



Workshop: tracking and forecasting of pest and pathogen movements

Final Report (PBSF028)

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2 Executive Summary

A two-day workshop “Tracking and forecasting of pest and pathogen movements” was held at the Ecosciences Precinct in Dutton Park, Brisbane from 26-27 February 2020, supported by APBSF. The workshop engaged thirty-two scientists from the UK, USA, Australia and NZ, from both government and non-government organizations as well as universities. The workshop had two main objectives:

1) Defining the key biosecurity challenges (agricultural pests and pathogens) we face in Australia (and globally) that could benefit from understanding patterns of long-distance atmospheric movement, to improve our ability to forecast these movements; and (2) Developing specific, integrated, methodologies with which to research the movement patterns of the identified key pests and address the key biosecurity challenges.

During the workshop, participants learned about novel research and networked with other researchers, gained insights on the integration of technologies and identified current applications for this research and possible collaborations. Workshop participants have since developed collaborative proposals to GRDC (Grains Research and Development Corporation) and for joint CAS (Chinese Academy of Sciences) -Qld or -CSIRO funding, along with the development of a draft ‘review’ or ‘opinion’ article to be pitched as a pre-submission inquiry to Trends in Ecology and Evolution next financial year: “Drought and the management of migratory insect pests”. The results of the workshop will also be synthesised as planned into a methods publication during the next financial year: “A methodological framework for rapid assessment of the threat posed by long-distance atmospheric movements of insect pests and pathogens”.

3 Introduction

Parallel research has been undertaken in both the UK¹ and Australia² that considers the risks posed by the long-distance atmospheric movement of insect pests and pathogens. This currently takes a range of independent methodological approaches:

- Atmospheric dispersal modelling
- Radar technology
- Near-ground monitoring
- Genetics

A Rothamsted Research-CSIRO Linkage grant was used to bring several Rothamsted scientists (both global experts in the field and emerging early career researchers) to Australia. The APBSF has provided additional funding to maximize the collaboration-building opportunity of this visit for plant biosecurity researchers across Australia, as well as to engage with policymakers at both State and Federal level.

A two-day workshop was held in Brisbane at CSIRO from 26-27 February 2020.

¹ Reynolds and Reynolds, 2008, Proceedings of the Royal Society B <https://doi.org/10.1098/rspb.2008.0880>; Bell et al., 2015, Journal of Animal Ecology <https://doi.org/10.1111/1365-2656.12282>

² Parry 2013 Movement Ecology <https://doi.org/10.1186/2051-3933-1-14>; Parry et al 2015 IN Venette (ed) Pest Risk Modelling and mapping for Invasive Alien Species, CABI <https://www.cabi.org/ISC/ebook/20153099612>; TAPPAS: <https://research.csiro.au/tappas/>

4 Aim

During the workshop, we sought to:

1. Identify key pests and pathogens that pose a threat to food and industry security in Australia or environmental risk and human health, whose threat can be reduced by understanding their patterns of long-distance atmospheric movement and improving our ability to forecast these movements.
2. Develop specific, integrated, methodologies with which to research the movement patterns of the identified key pests.

This built on previous work conducted both at Rothamsted and CSIRO, as well as by the PBCRC project PBCRC2153 which was focused on the arrival of exotic pests into Australia, particularly industry-specific pests for citrus, potato and sugarcane. The PBCRC project built stakeholder engagement but lacked a multi-institutional science-focused workshop. By hosting an inclusive, multi-institutional science-focused workshop, including biosecurity professionals and international researchers, we aimed to achieve some clarity on opportunities for collaboration on this topic to enhance Australian plant biosecurity.

