REVIEW OF THE SOUTHERN BOUNDARY OF JARVIS FRUIT FLY *BACTROCERA JARVISI* (TRYON) (DIPTERA: TEPHRITIDAE: DACINAE) AND ITS LIKELY SOUTHERN DISTRIBUTION IN AUSTRALIA

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Summary

Some international trading partners are interested in the distribution of the lesser known Australian fruit flies. Historical and current records for *Bactrocera jarvisi* were reviewed. Despite historical reports claiming *B. jarvisi* as far south as Sydney, current records indicated that there were only two years in 15 when *B. jarvisi* was detected in low numbers in the New South Wales fruit fly surveillance grid. It is likely that these detection were from incursions that did not establish, rather than from local populations. Current records support the concept that *B. jarvisi* is closely linked to its native host, cocky apple, which is known to be distributed in northern Western Australia, Northern Territory and the Queensland coast down to Maryborough. All states and territories other than Queensland, Northern Territory and Western Australia should be considered free from *B. jarvisi*.

Key words: market access, *Bactrocera tryoni*

INTRODUCTION

Crop pests and pathogens pose a significant and growing threat to food security (Bebber *et al.* 2014). For developing countries, food security is increasingly important and drives international fruit movements, along with the desire for minimum pesticide residues in food (Schulten 1997; Dominiak and Ekman 2013; Bebber *et al.* 2014). The gross value of Australian crops was valued at A$28 billion in 2012-2013. Over 75 per cent of Australia's fruit and vegetable exports, valued at about $640 million in 2012-13, are susceptible to fruit fly (CRC Plant Biosecurity 2014). Australia's "clean-green" image for exported produce depends on the supply of commodities susceptible to fruit fly attack but for which freedom from fruit fly infestation can be assured to international markets (Smith 2000).

For international market access, fruit fly populations can be placed into one of several standards varying from pest freedom to endemic status. Recognised pest area freedom is the ideal fruit fly status as no disinfestation is required for domestic and international market access. The requirements for international standards for phytosanitary measures for pest free areas are detailed in IPPC (2006). Requirements include conditions where a specific pest has been demonstrated not to occur by scientific evidence. Evidence can be in several forms. General or specific surveys are pivotal and can be supported by historical records in scientific or trade journals. The pest free area needs to be delimited. The pest free area should also be adequately isolated in relation to the biology of the pest. There are similar requirements for areas of low pest prevalence (IPPC 2008) although there is tolerance for transient fruit fly populations.

In the Asia and Pacific regions, Dacine fruit flies (Diptera: Tephritidae: Dacinae) are one of the key pest groups. Larval feeding causes direct damage, fruit drop and loss of export markets for a broad range of fruit and vegetable crops (Hancock *et al*. 2000: Clarke *et al.* 2005). The major economic fruit flies in Australia are Queensland fruit fly (Qfly) *Bactrocera tryoni* (Froggatt) and Mediterranean fruit fly (Medfly) *Ceratitis capitata* (Weidemann) (Dominiak and Daniels 2012) and initial research and extension focused on these two species. The biology and distribution of these two species is now well understood (Clarke *et al.* 2011) and scientific and market access interest is turning to the lesser known Australian fruit flies.

Jessup *et al.* (2007) reported on the extensive Australian monitoring network and interstate trade process for the well-known fruit fly pests. Royer *et al.* (2016) recently published a review of *Bactrocera frauenfeldi* (Schiner). Dominiak and Worsley (2016) reviewed the southern boundary of *Bactrocera neohumeralis* (Hardy). However many of the other lesser known native species are less well studied, particularly those not strongly attracted to conventional male lures (Royer *et al*. 2015). Historical records and observations may be used to provide evidence about the potential range of pest populations of these lesser known fruit flies but provide less confidence for fruit fly freedom. Distribution patterns may change due to changing climatic patterns (Zalucki 2015; Sutherest *et al*. 2000) however Australia's trade partners demand that these ranges be defined.

