The use of hand-held computers (PDAs) to audit and validate eradication of a post-border detection of Khapra Beetle, *Trogoderma granarium*, in Western Australia

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DOI: 10.5073/jka.2010.425.027

Abstract

Most of Australia's agricultural produce is exported. Demonstrating freedom from certain plant and animal pests and diseases is critical to securing and maintaining market access. Surveillance is an important tool in gaining market access and accordingly exporting countries now need to provide accurate, credible evidence to confirm pest freedom status.

In the past nearly all field-collected surveillance information was recorded manually to paper reducing the rate of capture, integrity, conformity as well as security of the data. This paper describes the development of pest surveillance data collection software and hardware using PDAs (Personal Digital Assistants) to provide auditing, validation, chain of evidence and increase the volume of data collected as well as its integrity through relational databases and seamless data transfer to corporate systems. The system's first deployment was during a *T. granarium* eradication.

The khapra beetle (*Trogoderma granarium*) is one of the most serious pests of stored grain and is a regulated quarantine pest in most countries around the world. In April 2007, there was a post-border detection of *T. granarium* larvae and adults in a Western Australian residence. Immediate and uncompromising action was taken to quarantine the home and fumigate it with methyl-bromide at an internationally established rate known to control *T. granarium* (AQIS T9056).

A two-year *T. granarium* trapping program was undertaken which used PDA software to provide evidence of complete eradication via 1273 trap inspections. This achievement was supported by GPS-located traps, digital voice navigation itineraries, digital time and date stamps, field printed barcode labels, site imagery, all in a single hand-held unit.

Keywords: *T. granarium*, Khapra beetle, Eradication, Biosecurity, PDA, Surveillance

1. Introduction

Australia remains committed to World Trade Organisation, Sanitary and Phytosanitary agreements, that require measures taken to protect animal, plant, or human health must be scientifically justified and supported by evidence (WTO 1995). As international concerns about food quality and safety increase, countries' import requirements are becoming more demanding and exporters including Australia must not only declare they are free from plant and animal pests and diseases, but they need to demonstrate it with evidence. It is no longer good enough to provide "absence of evidence"; international markets require "evidence of absence" for quarantine pests.

Trogoderma granarium Everts (Coleoptera: Dermestidae) is a stored product pest of great significance (Szito, 2006). In the 1950's, Australia was inadvertently recorded as a "*T. granarium* country" due to a misidentification of a non-pest, undescribed native beetle This misidentification created trade issues for Australia and took many years to correct (Lindgren et al. 1955). In order to continue to protect its reputation as an exporter of clean grain, Australia maintains a rigorous protocol of pre-loading inspection of export ships supplemented by port and urban based surveillance trapping programs to provide evidence of absence for *T. granarium*.

In April 2007, the Department of Agriculture and Food Western Australia (DAFWA), Pest Surveillance Team uncovered a post-border detection of *T. granarium* in the personal effects of a recently-arrived migrant family in suburban Perth, Western Australia. The residents were disturbed by the presence of beetles and larvae throughout their belongings and reported this to a pest controller who recognised the khapra beetle from DAFWA extension material. A biosecurity officer was sent out the same day to collect specimens which were identified the next day by the DAFWA taxonomist Mr A. Szito. This identification was confirmed a week later by the CSIRO taxonomist.

Immediate action was taken by Australian government and grain industry to eradicate this post-border detection with a methyl bromide fumigation followed by a two-year trapping program to reinforce complete eradication of the pest (Emery et al. 2008).

This trapping program provided the opportunity for the first use of novel PDA (personal digital assistant) technology developed with the Australian Cooperative Research Centre for National Plant Biosecurity (CRCNPB) at DAFWA, to provide verifiable surveillance data by using 1273 *T. granarium* trap inspections over two years. The PDA pest surveillance tool is supported by GPS-located traps, digital voice navigation itineraries, site imagery along with synchronisation to desktop server databases. It is not just the zero data that is important; we must consider the data behind the zeroes. This metadata can be very expensive and time consuming to collect. Unique user and location identifiers, date and time stamps, GPS coordinates, barcode labels, validation rules and integrity checking are all enhanced with the PDA pest surveillance tool.

