Tools, Technologies, and Transdisciplinary Science of Area-wide Management of Insects

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CSIRO Agriculture & Food
Why are we here?

SCIENCE PROTECTING PLANT HEALTH

‘...SCIPLANT 2017 is focused on facilitating engagement and the exchange of ideas between researchers and the end users of this research’ QLD Chief Scientist, Dr Geoff Garrett AO,
Why do I do what I do?

Why do you do what you do?

TED Talk Simon Sinek, ‘the golden circle’
WE PLAN TO SWARM IN AND TAKE THIS WHOLE REGION!

GOOD, I DON'T THINK THE HUMANS ARE ORGANIZED ENOUGH TO STOP US.
Arthropods don’t recognise borders!
Not unique to Arthropods!

• Natural resources & conservation – water, birds
• Air pollution
• Natural disasters
• Zombies
Massive Challenge: Manage highly mobile, often invasive, arthropods

1. Need support from many stakeholders, the community and public;
2. Target landscapes are heterogeneous;
3. Delays in knowing where and when pest shows up
What we do (end goal):

Area-wide Management (AWM)

Features:
- a solution beyond the spatial scale of a field,
- integrates multiple pest control tactics,
- neighbours-to-neighbour participation,
- coordinated,
- may involve a regulatory framework
How we do it (the journey):

- **Trans-disciplinary science** to know who needs to do what
- **Technologies** to simulate pest management actions across multiple spatial and temporal scales
- **Tools** to help us know where & when
Outline:

I. Setting the scene of area-wide management (AWM)

II. Case studies to illuminate T,T, and T:
   i. Silverleaf whitefly, *Bemisia tabaci* (MEAM1) invasion into Australia
      • AWM via classical biological control
   ii. QLD Fruit Fly, *Bactrocera tryoni*, range expansion into SE Australia
      • Who needs to do what to facilitate AWM
      • Where can AWM be most effective
   iii. QLD Fruit Fly, real-time monitoring

III. Conclusion - value of early end-user engagement
Key message:

Arthropods continue to challenge plant health

Research has to:
• 1st connect to the end user, and
• address simultaneously different parts of the problem to arrive at a solution
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Edward Knipling – ‘father of SIT’
Exploited the fact that screw worm mate only once
1\textsuperscript{st} success of eradication was in 1954 screw worm fly on the island of Curacao;
many dozens of programs globally for Tsetse fly, codling moth, fruit flies, etc.

- 1st define meta-populations; Distinguished b/t the dynamics of single populations and a set of local populations;
- Model motivated by- and applied to- a pest control situation over a large region, which local populations would fluctuate in asynchrony;
- Model showed that control measures should be applied synchronously throughout to achieve suppression
Evidence of AWM of pests by their Natural Enemies

- Reeve 1990 (theoretical)
- Ives and Settle 1997 (experimental & theoretical)
  - Considered the 3rd trophic level (natural enemies) and area wide suppression
  - Both showed that the combination of asynchronous planting of crops and highly mobile natural enemies resulted in area wide suppression of pests
Examples of pest control applied at an area-wide basis

- Coordinated timing of insecticide (Smith 1998; Lloyd et al 2010)
- Coordinated growing of trap crops (Sequeira 2001)
- Coordinated control of weeds (Mueller et al 1984; Abel et al 2007)
- Wide scale deployment of genetically modified insect resistant crops (Carriere et al 2003, Hutchinson et al 2010)
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The Problem:
Silverleaf whitefly, *Bemisia tabaci*, (MEAM1)

- 1996 – Poinsettias
- broad host range;
- Yield & quality;
- Transmits virus (begomoviruses TLCV, TYLCV)
The solution:

Classical Biological Control - parasitoid – *Eretmocerus hayati*

- *Eretmocerus hayati* - Aphelinidae
  - Originated in Pakistan
  - Attacks 1\textsuperscript{st} and 2\textsuperscript{nd} instar nymphs
The solution: Insecticide use – what type, how often?