Bactrocera jarvisi (Tryon) is one of the lesser known Australian fruit flies. There is considerable knowledge about the biology and management of *B. tryoni* (Clarke *et al*. 2011) and there are standards for *B. tryoni* such as flight distance (Dominiak 2012), thresholds for outbreaks (Dominiak *et al*. 2011) and areas of low pest prevalence (Dominiak *et al*. 2015a). Given the closeness in biology (but not host range) of *B. tryoni* and *B. jarvisi*, we will apply the *B. tryoni* standards to *B. jarvisi* in the absence of other data that suggest otherwise. In this manuscript, we review the published reports covering the distribution of *B. jarvisi* in Australia but primarily in New South Wales (NSW). We also review the trapping records in NSW and suggest why the species is so infrequently detected in NSW. Commodities from known endemic areas, such as Queensland and parts of the Northern Territory and Western Australia, will need to be disinfested (Gamage *et al.* 2015).

In the following text, historical records are compared with current surveillance to articulate the areas consistent with pest freedom or areas of low pest prevalence. Other areas are deemed to be endemic. We also identify the areas for each international standard for market access (IPPC 2006, 2008).

LURES AND SURVEILLANCE

Tobin *et al.* (2014) claimed that the relative detectability of any species is a key determinant for surveillance, detection and eradication outcomes. Fruit flies are usually ideal insects to control because of their response to lures, making detection and eradication easier than for many other insects (Suckling *et al.* 2016). Male *B. jarvisi* are weakly attracted to cuelure (White and Elson-Harris 1992, Hancock *et al.* 2000, Royer *et al.* 2012). More recently, Fay (2012) reported zingerone as a potential lure for *B. jarvisi.* Royer (2015) found *B. jarvisi* was attracted to zingerone and weakly attracted to cuelure and raspberry ketone. Cuelure is an acetyl analog of raspberry ketone; cuelure is not found in nature but is readily converted to raspberry ketone in the presence of moisture (Metcalf 1990). Fruit fly surveillance in New South Wales uses cuelure attractant in Lynfield traps (Dominiak *et al*. 2003, 2015b; Gillespie 2003): most traps in Australia use cuelure to attract Bactrocera (Jessup *et al*. 2007*)*. During a test of zingerone in Sydney, *B. jarvisi* was not detected (Dominiak *et al.* 2015b).

Raphael *et al.* (2014) claimed *B. jarvisi* had a narrower host range compared to *B. tryoni* and *B. neohumeralis*. The distribution of *B. jarvisi* has been claimed to be linked to its native host, *Planchonia careya* ((F.Mueil) R.Kauth) (Lecythidaceae) known as cockatoo apple, cocky apple, mangaloo or billygoat plum (Barrett 2006). Within this native host range, it would infest cultivated mango (*Mangifera indica*) and guava (*Psidium guajava*). Sherwin *et al.* (2015) claimed that the distribution closely followed its preferred host *P. careya* however where horticulture replaced the native host, *B. jarvisi* infested fruit crops such as mangoes and was a moderate host.

HISTORICAL DISTRIBUTION RECORDS

Zalucki (2015) claimed that mapping fruit fly distribution of species such as *B. tryoni* should be expunged from the record. Zalucki recognised that ranges or distributions of fruit flies did change, often as a result of climate change. However other issues may impact distribution such as the availability of hosts (Raphael *et al.* 2014). If the range is not reviewed and reported, trade partners may fear that this species is present in areas where it is not. Similarly if the range of Medfly was not defined (Dominiak and Daniels 2012), then all Australian produce would need to be disinfested for Medfly, even in the seven states and territories that are currently recognised free from this pest. To prevent this unnecessary and expensive activity, the historical and current information for NSW is discussed and the current range of *B. jarvisi* defined.