2. Materials and methods

2.1. Methyl bromide treatment

The two-year-old two-storey townhouse discovered to have a *T.* granarium infestation was covered with shrink wrapped plastic sheeting in May, 2007 using industrial grade 200 μ low density polyethylene. Shrink wrap plastics have several advantages over older techniques using tarpaulins or canvasses in that they fit more tightly around the structure, reducing leakage due to wear and tear in windy conditions and can be welded together onsite using hand held heat guns and shrink tapes.

The structure was fumigated with 80 g/m³ methyl bromide for 48 hours at 21°C at normal atmospheric pressure with an end point concentration at 48 hours of 20 g/m³ and is regarded as an effective standard by Australian Quarantine and Inspection Service (AQIS T9056). The fumigation was monitored at 24 hours to ensure a minimum concentration of 24 g/m³. An additional 8 g/m³ is added for each 5ºC the temperature is expected to fall below 21ºC to a minimum of 10°C, as this is the minimum temperature during the course of the fumigation that can be used for the calculation of the dose.

Three gas introduction points were installed in the infested house, with the primary one in the upstairs roof-space. Gas was also introduced at two points on the main floor and in the adjoining garage roof-space. Four electric fans for circulation were placed in appropriate locations throughout the house and six gas monitoring points and one temperature probe were installed in areas shown in Table 1 that were distant from in injection point and considered to be the most important for achieving and maintaining the desired gas concentration. Gas concentrations in the house were measured with Drager® tubes and pump and environmental concentrations with an MSA Sirius® Multigas electronic detector.

2.2. Post-treatment surveillance trapping

Insect monitoring was performed by implementing a trapping program over the two years after the fumigation using Trécé Storgard® traps baited with kairamone and ground raw wheat germ. These traps were placed in the treated residence (4 traps in the garage, garage roof cavity, pantry and upstairs roof cavity), 5 in neighbouring residences (1 trap in the kitchen of each house), 12 at the shipping container receival facility (22.0 km SE of the fumigated residence), 12 at a cardboard recycling facility (19.7 km SE of the fumigated residence) and 10 traps were placed at a waste transfer station (5.6 km NE of the fumigated residence).

These traps were checked visually by a biosecurity officer weekly for the first month of the program then monthly during winter when insect activity is low. Over the warmer months of September to April the traps were inspected except for the private residences which were checked monthly and lures replaced quarterly. All insects trapped were recorded and suspect Trogoderma specimens returned to the laboratory for identification by a taxonomist. Non-target specimens not belonging to the Dermestidae were identified in the field.

2.3. PDA trap surveillance tool

In the past nearly all field collected surveillance information was recorded manually to paper reducing the rate of capture, integrity, conformity as well as security of the data. The CRCNPB recognised the need for a more robust field surveillance data collection tool and commissioned a two-year project with DAFWA focussing on development of pest surveillance data collection software and hardware using hand-held computers, PDAs or smartphones. This approach provides chain of evidence control, increases the volume of data collected as well as its integrity through relational databases and seamless data transfer to corporate systems.

Recognising the need to encourage collaborators from different disciplines across the country to add value to each other for years to come, it was decided not to look for a “shrink wrapped solution”. This meant ignoring for the time being, less mature platforms and working in the Windows Mobile® PDA. The software development environment chosen was largely wizard driven to encourage collaborators to develop in-house solutions, to share techniques, code and modules. Visual CE® (SYWARE, Inc. Cambridge, MA) was found to provide the functionality this project required.

For field and laboratory mapping the PDA application collected digital latitude and longitudes and ported them to Google Maps for Mobiles® for display in the field. Digital latitude and longitudes (dd.ddddd) were chosen over analogue (dd mm ss) and UTM (eastings and northings) because they are now considered best practice for georeferencing by the Global Biodiversity Information Facility (Chapman et al. 2006) and can be captured directly from the GPS NMEA stream by the surveillance application.

PDA hardware running Microsoft Windows Mobile 5.0, bluetooth, WiFi internet, built-in Sirfstar III GPS and voice navigation were distributed to beta testers from the Australian Department of Agriculture Fisheries and Forestry, Surveillance Reference Group (DAFF 2008) for Urban Surveillance.

Trap run itineraries can be prepared using Google Earth or Google Maps on desktop PCs and uploaded to the PDA. These itineraries can then be used with several popular voice navigation programs to provide in-car voice navigation to sample sites. The ability to maintain itineraries and POIs on desktop computers and send to the PDA is important because it allows the surveillance administrator to keep libraries of the various “trap runs" and upload to PDAs as staff rotate.