### Bundaberg Insecticide use pattern

<table>
<thead>
<tr>
<th>Type of insecticide used</th>
<th>Frequency of insecticide use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always use softer insecticide</td>
<td>Only if becoming a problem</td>
</tr>
<tr>
<td>Use softer insecticide if possible</td>
<td>Once on young crop</td>
</tr>
<tr>
<td>Use the most cost effective insecticide</td>
<td>2-4 times throughout crop</td>
</tr>
<tr>
<td></td>
<td>weekly/fortnightly throughout crop</td>
</tr>
</tbody>
</table>

### Least disruptive

- Always use softer insecticide: 1
- Use softer insecticide if possible: 2
- Use the most cost effective insecticide: 2

### Most disruptive

- Only if becoming a problem: 4
- Once on young crop: 2
- 2-4 times throughout crop: 1
- Throughout crop: 1
The solution:
Crop rotations – what type, how often?

<table>
<thead>
<tr>
<th>Vegetable</th>
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The solution:
How fast can it move, establish and spread?

3 Scales:
Small - 10s of meters
Large - 100s of meters
Landscape – Kms (F1s only)

Release field; 130,000 adults as pupae
7 days PR – max 32 m

7 days PR – bi-modal; max 270,

Kristensen, De Barro, Schellhorn, 2013, *Plos One*
Kristensen, Schellhorn, Hulthen, Howie, De Barro, 2013, *Env Ent*
10s of metres - Flying-only

Kilometres - wind-only model

100s of metres – Combination = wind & flying

Kristensen, De Barro, Schellhorn, 2013, *Plos One*
Kristensen, Schellhorn, Hulthen, Howie, De Barro, 2013, *Env Ent*
Field Guide

How to get

**THE MOST**

out of *hayati*

---

- how to tell *hayati*
- where to source *hayati*
- the best crop rotations
- what sprays to avoid
- what sprays are compatible

Whitefly Public Enemy #1

*Hayati* [hay-ar-tee] is a very small parasitoid wasp that can help control Silverleaf Whitefly, a serious pest of fruit and vegetable crops.

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Ask questions ... find solutions ... change for the better
introduction

Lives 4.5 days longer
Produces 3 x more progeny

Villanueva-Jimenez, Schellhorn and De Barro, 2012, Biological Control
Grower self assessment of their SLW problem

- Independent survey ~ 68 growers
  - Significant reduction
  - Down from near catastrophic problem

![Graph showing the decrease in whitefly problem from 2000 to 2010. The problem starts as catastrophic and reduces significantly by 2004.]

- No problem
- Catastrophic problem

Year range: 2000 to 2010

- 2000: 10
- 2001: 2
- 2002: 4
- 2003: 6
- 2004: 8
- 2005: ?
- 2006: ?
- 2007: ?
- 2008: ?
- 2009: ?
- 2010: ?

Note: The data from 2005 onwards is not available.
Summary Ex 1.:

Problem + Tool + Grower Practices + Technologies
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The Problem: *Bactrocera tryoni*, Queensland Fruit Fly (Qfly)

#1 biosecurity barrier to trade of fruit & veg in Australia
Background: History of Fruit Fly Exclusion Zone

1994: Tri-State Fruit Fly Exclusion Zone (‘FFEZ’) established
2007: Hard to maintain, area reduced (subset of FFEZ)

*Frequency of outbreaks continued to rise*

2011-12: Restrictions placed on use of fenthion + dimethoate
2012: Goulburn Valley declared endemic
2014: Suspended the Sunraysia PFA

Export value AU$m (% of Australia’s fresh horticultural exports)

<table>
<thead>
<tr>
<th>State</th>
<th>Value</th>
<th>% of Australia’s Fresh Horticultural Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Australia</td>
<td>$204.9</td>
<td>(13%)</td>
</tr>
<tr>
<td>Victoria</td>
<td>$793.8</td>
<td>(51%)</td>
</tr>
<tr>
<td>New South Wales</td>
<td>$172.9</td>
<td>(11%)</td>
</tr>
</tbody>
</table>
The solution:
Remove the market barriers to trade fruit & vegetables

$5b fruit-fly susceptible fruit; export $500m

Area-wide Management &

SITplus

Port Augusta, South Australia
Adaptive AWM of Qfly using SIT

How?