Before 2012, all surveillance for *B. jarvisi* was based on attraction to cuelure as no other lures were known. *Bactrocera jarvisi* is endemic to parts of north Australia. In north eastern Australia, Royer *et al.* (2012) reported detections in Queensland at Archer River, Aurukun, Ayr, Bowen, Brisbane, Bundaberg, Cairns, Coen, Emerald, Gympie, Hann River, Karumba, Lockhart River, Mackay, Mt Isa, Mundubbera, Pormpuraaw, Rockhampton, Stanthorpe, Townsville and Weipa. In Western Australia, Drew *et al.* (1978) described the original distribution down the east coast to around Sydney, across to Arnhem Land in the Northern Terrirtory, and across to Broome in Western Australia. Drew (1989) place *B. jarvisi* in the same range but added the islands in the Torres Strait of Badu, Darnley, Horn, Prince of Wales, Saibai, Thursday, Yam and Yorke. Bateman (1991) and Shearman *et al*. (2010) claimed that *B. jarvisi* was found in a band across the top end of the Northern Territory and northern part of Western Australia.

In south eastern Australia, the distribution is less clear. Drew *et al.* (1978) claimed *B. jarvisi* was found down to the Sydney area. Bateman (1991) claimed the fly was found down to Wilton in Sydney. Fay (2012) cited Drew (1989) indicating that *B. jarvisi* was distributed down to Sydney. If this was the case and the distribution was driven by climate, it would seem logical that *B. jarvisi* would be found at similar latitudes in Western Australia. The map in Shearman *et al*. (2010) suggests that range of *B. jarvisi* extended to a location midway between Sydney and the Queensland border (perhaps Coffs Harbour) but their map is not clear. Raphael *et al.* (2014) claimed the distribution extended into coastal NSW. Their map makes it difficult to define the southern edge of the range however it appears to be near Coffs Harbour however the landmarks in map are not clear. Bateman (1991) claimed that the distribution of *B. jarvisi* may be limited due to the competition from *B. tryoni*. Osborne *et al.* (1997) reported on the detection of 14,778 *B. tryoni*, 1074 *B. frauenfeldi,* 685 *B. neohumeralis* and many other fruit flies in a national survey but reported only seven *B. jarvisi*. However Osborne *et al.* (1997) did not articulate where the *B. jarvisi* were detected. Gillespie (2003) claimed that no *B. jarvisi* were detected in NSW between June 1997 and June 1999, effectively questioning early claims regarding Sydney and Coffs Harbour being the southern edge of the distribution.

Bateman (1991) claimed that *B. jarvisi* was a versatile species and climatic analysis indicated that it was capable of spreading as far south as Victoria. Smith and Brown (2014) reported that *B. tryoni* was recorded in over 70 hosts including 48 cultivated plant species. *B. jarvisi* had a much narrower host range of 27 species of which 15 were cultivated. Fay (2012) reported that *B. jarvisi* was a moderate pest with mango thought to be the most susceptible crop (Smith *et al.* 1988). Hancock *et al*. (2000) subsequently claimed that *B. jarvisi* had been recorded from 83 wild and commercial hosts from 28 families. Hancock *et al*. (2000) identified six major hosts, three of which are Myrtaceae.

DISTRIBUTION OF COCKY APPLE

Shearman *et al*. (2010) and Raphael *et al.* (2014) claimed the distribution of *B. jarvisi* was linked to its native host, *P. careya.* This host is a small tree between 4 to 10 m tall and is briefly deciduous in the dry season (Australian Native Plants Society (Australia), 2016). The plant grows mainly in open forest and is found on the margins of rainforest and monsoon forest. The plant also occurs in New Guinea. The bark of this species was a well-known fish poison (Australian Tropical Rainforest Plants, 2016). The fruit is green, egg shaped, smooth and approximately 9 cm x 4 cm in size. Fay (2012) reported that *B. jarvisi* was highly active in January and February in North Queensland. This seasonal peak was possibly caused by the close association with the main native host, *P. careya* which fruits in the latter part of the year (Fitt 1986). Wiki (2016) reported fruiting from November to March. From this peak in activity, *B. jarvisi* posed a substantial threat to any mango crops that are harvested from January in North Queensland (Fay 2012).

