ignoring the effects on non-market goods. Our research aims to improve biosecurity planning and pest prioritisation by blending quantitative and qualitative expert-based impact assessment techniques in a structured, deliberative multi-criteria evaluation framework. A combination of neural network analyses estimating entry potential, bioeconomic impact simulation models and deliberative decision-facilitation tools are used to aid the design of appropriate risk mitigation and management strategies.

Theme 2 – Trade and pathways

The chrysomelid leaf beetle *Diabrotica virgifera virgifera* LeConte as an alien invasive maize pest in the Ticino canton, Southern Switzerland

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Diabrotica virgifera virgifera (Coleoptera:Chrysomelidae), the western corn rootworm (WCR), is an immigrant from North America and one of the top ten global agricultural pest species. Within the last 15 years, WCR invaded Europe at a minimum of three focal points at Belgrade, Milan and Paris and is a severe threat to commercial maize production. The progress of WCR from Italy to North Central Europe via Switzerland has been under scrutiny and of major concern to European quarantine officers. Geographic concentration of transport routes along river valleys of Ticino and Misox necessitated careful observations of these routes by pheromone and kairomone monitoring traps. Experiences with WCR monitoring whose population dynamics are still incompletely understood, may be briefly summarized for 2005 to 2007:

1. WCR moves in south–north direction preferably along major freeways, railroads and associated trading centers for goods and services.

2. WCR densities further remote from these strategic thoroughfares are generally lower than those in their immediate vicinity.

3. WCR likes to hitchhike with *Homo sapiens* using his established traffic technologies.

4. Mandatory crop rotation in the canton Ticino slowed the previous spreading and densities of WCR significantly. After introduction of mandatory crop rotation in the canton Ticino, no further WCR infestations were detectable north of the main Alpine mountain chain during 2005 to 2007.

5.Traps in the side valley of Misox situated in the neighboring canton of Grisons (with delayed obligation for mandatory crop rotation) show a population increase, but WCR counts now stagnate at a higher level than in the canton Ticino.

6. Metcalf sticky traps baited with sex pheromones and kairomones as attractants are highly effective and early indicators of WCR populations.

7. Switzerland with its rigorous crop rotation program may serve as an example and a role model for prudent WCR pest management in the European context.

Theme 3 – Detection and Diagnostics

Taxonomic needs in managing invasive species: A global assessment

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Although taxonomy is recognised as important in managing invasive species there is little clarity on the overall priorities at a global policy level. The lack of explicit statements hinders access to taxonomic expertise and the development of protocols and practices to ensure taxonomic information and expertise are available when and where they are needed. An assessment of taxonomic needs in the context of Invasive Alien Species (IAS) management at a global level showed that high prioritisation was given by members of the IAS community to provision of names, their synonyms and their vernacular equivalents, to identification tools, and to the availability of expert taxonomists to provide identifications. The assessment provides recommendations to address the taxonomic impediment in IAS, and these are being made available both publicly and to relevant policy and implanting bodies, such as the Convention on Biological Diversity and the Global Invasive Species Programme.

New Challenges Facing Regulatory Agencies: Providing Technologically-Based Identification Support

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The magnitude of providing support to ensure accurate and prompt identification of potential pests is often overwhelming due to the diversification of trade products now entering our borders and the increasing number of trading partners we now have. Some of the major challenges that face teams providing identification resources and technologies to regulatory agencies and their cooperators are reviewed. Following the review, there will be a discussion how USDA’s Identification Technology Program is attempting to meet some of these challenges.

The presentation will end with a discussion on the following recommendations for those of you that face the challenges of providing technologically-based identification support to a regulatory agency and its associated cooperators:

1. Make sure to stay informed on new pests, diseases, and weeds of potential concern to your country.
2. Be aware of existing and new technologies that you might be able to adapt to increase efficiency and accuracy for your agency.
3. Stay in touch with the taxonomic community so that you are aware of changes in pest taxa classification, circumscription, and new species descriptions.
4. Make sure to continually interact with your clients – learn what they need to increase efficiency and accuracy for their identification responsibilities.
5. Be future focused - design, develop, and deliver resource projects for future identification needs within your agency.
6. Remain informed on identification resources and technologies being developed in other countries to minimise duplication and efficient use of resources.
7. Develop international collaborative projects to share expertise, costs, and technologies; many of us require the same type of resources and technologies.
8. Share issues with other outside agencies to learn how they deal with similar issues – we all share many of the same problems.
9. Share your identification resources, tools, and keys internationally.

A tool to assist with invasive pest recognition

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The best biosecurity measures are aimed at keeping invasive species offshore or away from the borders. To do so, invasive species need to be able to be accurately and efficiently recognised, both outside and inside a country. Most of this task falls to diagnosticians working within a localised fauna. Also, diagnosticians support surveillance and monitoring programmes, hence need information and images to facilitate reporting on submitted specimens. Added to the complexity of this task are two factors: first, the majority of invasive pests encountered are not local, hence diagnosticians often require a world-wide knowledge of the invasive pests; and second, there is a worldwide decline in the availability of diagnosticians and taxonomists for invasive pests.