Cost-effective AWM & SIT

Regionally-focused programs for AWM & SIT

Strategy to maximise uptake of AWM & SIT

IMPACT

Uptake of AWM for Qfly and the ability to incorporate SIT fly
Background
Setting the scene: Qfly status

**Riverland**
*Fruit Fly “Pest Free Area”*
**Major crops:** citrus, table grapes, stone fruit
- State government conduct surveillance and response to fruit fly
- Gov release SIT (Qfly + Medfly)

**Sunraysia**
*Suspended PFA*
**Major crops:** citrus, table grapes, stone fruit
- 2007 GSPFA established to replace the FFEZ
- 2011-2014 persistent + increasing outbreaks
- 2014 voluntary suspension of PFA

**Goulburn Valley**
*Endemic*
**Major crops:** stone fruit, apples, cherries, pears
- 2011 persistent and increasing outbreaks
- 2012 endemic status declared
- Shifting from canning to fresh or value added produce
Area suitability to receive SIT = 1st reduce flies

Best Management Practice (BMP)

Protein bait:
- start early (4 weeks before ripening)
- apply weekly
- until 3 weeks after harvest

Male annihilation:
- place MATs in orchards (10-20 per ha)
- apply three times a year
- leave out all year

Sanitation:
- remove all unpicked or fallen fruit after harvest
Social challenges and constraints to AWM and possible use of SIT

**Solution:** What are the factors that will allow people to work together?
Solution: The main factors for the acceptance of AWM was perception of **fairness**
Solution: **Self-efficacy** and *‘team spirit’* most important factors contributing to the intention of implementing AWM

**Intention to implement AWM: Threat context**
- Self-efficacy re AWM
- Knowledge of Qfly controls
- Vulnerability to Qfly
- Efficacy of AWM
- Threat severity of Qfly

**Intention to implement AWM: Social context**
- Team Spirit
- Age
- Personal responsibility
- Willingness to cooperate
- What do others think about AWM?
What are the landscape factors that will make AWM and SIT feasible?
Spatially explicit population model

Ecology and behaviour of Qfly (reproduction, mortality, movement),

Host data (seasonality, quality, distribution)

complex landscapes
Population dynamics follow fruit availability peaks at the end of Stonefruit/Grapes season (high quality crops)

number of affected properties peaks later (flies searching for resources)
Simulate Management Scenarios

Best Management Practice (BMP)

**Protein bait:**
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- Apply weekly
- Until 3 weeks after harvest

**Male annihilation:**
- Place MATs in orchards (10-20 per ha)
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**Sanitation:**
- Remove all unpicked or fallen fruit after harvest

- 60% of farms adopt BMP -
Effectiveness

![Diagram showing the effectiveness of controlling fly density per patch over time, with graphs for log10 population density and no. patches with flies, and a histogram for fly density per patch.

- The effective area is indicated with arrows.
- The red line represents managed areas, while the blue dashed line represents unmanaged areas.
- The graphs show a comparison between managed and unmanaged areas over time.