5 Workshop: tracking and forecasting of pest and pathogen movements

5.1 Summary

The workshop was organized by Hazel Parry, CSIRO, and was held at the Ecosciences Precinct in Dutton Park, Brisbane from 26-27 February 2020. The workshop was held over two days and brought together a total of thirty-two scientists ranging from early career (PhD student/postdocs) to highly respected professors and senior scientists in the fields of biosecurity, entomology and movement ecology. It was an international workshop, with scientists present from Rothamsted Research (UK) as well as Lincoln University (NZ), and a PhD student supervised primarily at Arizona State University (USA). We had scientists from across Australia present, from Universities (University of New England, University of NSW/University of Canberra) as well as Government (Queensland Government DAF, Agriculture Victoria, Plague Locust Commission) and non-Government/Industry (Plant Health Australia, GRDC, cesar, RapidAim) Organizations, with a large contingent from across several business units of CSIRO (Agriculture and Food, Health and Biosecurity, Data61, Oceans and Atmosphere).

Day 1 was a full agenda of research talks given by attendees, each lasting 15 minutes. We began with a retrospective on past and current biosecurity research into movement ecology of insect pest and pathogens firstly from an Australian/NZ perspective, and then from a UK perspective. This covered research both tracking and forecasting pests. From this we discussed some key cross-cutting themes and methodologies. A vegan banquet group dinner was held at a nearby restaurant, which extended networking opportunities for the group.

Day 2 began with some government and industry perspectives on current biosecurity priorities, delivered by Plant Health Australia, the Queensland Government and GRDC. We then utilized the rest of the day to brainstorm and discuss our workshop objectives: (1) Defining the key biosecurity challenges (agricultural pests and pathogens) we face in Australia (and globally) that could benefit from understanding patterns of long-distance atmospheric movement, to improve our ability to forecast these movements; and (2) Developing specific, integrated, methodologies with which to research the movement patterns of the identified key pests and address the key biosecurity challenges. From this, some preliminary collaboration, proposal and publication ideas emerged.

The following summarizes the workshop agenda and outputs (meeting the workshop aims).

Figure 1: Examples of some of the content from presentations given at the workshop

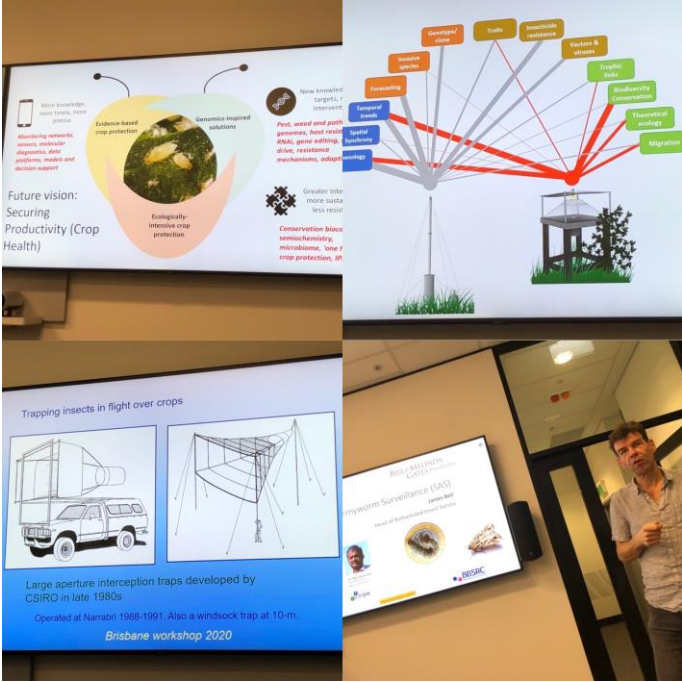


Figure 2: Workshop participants during the meeting listening to talks and discussing ideas



Figure 3: Workshop dinner and networking event



5.1 Workshop agenda

Tracking and forecasting of pest and pathogen movements

This workshop is generously supported by the Australian Plant Biosecurity Science Foundation
<https://www.apbsf.org.au/>