Given the evidence that *B. jarvisi* is so closely linked to *P. careya*, there is merit is assessing the distribution of this native host. The range of *P. careya* was claimed to be across northern tropical Australia and down the east coast to about Fraser Island near Maryborough in Queensland, near 25.5°S (Australian Native Plants Society Australia, 2016). The Atlas of Living Australia (2016) displays a map showing the range stops north of Brisbane in Queensland. Australian Tropical Rainforest Plant (2016) also place this host as present in Western Australia, Northern Territory and North East Queensland as far south as coastal central Queensland. Both The Atlas of Living Australia (2016) and Australian Native Plants Society Australia (2016) place the southern boundary in Western Australia at about Broome (17.5°S). The map in Barrett (2006) places the cocky apple range from about Broome to Fraser Island. This plant is also found in Papua New Guinea and southern Irian Jaya (Barret 2006).

Table 1. Detections of *Bactrocera jarvisi* in New South Wales in 2002 and 2004.

Year	Month											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2002												
Grafton	0	3	2	0	0	0	0	0	0	0	0	0
2004												
Yamba	0	1	0	0	0	0	0	0	0	0	0	0
Sydney	0	0	3	0	0	0	0	0	0	0	0	0
Griffith	0	0	0	1	0	0	0	0	0	0	0	0
Total	0	4	5	1	0	0	0	0	0	0	0	0

CURRENT DISTRIBUTION IN NEW SOUTH WALES

Data were extracted from the NSW PestMon database (Dominiak *et al*. 2007). Electronic trap data were available for most areas in NSW from 2001 to 2015. *Bactrocera jarvisi* was detected in NSW in two of the 15 years that data were available. Detections occurred in February, March and April and only five flies were trapped in each year (Table 1). Applying the standard for declaring a *B. tryoni* outbreak, the catches of *B. jarvisi* presented in Table 1 would not have triggered a management response due to an outbreak, i.e. there was no local population. These months are reasonably aligned with the peak mango season in January and February reported by Fay (2012). The most recent year was 2004 and detections were more widely spread than in 2002. Detections in 2004 are presented in Figure 1. The area of pest freedom therefore includes the states of Victoria, Tasmania, South Australia and the Australian Capital Territory. This includes the areas such as the Greater Sunraysia Pest Free Area and previously known Fruit Fly Exclusion Zone.

REPORTS FROM OTHER STATES

In South Australia, *Bactrocera jarvisi* has not been detected in locally grown fruit in the past 25 years (Secomb 2016, *pers. comm*.). However since 2003, *B. jarvisi* larvae have been detected 13 times in fruit imported into South Australia. These are widely dispersed detections (once in 2003, 2004, 2007, 2010, 2012, 2013 and 2015; five times in 2011). All detections were in mangoes and the detections were promptly dealt with according to national standards. The Northern Territory was the source on six occasions and Queensland on one occasion; the database did not record the source of other detections.

In Victoria since 2011, there were five single detections of *B. jarvisi* (three times in 2011, once in 2013 and 2015) (Mapson *pers comm.* 2016). All samples were detected in imported mangoes, four of which came from Northern Territory and one from Queensland. There are no records of *B. jarvisi* detected in locally grown fruit. These reports conform to the international standard for fruit fly freedom and South Australia and Victoria should be declared *B. jarvisi* free (IPPC 2006).

In Western Australia, *B. jarvisi* are detected as far south as Kununarra (15.5°S) and Broome (17.5°S) (Woods, *pers. comm*. 2016). Flies were trapped mainly during January and February at Broome and between November to February at Kununurra. Cuelure baited traps caught very few *B. jarvisi* except in the December-January period. In a trial between 2013 and 2015, zingerone attracted more *B. jarvisi* than cuelure (Henshaw *pers.comm.* 2016).