- The x-axis represents time.
- The y-axis for the left graph shows log10 population density per m².
- The y-axis for the lower graph shows no. patches with flies.
- The right graph shows the frequency distribution of fly density per patch, with histograms for managed and unmanaged areas.
Example

- Graphs showing the log10 (population density [1/m²]) and the number of patches with flies over time.
- Heatmaps comparison between unmanaged and managed areas.
- Frequency distribution of log10 (population density per patch [1/m²]) for 1 Apr and 1 Oct.
Feasability

Citrus, vegetables, Trees

Table grapes & Urban

log10 (population density per patch [1/m²])

Frequency

1. Apr

1. Oct

effective

not effective

unmanaged

managed
Trajectory for success – social + biophysical

get growers engaged in BMP

social: self-efficacy; make sure they know what to do

Citrus, vegetables, Trees

get both residents & growers involved; options of urban treatment

Social: perception of fairness; people experiencing problem is different that people affected by the problem

e.g., Swan Hill, town given traps; buying into the solution, solved buying into the problem

Table grapes & Urban
Problem

- Solution needs to be flexible to appeal to people with different motivations & challenges.

Tool

- BMP
- SIT

Technologies

Trans-disciplinary

- AWM using SIT
- Barriers
- Institutional Mechanisms
- Personal Factors
- Facilitators
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**Problem:** Inability to know in real-time the presence and location of arthropod pests

Greatest barriers to better border security and sustainable food production
Global fruit & veg
Threatened: $US18b
Lost: $US30b
Millions of traps are checked manually.
South Australia, AUSTRALIA

Legend

- Permanent Trapping Grid

2000 traps
We believe in making agriculture SMART

RapidAIM

www.rapidaim.io
A New Era...
Unique Sensors – Behavioral “fingerprint”
Fruit Fly Alert!

LoRa Alliance™
Wide Area Networks for IoT
RapidAIM generates value to end users by:

- Real-time alert for rapid response = less damaged fruit
- Improved workflow = 8 fold reduction in labour
- Early warning of future FF ‘hot spots’ = keeps trade flowing
Completed a semi-commercial trial Shepparton, VIC Feb – April 2017

• 40 rapidAIM traps; 40 manual traps
• 15 Growers; 26 properties
• All growers had alert dashboard on their phones
• What they liked, what they wanted to change
GENERAL RESULTS

- Traps communicate to gateway from 3.5Km
- IoT LoRaWAN – each gateway ~ 50 km²
- 2 lithium ion batteries, lasting 9 months

Peak season

- Empty traps = 44%; Traps with flies = 56%
- Time is wasted checking traps
- Further reduce time checking traps,
  - only visit to change lures, and general maintenance
Value of end user engagement -

- Low power, high quality images of fruit fly sent as alert to an end user;

- Patented technology;

- Out of the building, engaged with end users (those wanting better fruit fly monitoring)

  - We learned:
    - Only need to know if a fruit fly has arrived in the trap;
    - Don’t need an image;
    - Allowed us to develop new technology
      - Low cost, low power
- Enabling the global trade of fruit and veg

We believe in making agriculture SMART

www.rapidaim.io
Re-cap

• Scope and historical context of AWM
• Challenge of AWM – people, mobile arthropods, and heterogeneous landscapes
• Case studies from Silverleaf whitefly and QLD Fruit Fly
  • tools (classical biological control & novel sensors for real-time monitoring),
  • technologies (analytical and simulation modelling); and
  • transdisciplinary science (social & biophysical scientists; engineers (hardware, software, cloud) & insect ecologists and socio-economics.
Conclusions

• **Make your great science count!**
  – Collect baseline information on the extent of the problem at the beginning
  – *Outcome:* Demonstrate the impact of the research
  – Involve your end users at the beginning
  – *Outcome:* Better hypotheses, and generate information that can affect change

• **Consider a trans-disciplinary approach to problem solving**
  – Include multiple disciplines from the beginning to simultaneously address many parts of the problem
  – *Outcome:* Pathway to impact can happen faster (social-ecological networks; social network has to match the biophysical network to make progress)
SLW Example: Acknowledge and thank growers, funders, and collaborators
Fruit fly simulation modelling and social science example: Acknowledge Hazel Parry, Penny Measham, and the wider team, growers, and community stakeholders!

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