Location: Hayman Room, EcoSciences Precinct, Brisbane

Date: 26-27 February 2020

Contact: Hazel Parry
Mob: 042904316



5.1.1 Workshop Objectives

- Workshop Objective 1: **Defining the key biosecurity challenges (agricultural pests and pathogens) we face in Australia (and globally)** that could benefit from understanding patterns of long-distance atmospheric movement, to improve our ability to forecast these movements.
- Research problems
- Key questions
- Which economically-important pests and/or pathogens disperse significant distances for which our knowledge is still limited?
 - can we generalize these pests and/or pathogens into functional groups?
 - What are the research questions we need to ask in order to better understand their long-distance movement and improve management?
- Workshop Objective 2: **Developing specific, integrated, methodologies** with which to research the movement patterns of the identified key pests.
- Research methods and integration
- Key questions
- How might we gain a better understanding of long-distance movement in order to manage economically-important pests/pathogens?
 - To enable management, is the movement forecast/signal enough, or does it require additional information (genetics, population dynamics)?
 - What technologies/methods are available to track or forecast different types of pest/pathogen movement?
 - What are the capabilities/limitations of these technologies/methods in forecasting/tracking pests/pathogens?
 - How might the technologies/methods be better integrated, what benefit might that give?

5.1.2 Day 1

Wednesday 26 th Feb	Topic	Presenter
8:15-8:45	Arrival (coffee and tea available)	
	<i>Intro to the workshop and what we hope to achieve</i>	
8:45	Welcome to country. Introductions and objectives.	Hazel Parry (CSIRO)
8:55	Overview: Biosecurity research themes at CSIRO	Gary Fitt (Science Director, CSIRO Health and Biosecurity)
9:10	Overview: Rothamsted Research themes, infrastructure and the 'insect survey'	James Bell (Head of the Insect Survey, Rothamsted Research)
	<i>What have we studied and why/how (Australian/NZ researchers), and what next?</i>	
	Tracking	
9:25	Radar studies and traps	Alistair Drake (UNSW/Uni Canberra)
9:40	Genetics studies (incl. resistance mgt)	Tek Tay (+Tom Walsh?) (CSIRO)
9:55	Biogeochemical tracers of natal geographic origin	Karen Armstrong (Lincoln Uni, NZ)
10:10	Human assisted dispersal: shipping pathways and air transportation	Dean Paini (CSIRO)
10:25	The Australian Plague Locust Commission research and monitoring	Haikou Wang (APLC)
10:40 – 11:00	BREAK	
	Forecasting	
11:00	Trajectory modelling of insect pest populations at CSIRO: an historical perspective	Hazel Parry/Peter Gregg/Myron Zalucki/Gary Fitt/Wayne Rochester (CSIRO)
11:15	Modelling the threat from long-distance dispersal of plant pathogens to Australia	Ming Wang (CSIRO)
11:30	TAPPAS project and 'one health'	Rieks Van Klinken (CSIRO)

11:45	Natural dispersion pathways and surveillance for horticultural pests and diseases	John Weiss (AgVic)
12:00	Defining favourable locations for Australian plague locust outbreaks	Douglas Lawton (ASU)
12:15	Risk mapping	Darren Kriticos (CSIRO)
12:30 -13:10	LUNCH	

PM

13:10 Discussion – key cross-cutting themes, and what next? (identify case studies for day 2)

What have we studied and why/how (UK researchers), and what next?

All Rothamsted Research:

13:40	Epidemiological and evolutionary modelling of pests and pathogens	Joe Helps
14:00	Pest and disease detection and control scenarios	Vasthi Alonso-Chavez
14:20	Sampling, Detection and Assessment – a statistical perspective	Kirsty Hassall
14:40	Monitoring the fall armyworm in Africa using AI and radar – a success?	James Bell

15:00 – 15:30 **BREAK**

15:30 Discussion – key cross-cutting themes, and what next? (identify case studies for day 2)

16:00	Atmospheric physics and the movement of insects	Andy Reynolds (from UK via Webex)
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16:30-17:00 Discussion and wrap up, incl. refinement of agenda for day 2

18:00 **Group dinner @ Paw Paw Woolloongabba**
Cnr Potts and Stanley St, Woolloongabba