CLOSING COMMENTS

On the eastern Australian coast, the southern boundary of the endemic range of *B. jarvisi* is somewhere north of the border between Queensland and NSW, possibly at about 25.5°S. This range would appear to be consistent with the southern range of the main host, cocky apple, in Queensland near Maryborough. The few and isolated detections in NSW should be regarded as incursions that did not establish. Currently, New South Wales should be considered free from *B. jarvisi* at least for domestic trade as domestic agreements are reached quickly compared to the time required to complete international bilateral negotiations.. In Western Australia, *B. jarvisi* is not detected south of 18°S. Areas south of this latitude could be considered free from this pest for domestic trade perspective at least. All Australian states and Territories other than Queensland, Western Australia and Northern Territory should be recognised as being free from *B. jarvisi.*

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REFERENCES

Australian Native Plant Society (Australia) (2016). http://anpsa.org.au/p-car.html (accessed 15 April 2016).

Australian Tropical Rainforest Plants (2016). http://keys.trin.org.au/key-server/data/0e0f0504-0103- 430d-8004-060d07080d04/media/Html/taxon/Planchonia_careya.htm

Atlas of Living Australia (2016). http://bie.ala.org.au/species/urn:Lsid:biodiversity.org.au:apni.taxon:297005 (accessed 8 February 2016).

Barrett, R.L. (2006). A review of *Planchonia* (Lecythidaceae) in Australia. *Australian Systematic Botany* **19**: 147-153.

Bateman, A. (1991). The impact of fruit flies on Australian horticulture. Horticultural Policy Council. HPC Industry Report No. 3. 124 pp.

Bebber, P.D., Holmes, T., Smith, D. and Gurr, S.J. (2014). Economic and physical determinants of the global distributions of crop pests and pathogens. *New Phytologist* **202**: 901-910.

Clarke, A.R., Armstrong, K.F., Carmichael, A.E., Milne, J.R., Raghu, S., Roderick, G.K. and Teates, D.K. (2005). Invasive phytophagous pests arising through a recent tropical evolutionary radiation: The Bactrocera dorsalis Complex of fruit flies. *Annual Review of Entomology* **50**: 293-319.

Clarke, A.R., Powell, K.S., Weldon, C.W. and Taylor, P.W. (2011). The ecology of *Bactrocera tryoni* (Diptera: Tephritidae): what do we know to assist pest management? *Annals of Applied Biology* **158**: 6-54.

CRC Plant Biosecurity (2014). National Fruit Fly Research, Development and Extension Plan Consultation Draft 2014. 66 pp.

Dominiak, B.C., Gilmour, A.R., Kerruish, B. and Whitehead, D. (2003). Detection low populations of Queensland fruit fly (*Bactrocera tryoni* (Froggatt)) populations based on trap catch data. *General and Applied Entomology* **32**: 49-53.

Dominiak, B.C., Gillespie, P. and Tom, G. (2007). Changes in data management and the impediments to change – a case study for fruit fly surveillance. *Plant Protection Quarterly* **22**: 95-99.

Dominiak, B.C., Daniels, D. and Mapson, R. (2011). Review of the outbreak threshold of Queensland fruit fly (*Bactrocera tryoni* Froggatt). *Plant Protection Quarterly* **26**(4): 141-147.

Dominiak, B.C. (2012). Review of dispersal, survival, and establishment of *Bactrocera tryoni* (Diptera: Tephritidae) for quarantine purposes. *Annals of Entomological Society of America* **105**: 434-446.

Dominiak, B.C. and Daniels, D. (2012). Review of the past and present distribution of Mediterran fruit fly (*Ceratitis capitata* Wiedemann) and Queensland fruit fly (*Bactrocera tryoni* Froggatt) in Australia. *Australian Journal of Entomology* **51**: 104-115.

Dominiak, B.C. and Ekman, J.H. (2013). The rise and demise of control options for fruit fly in Australia. *Crop Protection* **51**: 57-67.