On demand printing of specimen barcode labels in the field provides chain of evidence and was achieved with ruggedized, portable, bluetooth thermal printers costing about US$300. These units can print adhesive two inch barcode labels for specimen vial tracking through laboratory information management systems.

The PDA surveillance application, more fully described in Emery, 2009, has a user-friendly interface with sub-forms to "drill-down" from properties through activities, inspections to specimens. The interface incorporates one-click links to Google Maps for Mobiles allowing easy navigation to sites, the ability to view aerial photography of sites and even street views of property frontages.

Several issues needed to be resolved before the application could be deployed. One-click GPS activation from within the application, unique record identifier generation by combining device_ID and an auto-number was required so that data from multiple PDAs could be synchronised without primary key errors. Photographic image recordings of trap locations and specimens can be stored in the database.

3. Results

3.1. Methyl bromide treatment

Two hours after introduction of 100 kg of methyl bromide through the primary line, five of the monitoring points showed the maximum concentration readable by Drager tubes of 80 g/m³ and one point at 68 g/m³ (Table 1). The average recorded could have been well over 80 g/m³ if the gas monitoring equipment was able to read higher. Given the superior state of sealing afforded by the shrink-wrap process, the methyl bromide was able to be introduced through only one point in the upstairs roof space, the gas dispersed throughout the house and adjoining garage rapidly and evenly without the need for the circulation fans to be turned on. After 24 hours the average gas concentration was 39.8 g/m³ (24 g/m³ required by T9056) and at 48 hours 30.8 g/m³ (20 g/m³ required by T9056. The average temperature over 48 hours on the concrete lower floor was 20.7°C. More detail of the fumigation readings can be found in Emery (2008).

Table 1 Fumigation data for *T. granarium* eradication.

		Methyl Bromide Concentration (g/m^3)					
Time	**Temp**	**Line 1**	**Line 2**	**Line 3**	**Line 4**	**Line 5**	**Line 6**
d h:mm	**(°C)**	**Downstairs lounge**	**Kitchen**	**Upstairs bathroom**	**Upstairs roofspace**	**Master bedroom**	**Garage**
0 00:55	20.8	44	40	48	48	40	72
0 01:55	21.1	68	80	72	80	76	80
0 02:55	20.5	64	80	80	80	80	80
0 03:55	20.3	80	80	80	80	80	80
0 04:55	20.4	40	56	60	64	64	80
0 05:55	20.4	64	80	56	72	64	76
0 06:55	20.4	76	80	80	64	48	72
0 07:55	20.5	64	80	76	72	72	76
0 08:55	20.5	72	72	72	72	72	72
0 09:55	20.3	64	72	68	76	72	72
0 10:55	20.5	72	72	72	72	72	72
0 11:55	20.6	76	72	68	72	68	72
0 13:55	20.8	64	72	64	60	64	68
0 15:55	20.4	48	64	64	72	56	64
0 17:55	21.1	48	56	52	64	32	52
0 18:55	21.0				40	32	
0 20:55	21.5					40	
0 21:55	21.4		40				
1 01:55	20.7		38				
1 04:55	20.4		35	36	40	40	48
1 07:55	20.2	36	36	36	40	32	40
1 10:55	19.9	34	32	32	36	36	36
1 13:55	21.1	35	35	30	32	35	35
1 16:55	21.3	35	35	28	35	30	35
1 19:55	21.7	32	35	30	30	28	30
2 00:55							

3.2. Post-treatment surveillance trapping

Trapping and monitoring at the infested site and all suspect residential and industrial premises was undertaken over the two year period from June 2007 to May 2009. No detections of *T. granarium* in any trap were made during this period (Table 2) despite a number of non-target pests being trapped (Table 3).

Table 2 Post-treatment trap inspection data for *T. granarium* eradication.

Property	**Trap Inspections**	***T. granarium***
Residential property 7A Duke	20	0
Residential property 7B Duke	20	0
Residential property 9A Duke	18	0
Residential property 9B (infested premises)	87	0
Residential property 1A	8	0
Residential property 1B	20	0
Industrial transfer station	328	0
Industrial recycling facility	390	0
Industrial container receival	382	0
Totals	1273	0

Table 3 Raw PDA data for non-pest species trapped during post-treatment trap inspections.