5.1.3 Day 2

Thursday 27 th Feb	Topic	Presenter/Facilitator
AM		
8:30-9:00	Arrival (coffee and tea available)	
9:00	Refinement of agenda/objectives for the day	Hazel Parry
9:10	Overview: government and industry biosecurity priorities in Northern Australia for pest and pathogen movements	Trevor Dunmall (Industry Liaison Manager, Plant Health Australia)
9:30	Overview: Qld government biosecurity priorities	Suzy Perry, QDAFF (Risk Analysis and Scientific Advice Sub-Program Leader)
9:50	Overview: GRDC biosecurity priorities	Ken Young, GRDC
10:10	<i>Defining the key biosecurity challenges (agricultural pests and pathogens) we face in Australia (and globally) that could benefit from understanding patterns of long-distance atmospheric movement, to improve our ability to forecast these movements.</i>	Breakout groups
Workshop Objective 1: Research problems		
Case study 1	Group discussion focused on case-studies.	
Case study 2		
Case study 3		
10:50-11:10	Break	
11:10	<i>Summarizing key biosecurity challenges</i>	
11:30	<i>Developing specific, integrated, methodologies with which to research the movement patterns of the identified key pests.</i>	
Workshop Objective 2: Research methods and integration		
	Discussion focused on methodological questions, in particular the integration of methods, in relation to the case studies.	Scenario-based activities
12:30 – 13:30	Lunch	
PM		
13:30 <i>What is next for this group?</i>	Identifying potential for projects/collaboration going forward.	Breakout groups
	Identifying potential publication (map out structure, authors etc) going forward.	Breakout groups
Workshop finish 15:30		

5.1.4 Attendees (in-person)

Name	Institution	Interests	Contact	PawPaw
Hazel Parry	CSIRO Ag & Food	Spatial Ecology, simulation modelling, insect pests (incl. disease vectors)	hazel.parry@csiro.au	Y (veg)
Ming Wang	CSIRO Health & Biosecurity	Long-distance dispersal (trajectory) modelling, insect pests, agent-based modelling	ming.wang@csiro.au	Y
Darren Kriticos	CSIRO Health & Biosecurity	Ecology, ecological modelling for invasion biology and pest management	darren.kriticos@csiro.au	Y
Rieks van Klinken	CSIRO Health & Biosecurity	Ecology and management of invasive species	Rieks.Vanklinken@csiro.au	(GF) Lunch day 1 only
Dean Paini	CSIRO Health & Biosecurity	Invasive species modelling, competition theory, ideal free distribution, foraging strategies, network theory and emerging infectious diseases	dean.paini@csiro.au	Y
Mary Whitehouse	CSIRO Ag & Food	Insect ecology, IPM, moth migration using radar and aerial sampling techniques to monitor the movement of <i>Helicoverpa</i> and other pests.	mary.whitehouse@csiro.au	Y
Ross Darnell	CSIRO Data61	Survey and experimental design and statistical modelling of environmental and agricultural systems.	ross.darnell@csiro.au	N
Gary Fitt	CSIRO Health & Biosecurity	Honorary Fellow, Health and Biosecurity	gary.fitt@csiro.au	Y
Tek Tay	CSIRO Health & Biosecurity	Senior research scientist, genetics	Weetek.Tay@csiro.au	Y
Wayne Rochester	CSIRO Oceans and Atmosphere	Movement pathway analysis and modelling	wayne.rochester@csiro.au	Y
Sharon Downes	CSIRO Ag & Food	Insect ecology, IPM, <i>Helicoverpa</i> resistance management and migration	Sharon.downes@csiro.au	Y (veg)
James Bell	Rothamsted Research	Quantitative ecologist, project leader – the insect survey. distributional and longitudinal trends of insects and how these are driven by environmental and climate-driven processes	james.bell@rothamsted.ac.uk	Y (veg)
Kirsty Hassall	Rothamsted Research	Statistician, molecular cell biology, 'omics technologies, sampling methods, insect classification, Bayes net modelling	kirsty.hassall@rothamsted.ac.uk	Y
Vasthi Alonso-Chavez	Rothamsted Research	mathematical and epidemiological models for the monitoring, detection and control of diseases in plant, crops and trees	vasthi.alonso-chavez@rothamsted.ac.uk	Y
Joe Helps	Rothamsted Research	management strategies to delay the development of insecticidal and fungicidal resistance in agricultural pests	joe.helps@rothamsted.ac.uk	Y
Trevor Dunmall	Plant Health Australia	Industry liaison manager	tdunmall@phau.com.au	N
Suzy Perry	Queensland DAF (State Government)	Risk Analysis Plant Biosecurity	Suzy.Perry@daf.qld.gov.au	N