Dominiak, B.C., Wiseman, B., Anderson, C., Walsh, B., McMahon, M. and Duthie, R. (2015a). Definition of and management strategies for Areas of Low Pest Prevalence for Queensland fruit fly *Bactrocera tryoni* Froggatt. *Crop Protection* **72**: 41-46.

Dominiak, B.C., Fay, H.A.C. and Fanson, B.G. (2015b). Field evaluation of the efficacy of zingerone and other chemical lures on seven species of fruit fly in Sydney, New South Wales, Australia. *Plant Protection Quarterly* **30**: 67-71.

Dominiak, B. C. and Worsley, P. (2016). Lesser Queensland fruit fly *Bactrocera neohumeralis* (Hardy) (Diptera: Tephritidae: Dacinae) not detected in inland New South Wales or south of Sydney. *General and Applied Entomology* **44**: 9-15.

Drew, R.A.I., Hooper, G.H.S. and Bateman, M.A. (1978). Economic fruit flies of the South Pacific Region. Brisbane – Queensland Department of Primary Industries, Watson Ferguson and Co, Brisbane. 16-18.

Drew, R.A.I. (1989). The tropical fruit flies (Diptera: Tephritidae: Dacinae) of the Australasian and Oceanian Regions. *Memoirs of the Queensland Museum* **26**: 1-521.

Fay, H.A.C. (2012). A highly effective and selective male lure for *Bactrocera jarvisi* (Tryon) (Diptera: Tephritidae). *Australian Journal of Entomology* **51**: 189-198.

Fitt, G.P. (1986). The roles of adult and larval specialisations in limiting the occurrence of five species of *Dacus* (Diptera: Tephritidae) in cultivated fruits. *Oecologia* **69**: 101-109.

Gamage, T.V., Sanguansri, P., Swiergon, P., Eelkema, M., Wyatt, P., Leach, P., Alexander, D.L.J. and Knoerzer, K. (2015). Continuous combined microwave and hot air treatment of apples for fruit fly (*Bactrocera tryoni* and *B. jarvisi*) disinfestation. *Innovative Food Science and Emerging Technologies* **29**: 261-270.

Gillespie, P. (2003). Observations on fruit flies (Diptera: Tephritidae) in New South Wales. *General and Applied Entomology* **32**: 41-47.

Hancock, D.L., Hamacek, E.L., Lloyd, A.C. and Elson-Harris, M.M. (2000). The distribution and host plants of fruit flies (Diptera: Tephritidae) in Australia. Information Series Q199067. Department of Primary Industries, Queensland.

International Plant Protection Convention (2006). International standards for phytosanitary measures. ISPM No 26. Establishment of pest free areas for fruit flies (Tephritidae). 15 pp.

International Plant Protection Convention (2008). International standards for phytosanitary measures. ISPM No 30. Establishment of areas of low pest prevalence for fruit flies (Tephritidae). 16 pp.

Jessup, A.J., Dominiak, B.C., Woods, B., De Lima, C.P.F., Tomkins, A. and Smallridge, C. (2007). Area-wide management of fruit flies in Australia. *In* Vreysen, M.J.B., A.S. Robinson, *and* J. Hendrichs (Eds), Area-wide control of insect pests: From research to field implementation. Springer, Dordrecht, The Netherlands. 685-697.

Metcalf, R. (1990). Chemical ecology of Dacinae fruit flies (Diptera: Tephritidae). *Annals of the Entomological Society of America* **83**: 1017-1030.

Osborne, R., Meats, A., Frommer, M., Sved, J.A., Drew, R.A.I. and Robson, M.K. (1997). Australian distribution of 17 species of fruit flies (Diptera: Tephritidae) caught in cue lure traps in February 1994. *Australian Journal of Entomology* **36**: 45-50.