Activity Name	Non-target specimens trapped
Infested House	
189BGarage	spider; *Trogoderma* spp native Trogoderma
189BGarageRfspc	cockroach; *Anthrenus* carpet beetle
189BPantry	fly; termite
189BUpstairsRspc	Silvanidae foreign grain beetle
Five neighbouring residences	
Pantries	nil
Refuse recycling centre	
Balcatta1	Curculionidae *Sitophilus oryzae* rice weevil; springtails; *Anthrenus verbasci* European carpet beetle; spider beetle; *Anthrenus* spp; psocids/booklice; *Rhyzopertha dominica* lesser grain borer; Psocidae booklice; Lepismatidae silverfish
Balcatta2	unknown larval skin; Psocidae booklice; *Anthrenus* carpet beetle; Lathridiidae; Trogoderma spp; Portuguese millipede; psocids/booklice; Mezium sp. spider beetle; Tenebrionidae vegetable beetle; spider beetle; *Trogoderma variabile* warehouse beetle; cockroach; Ptinidae *Mezium americanum* spider beetle.
Balcatta3	Psocidae booklice; German cockroach; psocids; Dermestidae
Balcatta4	Psocidae booklice; spider; German cockroach; *Trogoderma* sp.; Rhyparochromidae.
Balcatta5	unknown weevil; Psocidae booklice *Trogoderma* sp.
Balcatta6	Blattidae flower cockroach; Psocidae booklice; silverfish.
Balcatta7	Psocidae booklice; *Typhaea stercorea* hairy fungus beetle; Ant; *Anthrenus* spp. carpet beetle.
Balcatta8	Psocidae booklice; *Trogoderma* sp.; cricket
Balcatta9	Psocidae booklice; Simuliidae fly; Mezium spider beetle; cockroach; *Anthrenus* carpet beetle; spider
Balcatta10	*Anthrenus* carpet beetle; spider beetle; spider; psocid
Cardboard recycling facility	
Visy1	*Trogoderma variabile* warehouse beetle; *Anthrenus* sp. carpet beetle; *Trogoderma* sp.
Visy2	*Trogoderma variabile* warehouse beetle; Psycodidae moth fly; *Anthrenus* carpet beetle; *Trogoderma* sp.
Visy3	*Trogoderma variabile* Warehouse beetle; *Anthrenus* carpet beetle.
Visy4	*Trogoderma variabile* Warehouse beetle; *Typhaea stercorea* hairy fungus beetle; Trogoderma sp.; spider beetle; Hygrobidae water beetle; Dermestidae
Visy5	Psocids
Visy6	*Trogoderma* native Trogoderma; *Trogoderma variabile* Warehouse beetle; *Anthrenus* carpet beetle; Dermestidae
Visy7	*Trogoderma variabile* warehouse beetle; ant; Dermestidae
Visy8	*Trogoderma variabile* warehouse beetle; parasitic wasp; black beetle; hunchback fly; scarab beetle; non-biting midge; Dermestidae *Trogoderma variabile* warehouse beetle; *Anthrenus* sp; Dermestidae
Visy9	Simuliidae fly; *Trogoderma variabile* warehouse beetle
Visy11	*Trogoderma variabile* Warehouse beetle; *Phradonoma bicolor*
Visy12	*Trogoderma variabile* Warehouse beetle; Rutherglen bug; *Anthrenus* carpet beetle; *Trogoderma* native Trogoderma; Staphylinidae
Shipping container receival facility	
Wridgways1	Psycodidae moth fly; moth; spring beetle
Wridgways2	*Anthrenus* sp. carpet beetle
Wridgways3	Dermestidae *Trogoderma variabile*
Wridgways4	*Trogoderma* sp.
Wridgways5	psocids
Wridgways7	*Trogoderma* spp.; *Trogoderma variabile*
Wridgways8	warehouse beetle; drugstore beetle
Wridgways9	psocids; case-making clothes moth.
Wridgways12	Psycodidae hunchback fly; non-biting midge; scale insect; Psycodidae moth fly; non-stinging midge; spider; Rutherglen bug

4. Discussion

Fumigation data shown in Table 1 clearly demonstrate the high standard of gas retention which was well above the CT required and provides a level of assurance of eradication of any *T. granarium* that were in the fumigated residence. However, eradication can only be declared once extensive, validated trapping data are presented.