To address these issues a virtual Pest and Disease Image Library (PaDIL) has been developed. PADIL (http://www.padil.gov.au/) is a website that provides high quality, colour, diagnostic images and information on invasive pests (ie. taxonomy, distribution, hosts). No software downloads are required to make full use of the site. The software allows the user multiple query points and the ability to build user-defined image tables which combine characters chosen by the user. PaDIL is freely accessibly and the images are available for non commercial use. Currently, it includes 1,200 pests. Australia has developed PaDIL to enhance its biosecurity capability with the recognition of invasive species domestically and internationally. Although the primary user audience is phytosanitary diagnosticians, the image-based website can be easily used by specialists and non-technical persons in all areas of prevention of invasive species.

New technologies for tackling major challenges in border diagnostics

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Accurate diagnosis of exotic insect species involves various types of information being made available to support different aspects of border biosecurity. However, for many taxa there are technological and knowledge barriers that thwart this. These can arise through difficult access to taxonomic expertise, absence of relevant keys for immature life stages or closely related species, indiscernible vector status of specimens, the live/dead status of sessile forms, no indicators to verify geographic origin, or even physical barriers to detection in the first place.

In New Zealand, new technologies have been researched, to alleviate some of these challenges. At the border, the pressure to rapidly clear fresh produce has driven the development of diagnosis by remote microscopy, linking diagnosticians with border personnel. For cryptic forms of high risk species, accurate identifications have been significantly improved by adoption of DNA barcode technology; this approach is now being considered as a sustainable diagnostic resource to improve diagnosis of any intercepted immature life stage. Pre-border, the onerous task of detecting organisms that contaminate large numbers of containers arriving at the ports is being addressed through pioneering research on a screening system using Sniffertech™ sampling and Syft detection technology. Finally, post-border, the innovative application of stable isotopes and trace elements as point-of-origin identifiers is being examined, particularly as applied to high-risk pest post-eradication decisions.

Non-taxonomic biochemical tools for enhancing decision making at the border

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In addition to the daunting task of making taxonomic identifications of organisms that are intercepted at the border, regulatory authorities must also evaluate other characteristics of intercepted organisms such as their viability. When the intercepted organisms are sessile (e.g. eggs, pupae, scale insects) the challenge of rapidly and objectively assessing viability is significant, and the costs of incorrectly interpreting viability can be high. For example, if regulated scale insects associated with a consignment of imported produce were incorrectly assessed as being alive, the consignment may be unnecessarily rejected and either destroyed, fumigated or returned to the exporter. Alternatively, if the scale insects were incorrectly assessed as being dead, they could be allowed to cross the border into a new region or country, thus risking the establishment of a new pest. Viability assessments of sessile organisms are generally made using morphological criteria that demand high levels of user-experience to obtain reliable results. Moreover, morphological observations are often difficult to quantify or otherwise record in an objective manner, and this can cause problems when border authorities need to defend their viability assessments. This presentation describes a series of rapid, sensitive, inexpensive, simple-to-use biochemical tests that have been developed primarily for use by border authorities to make viability assessments of sessile organisms. The tests are also proving useful in other applications such as validating the efficacy of treatments that have been applied to consignments prior to export. The tests perform well across a diverse range of arthropods, and give easily interpreted, contrasting colour reactions depending on the viability of the organism; these can readily be quantified using a spectrophotometer or by measuring pixel values. The biochemical data have also shown that the physical appearance of sessile organisms can sometimes be misleading with respect to their viability. This work illustrates how relatively small research projects can help to increase the speed, reliability, objectivity, transparency, defensibility and overall efficiency of border biosecurity processes.

Theme 4 - Incursion response

Tools to improve surveillance for insect plant biosecurity in Australia

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When an invasive insect species becomes established in a new area/region/country populations are initially very low and hard to detect, however with every month that they remain undetected they will become more abundant and harder and more expensive to eradicate. Australia with a coastline of 60,000 km requires sentinel trapping to detect key threats like Asian gypsy moth and fruit fly species. We are looking to develop new traps, including remote traps that wirelessly self-report, and have software for identification through shape and pattern recognition. Regularly serviced grids of traps are used to acquire measurable evidence of absence for fruit flies. Even when an incursion has occurred, many traps catch no flies. We are researching the use of fewer traps placed in strategic locations predicted from fly behaviour studies using new spatial statistical methods. New trends in surveillance will produce massive amounts of biological and spatial data and the development of software tools on hand-held PDAs (Personal Digital Assistants) is a cost effective way to collect, audit and validate these biological and spatial data in the field. Spatial data from GPS can be used to navigate to traps and the data collected can be ported to third party web applications like Google Earth for desktop validation. The CRCNPB is bringing together many organisations to develop a new generation of surveillance tools that can be used by regulatory authorities throughout Australia to detect incursions earlier, allowing eradication before they impose a major economic impact on industry and government.