Name	Institution	Interests	Contact	PawPaw
Mark Schutze	Queensland DAF (State Government)	Risk Analysis Plant Biosecurity	Mark.Schutze@daf.qld.gov.au	N
Mandy Christopher	Queensland DAF (State Government)	Risk Analysis Plant Biosecurity	Mandy.Christopher@daf.qld.gov.au	N
Ken Young	GRDC	General manager crop protection and biosecurity	Ken.Young@grdc.com.au	Y
John Weiss	Agriculture Victoria (State Government)	Weed and invertebrate sciences	John.Weiss@agriculture.vic.gov.au	Y
Peter Gregg (27th only)	University of New England	Professor: Agricultural entomology and insect ecology	pgregg@une.edu.au	N
Haikou Wang	Australian Plague Locust Commission	Locust monitoring and forecasting	Haikou.Wang@awe.gov.au	Y
Alistair Drake	UNSW/Uni Canberra	Honorary professor – radar entomology	A.Drake@adfa.edu.au	Y (veg)
Myron Zalucki	University of Queensland	Professor Entomology	m.zalucki@uq.edu.au	
Douglas Lawton	PhD student Arizona State University	Locusts and landscapes	ddlawton@asu.edu	Y
Stephane Mangeon	CSIRO Data61	Model-data fusion	Stephane.Mangeon@data61.csiro.au	N
Karen Armstrong	Lincoln Uni NZ	Diagnostics for Biosecurity	Karen.Armstrong@lincoln.ac.nz	Y

5.1.5 Attendees (remote)

Name	Institution	Interests	Contact
Andy Reynolds	Rothamsted Research	Atmospheric physics and the movement of insects	andy.reynolds@rothamsted.ac.uk
James Maino	Cesar	Remote sensing and forecasting of insect populations	jmaino@cesaraustralia.com
Nancy Schellhorn	RapidAim Pty Ltd	Real-time detection and monitoring of insect populations	nancy@rapidaim.io
Tom Walsh	CSIRO Health & Biosecurity	Team Leader: Integrated Omics	Tom.walsh@csiro.au

5.2 Summary of workshop outcomes

5.2.1 Key pests and pathogens discussed during the workshop

Of immediate relevance to Australia (in no particular order)

- Fall Army worm (*Spodoptera frugiperda*)
- Wheat rusts
- Cotton bollworm (*Helicoverpa armigera*)
- *Puccinia psidii*
- Locusts
- Culicoides (blue-tounge midge)
- Bemisia spp.
- Culex spp.
- Cotton Leaf Curl Virus
- Asian tiger mosquito *Ae. Albopictus*
- Bees, pollination, Varroa and be viruses
- Khapra beetle
- Asian gypsy moth
- Aphids
- Qfly and Medfly
- Sugarcane pests north of Australia (previous PBCRC project)
- Potato pests and pathogens near Australia (previous PBCRC project)

Global pests researched by the group (not currently in Australia/threat)

- psyllid vectors of the pathogen *ca. L. solanacearum*
- Septoria
- Pollen beetle
- Emerald ash borer
- Ash dieback
- Late blight (potato)

- Huanglongbing
- Cassava mosaic virus and cassava brown streak virus
- Rice blast
- Bacterial blight

It is important to note that, in general, although often the focus is on invasive SPECIES as the threatening agent, it is often specific TRAITS of those organisms that have impact “GENES of biosecurity concern”. The species may already be here, but if new genetics arrive then impacts could be much greater. For example, risks of incursion of Bt resistance genes in *Helicoverpa armigera* from Asia, global resistance dynamics based on *Helicoverpa* genome cf. current situation of *H. armigera* in Brazil.