Non-target specimens trapped provide assurance that the traps were serviceable. Over 180 specimens were found in the traps during the two-year survey. They included 43 adult beetles and larvae belonging to the Dermestidae which required determination by a taxonomist. None of the specimens trapped were *T. granarium*. These trap records are summarized in Table 3.

The efficiencies provided by the PDA pest surveillance tool facilitated the collection of high quality data. This first deployment of PDAs for *T. granarium* surveillance in Australia has shown that data can now be collected with utmost integrity. While these data may not be required to support export industries right now, they could be in future if an importing country challenges Australia's stated position that it is free of a quarantine pest. More extensive collection of "evidence of absence" data can be achieved through the efficiencies of the PDA approach. These data have improved credibility and auditing with GPS coordinates, time and date stamps as well as evidentiary chain through sample barcodes and PDA "nag screens" to remind field staff to replace lures all add value to the zeros. Trap data can now be easily correlated with metadata and more traps can be serviced quickly. This is paramount to implementing corrective actions when necessary. The ability to correlate insect trap capture with metadata can also be used with population models to assist in evaluating risk for the regulatory bodies

Information on the habitat/terrain, prevailing weather conditions and training records of the surveillance officer can also be cross-referenced to each inspection made thereby adding metadata veracity to each collected zero.

This project used one dimensional barcodes to identify traps and specimens, however, recently developed two dimensional barcodes could be used on traps to trigger automatic actions such as an emergency response text message that cannot be interfered with by the user.

One area still to be explored is the use of wireless synchronisation. Syware's mEnable wireless synchronisation server has not been installed due to security implications. The location of servers will need to be negotiated as will agreement of industry participants who may have concerns over the security of their data. When this is resolved, field staff will be able to synchronise PDA-collected data from anywhere in the world provided their PDA can be connected to the internet via wifi, GPRS or host desktop PC.

The challenge now is to encourage user uptake of this new technology. Some data collectors see the PDAs as an imposition because they have an established routine, while others are concerned about their privacy being violated by GPS tracking of their movements. While it may take longer to input data on the PDA compared with writing on a clipboard, there is considerably less time spent on data input when returning to the laboratory. These data handling hours are completely removed with the PDA approach as data are seamlessly synchronised with computer systems. User training and support will be the key to gaining acceptance for this type of technology and endorsement from management will be pivotal in this process.

Another concern is that some data collectors continue to store their data in personal spreadsheets and will tout "It's all on the computer". Unfortunately these data have minimal integrity; there are no relational records and no lookup tables with the result that duplication of records through mis-spellings and alternative spellings can be rampant. An erroneous trap location entered in this way could sit among thousands of other records and not be found. The challenge is to encourage field pest surveillance staff to work with PDAs and take advantage of the data integrity that will provide avenues for data to have multiple uses and reduce the level of data displacement to filing cabinets and other non-digital storages.

New applications are under development for other surveillance projects including the Australian bulk handling industry. The grain storage prototype application tracks maintenance tasks, records quarantine pest surveillance and, most importantly, monitors stored grain fumigations to improve fumigations through assistance in extensive monitoring and real time evaluation of fumigation effectiveness.

Acknowledgments

Supporting organisations; Cooperative Research Centre for National Plant Biosecurity, Department of Agriculture and Food Western Australia, CBH Group, Murdoch University. Damian Shepherd, Iain Martin, John Bruce (DAFWA Spatial Information Systems) and Bob Vassallo (DAFWA Animal Biosecurity) provided technical input. DAFF Surveillance Reference Group participants collaborated with beta testing the Urban Surveillance application; Peter Gillespie, Deborah Kent, Craig Murdoch, Tony Monteith, Rebecca Yarrow, Bruce Baker, Wayne Marshall, Russell Elliott, Megan Szczerbanik, Nita Ramsden, James Swan, Heather Wallace, Richard Johnston, Cain Roberts, Melanie Hay, Jo Slattery, Sharyn Taylor, Stephen Dibley, Paul Pheloung, Gareth Men, Greg Hood, Debra Riddell, Peter Frecklington. Shirani Poogoda (DAFWA) beta tested the Fruit Fly Phenology application. Ern Kostas (CBH Group) beta tested the Grain Fumigation application. Peter Davis (DAFWA) beta tested with ant surveys on Christmas and Norfolk Islands. Giles Hardy and Yonglin Ren (Murdoch University) are leading the PDA project from 2010.

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