Integrated pest eradication: technologies for incursion response against invasive species

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Introduction: Eradication of any insect from an area is normally only undertaken after justification from an economic and/or environmental impact analysis. Further key considerations include the ability to fully delimit and characterise the target population, as well as the availability of suitable technologies that can be used in the landscape where the pest has been detected. While standard IPM tools such as insecticides may be available, their suitability for use in an eradication programme may be constrained in urban or natural ecosystems. The types of tools available depend on the pest biology, and certain orders of insects have a wider arsenal available than others. For example, there are attractants identified for many Lepidoptera, while the same applies for certain Coleoptera, Diptera and Hymenoptera, and to a lesser extent for Hemiptera and other groups. In many cases pest management programmes have provided the basis for "Integrated Pest Eradication" when pests are detected in new regions.

Conclusions: More socially-acceptable tactics are urgently needed to reduce the almost inevitable establishment and range expansion of invasive species. Research challenges include the discovery of new and more powerful attractants and their development into mass trapping, lure and kill, mating disruption or other tactics which are broadly more acceptable than broadcast insecticides. In addition, the sterile insect technique, biopesticides, and other methods will be used increasingly, but need research along with key aspects of pest biology and ecology. Recent experience with successful and unsuccessful eradications of various species will be used to illustrate progress in this area.

Spatio-temporal population probability models for monitoring eradication success, and a demonstration using painted apple moth

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Introduction: Successful incursion response relies on accurately delimiting the pest population, application of effective eradication treatments, and determining when the likelihood of continued pest presence becomes acceptably small. Here, I propose that spatiotemporal population probability models, which combine conventional population models with statistical probability approaches across space and time, can inform delimitation and eradication monitoring. This approach is demonstrated using painted apple moth (*Teia anartoides*) in Auckland, New Zealand.

Methods: A population model for daily temperature-determined male production was used in conjunction with spatially-explicit pheromone trap locations and attraction radii to determine the daily probability of detecting a wild population at a particular location. Over time, these probabilities multiply up to decrease the likelihood of presence given ongoing lack of detection. The model was parameterised for painted apple moth using data collected during the Auckland incursion response, allowing spatio-temporal risk maps to be produced.

Results: The model suggested that trapping in winter yields relatively little useful information on painted apple moth presence. Eradication was likely to have been successful in the main infestation areas by mid 2005, with subsequent catches likely to represent further small incursions, as corroborated by molecular evidence. It was plausible that a wild population was present in the Otahuhu area in 2005 but very unlikely that it remained by the end of 2006.

Conclusions: Spatio-temporal population probability models can assist decision-making during incursion response, but depend on quantification of sampling efficacy and good data management. They show particular potential for use with future automated trapping systems.

Using EPG to compare acceptance by the spittle bug Carystoterpa fingens of four plant species

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New Zealand is currently free of both *Xylella fastidiosa* (a bacterium that causes several diseases of agricultural, horticultural and ornamental plants) and its vector, glassy-winged sharpshooter (GWSS). Nevertheless, it remains vulnerable to invasion by both organisms. *Citrus sinensis*, *Coprosma repens*, *Hydrangea peniculata* and *Vitis vinifera* (grape), are four of many species in New Zealand known to be hosts of both GWSS and *X. fastidiosa*. The electrical penetration graph (EPG-DC) technique was used to compare their acceptance as food by the endemic spittle bug *Carystoterpa fingens*; one of the several xylem feeders may potentially act as a conduit for *X. fastidiosa* into native host plants. EPG waveforms representing main stylet penetration activities [pathway, xylem ingestion, resting, and non-probing phases] of 54 adults were recorded for 12 hours per insect. The durations and the number of events were analysed to compare host acceptance. The total probing times on grape were not significantly different from citrus but were longer than on hydrangea and coprosma. Non-probing times were longest on coprosma. The longest periods of xylem ingestion (total duration and the longest event) were recorded on grape and the shortest on coprosma. The shortest durations of pathway were recorded on grape. Citrus and hydrangea were intermediate and not significantly different from one another. The number of xylem ingestion events on citrus was significantly higher than grape, coprosma and hydrangea. It was concluded that grape was the best host, citrus and hydrangea were accepted and coprosma was the least accepted.

The importance of Allee effects in predicting and managing insect pest invasions

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The Allee effect refers to decreasing net population growth with decreasing density; under strong Allee effects there exists a threshold below which low-density populations are driven toward extinction. They may arise from a variety of factors such as failure to find mates, failure to saturate predators and inability to utilise hosts through cooperative feeding. Though Allee effects have historically been applied to species conservation, there has been recent recognition of their importance in low-density populations during biological invasions. Given the importance of Allee dynamics during the establishment and spread of invading species, Allee effects create powerful opportunities for managing invasions. Specifically, by strengthening Allee effects, low-density populations of invaders can be driven to extinction without further management intervention, defying the notion that eradication can only be achieved by killing all individuals. Here we briefly review Allee effects with specific attention to their role in biological invasions and outline current management techniques, such as mating disruption and the sterile insect technique, from the context of their manipulation of the Allee threshold to manage invasions. We also suggest new approaches for manipulation of Allee effects that could be used to manage invading species; these approaches include natural enemy augmentation and other methods that affect population growth and consequently alter the Allee threshold. Finally, we discuss how variation in life history traits influence the strength of Allee effects and how this information can be used to predict invasions success among different pest species.

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