Raphael, K.A., Whyard, S., Shearman, D., An, X. and Frommer, M. (2004). *Bactrocera tryoni* and the closely related pest tephritids – molecular analysis and prospects for transgenic control strategies. *Insect Biochemistry and Molecular Biology* **34**: 167-176.

Raphael, K.A., Shearman, D., Gilchrist, A.S., Sved, J.A., Morrow, J.L., Sherwin, W.B., Riegler, M. and Frommer, M. (2014). Australian endemic pest tephritids: genetic, molecular and microbial tools for improved Sterile Insect Technique strategies. *BMC Genetics* **15** (Suppl 2): 59.

Royer, J.E. and Hancock, D.L. (2012). New distribution and lure records of Dacinae (Dacinae: Tephritidae) from Queensland, Australia, and description of a new species of *Dacus* Fabricius. *Austral Entomology* **51**: 239-247.

Royer, J.E. (2015). Responses of fruit flies (Tephritidae: Dacinae) to novel male attractants in north Queensland, Australia, and improved lures for some pest species. *Austral Entomology* **54**: 411-426.

Royer, J.E., Wright, C.L. and Hancock, D.L. (2016). *Bactrocera frauenfeldi* (Tephritidae: Dacinae), an invasive fruit fly in Australia that may have reached the extent of its spread due to environmental variable. *Austral Entomology* **55**: 100-111.

Schulten, G.G.M. (1997). Food security, pre- and post-harvest food losses and integrated pest management. In Management of Fruit Flies in the Pacific. A regional symposium, Nadi, Fiji 28-31 October 1996. Eds AJ Allwood and RAI Drew. pp 10-14.

Shearman, D.C.A., Frommer, M., Morrow, J.L., Raphael, K.A. and Gilchrist, A.S. (2010). Interspecific hybridisation as a source of novel genetic markers for the sterile insect technique in *Bactrocera tryoni* (Diptera: Tephritidae). *Journal of Economic Entomology* **103**: 1071-1079.

Sherwin, W.B., Frommer, M., Sved, J.A., Raphael, K.A., Oakeshott, J.G., Shearman, D.C.A. and Gilchrist, A.S. (2015). Tracking invasion and invasiveness in Queensland fruit flies: from classical genetics to “omics”. *Current Zoology* **61**(3): 477-487.

Smith, E.S.C. (2000). Internal and external fruit fly quarantine in Australia. Proceedings of the Indian Ocean Commission

Regional Fruit Fly Symposium. Mauritius. 5th-9th June 2000. ISBN 99903-71-02-4. pp 171-177.

Smith, E.S.C. and Brown, H. (2014). Fruit flies in the home garden. Agnote no; A20. Northern Territory Government. 4 pp.

Suckling, D.M., Kean, J.M., Stringer, L.D., Caceres-Barrios, C., Hendrichs, J., Reyes-Flores, J. and Dominiak, B.C. (2016). Eradication of tephritid fruit fly pest populations: outcomes and prospects. *Pest Management Science* **72**: 456-465.

Sutherst, R.W., Collyer, B.S. and Yonow, T. (2000). The vulnerability of Australian horticulture to the Queensland fruit fly, *Bactrocera (Dacus) tryoni*, under climate change. *Australian Journal of Agricultural Research* **51**: 467-480.

Tobin, P.C., Kean, J.M., Suckling, D.M., McCullough, D.G., Herms, D.A. and Stringer, L.D. (2014). Determinants of successful arthropod eradication programs. *Biological Invasions* **16**: 401-414.

White, I.M. and Elson-Harris, M.M. (1992). Fruit flies of economic significance: their identification and bionomics. CAB International.

Wiki (2016). http://wiki.bdtnrm.org.au/index.php/Cocky_apple (accessed 8 February 2016).

Zalucki, M. (2015). From natural history to continental scale perspectives: an overview of contributions by Australian entomologists to applied ecology – a play in three acts. *Austral Entomology* **54**: 23

Figure 1. Map of detections of *Bactrocera jarvisi* in New South Wales in 2002 and 2004.