5.2.2 What people hoped to get out of the workshop

Learning and networking

- Technical updates/state of research
- Ideas for extending current research/knowledge gaps
- Increased international collaboration/new insights and perspectives
- Understanding of ‘migration’ – what it means exactly and how it relates to existing research at different scales
- Insights into how monitoring of migratory insects could be done more efficiently

How technologies could be integrated

- Insights into how data and models can be better linked
- Insights into how field ecology could be integrated with new techniques like genetics
- Synergies between methods and new perspectives on how integration could work in practice: combined, could some methods be more powerful?

Applications/possible collaborations

- Opportunities for radar and lidar to monitor moths and other insects in Australia
- Identification of applied questions/stakeholder needs/real-world relevance
- Priorities and pathways for exotics
- Need more research to support on-ground action
- Fall Army Worm
- Overlap across disciplines (e.g. ocean current research)
- Role for isotopes in post-border incursions

5.2.3 The range of research methods used by the group to conduct research into long distance tracking and forecasting of pest/pathogen movements

Current methods

- Genetics
- Trajectory modelling/spread modelling
- Isotopes
- Ecology/Entomology/biology
 - Environmental niche/habitat/traits
 - Integrated Pest Management
 - Resistance Management
 - Laboratory and field studies
- Population dynamic modelling
- Surveillance/sampling
- Pest risk mapping
- Citizen science
- Pathway analysis
- Expert elicitation/Bayesian networks

Methods not currently used by the group, but which may be useful to employ/engage with

- Pollen analysis
- Metabarcoding
- Breeding (crops)
- Biopesticide development (virus, Bt spray etc)
- New/revised cultural management methods
- Social science
- Economics
- App/computer software development
- Lipids

5.2.4 Key points raised

Data issues

- Availability, collection, and sharing of data for biosecurity is currently not satisfactory
- This data includes that from transportation networks as well as surveillance or interception data (e.g., NAQS).
- There is much lacking in good surveillance design implementation, and design depends upon purpose and situation (e.g. detection, ongoing surveillance, area-freedom, trap placement)

Medium-scale (landscape-scale) questions are key for preparedness/early warning (vs. regional vs. farm) ~ area-wide management

Management options and advice needs to be a focus for future research:

- It is not enough to only determine a threat. For example, when predicting the spread rate of a pest, we also need to consider management options for the delay of movement.
- Decision support for growers is potentially very valuable in this space and may provide some motivation to conduct surveillance on-farm.
- Exotic pests are not likely to be that distinct from management of ongoing issues from a growers' perspective – how the management of novel pests integrates with existing practice is important to consider.
- Research needs to consider industry and government priority pest focus – economic motivations etc. are constantly shifting, and therefore so are priorities.
- Exotic biosecurity is hard to value – kind of like insurance purchasing!

6 Draft Publication

6.1 A methodological framework for rapid assessment of the threat posed by long-distance atmospheric movements of insect pests and pathogens.

Due to COVID-19, there has been no return visit as planned to Rothamsted (UK) by CSIRO staff (Hazel Parry and Ming Wang) where we had intended to focus on the development of a methods-oriented publication, including some analysis of data from Rothamsted Research. We gathered a lot of information on methods from the Brisbane workshop, including their complementarity and relative advantages/limitation to address movement ecology research questions. These methods are summarized in this report, and were detailed in individual talks and presentations. This provides a reasonable basis to progress the methods paper prior to this return visit.

6.1.1 Timeline for methods paper

End August 2020: Outline of paper

End December 2020: Confirmation from workshop participants who will contribute and what they will contribute to this paper

End June 2021: Full draft of paper, including data analysis from a Rothamsted-led workshop (or most likely a virtual workshop, if travel still not permitted) to be held in early 2021.

6.2 Drought and the management of migratory insect pests

In relation to the CSIRO Agriculture and Food Drought 'mission' (part of CSIRO's current science strategy) and the focus of the discussions at the workshop on the recently invaded Fall Army Worm, an additional concept for a publication has been drafted and will be developed further over the next few months. The target journal initially will be Trends in Ecology and Evolution (with Movement Ecology also a potential journal we are considering), with a 'review' or 'opinion' article to be pitched as a presubmission inquiry to be sent to the journal by the **end of August 2020**.

7 Collaborative Proposal

Discussion at the workshop focused a lot on Fall Army worm as a case study. In Australia, two opportunities have arisen in the last few months to submit proposals in relation to this newly invaded pest, and some of the collaborators at the workshop have taken the initiative to submit proposals that relate to some of the discussions that arose during the workshop.

7.1 Fall Army Worm proposals

A proposal was submitted to GRDC in response to their call for FAW (“Prevention and preparedness for fall armyworm (*Spodoptera frugiperda*)”). The CSIRO proposal was led by workshop participant Tek Tay and has been funded as a collaboration led by cesar (who participated in the workshop remotely), with objective 2 led by CSIRO (Tay).

We also note forthcoming opportunities for further research into FAW across multiple industries, and the group will work towards the development of collaborative proposal(s) as the opportunities arise in relation to funding provided by the Australian Government to PHA to support a range of valuable activities to manage impacts <https://minister.ag.govcms.gov.au/littleproud/media-releases/pha-research-fall-armyworm>.

Note that the Rothamsted Research Phase I project on Fall Army Worm has now finished and a Phase II application has been submitted that, if funded, will start in spring 2021. Rothamsted are still reporting fall armyworm in Kenya till Nov 2020, whatever the funding does or does not deliver.

7.2 Queensland- and CSIRO- Chinese Academy of Sciences proposals

There have been two opportunities to collaborate with the Chinese Academy of Sciences. A proposal has been submitted led by Myron Zalucki (UQ) with CSIRO workshop participants as collaborators for the Queensland Government-CAS grant. Hazel Parry is developing a CSIRO-CAS proposal focused on Drought and the management of insect pests, likely to focus on Lepidopteran pests in particular Helicoverpa and Fall Armyworm, complimentary to the draft publication described above.

We anticipate that further proposals will arise from collaborations developed at the workshop, particularly following the exchange visit of CSIRO scientists to Rothamsted (UK) which has been deferred until 2021 due to COVID-19.

8 Achievements, Impacts and Outcomes

The workshop engaged thirty-two scientists from the UK, USA, Australia and NZ, from both government and non-government organizations as well as universities. The APBSF was acknowledged during the workshop as providing full support for the workshop, with a brief description of the activities of the foundation given at the workshop introduction by Hazel Parry. Unfortunately, the date of the workshop that best suited participants (particularly constrained to allow for participation in-person from Rothamsted (UK) colleagues) didn’t allow for attendance at the workshop by an APBSF representative (Michael Robinson).

The workshop has made progress in achieving both objectives (defining key biosecurity challenges that could benefit from understanding patterns of long-distance atmospheric movement and developing specific, integrated, research methodologies), and participants also gained much from their attendance and sharing of research findings. The general areas where people sought to gain new knowledge and collaboration during the workshop were: learning about novel research and networking with other researchers, insights on the integration of technologies and identifying current applications for this research and possible collaborations. Proposals and publications emerging from linkages made at the workshop are evidence of the impact this workshop has had, and hopefully they will lead to some successful outcome in the next financial year. APBSF support will be acknowledged on the publications as drafted/proposed here.



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