Australian Government

Rural Industries Research and Development Corporation

Sustainable Pest and Disease Management in Australian Olive Production

A report for the Rural Industries Research and Development Corporation

by Robert Spooner-Hart

June 2005

RIRDC Publication No 05/080
RIRDC Project No UWS-17A

ISBN 1 74151 143 7
ISSN 1440-6845

Sustainable Pest and Disease Management in Australian Olive Production
Publication No. 05/080
Project No. UWS 17A

Researcher Contact Details

Assoc. Prof. Robert Spooner-Hart
Centre for Horticulture and Plant Sciences
University of Western Sydney
Locked Bag 1797 South Penrith DC NSW 1797
Phone: 02 45701429
Fax: 02 45701103
Email: r.spooner-hart@uws.edu.au

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details
Rural Industries Research and Development Corporation
Level 1, AMA House
42 Macquarie Street
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6272 4819
Fax: 02 6272 5877
Email: rirdc@rirdc.gov.au.
Website: http://www.rirdc.gov.au

Published in June 2005
Printed on environmentally friendly paper by Canprint

Foreword

This project is the first to address pests and diseases in Australian olives. Although Australia appears to be free of many cosmopolitan olive pests, the rapid expansion of the olive industry in all mainland states (particularly New South Wales and Queensland where the climate is not typically Mediterranean) has led to increased problems with pests and diseases not previously encountered.

The relatively young stage of development of the olive industry meant that it was an opportune time for a project to provide a clear picture of the pest and disease complex in major olive-growing districts and to provide education on sustainable options for their management.

The project had a national focus with a team comprised of researchers and extension personnel from all mainland olive-producing states. It conducted numerous workshops around Australia on pest and disease recognition and their sustainable management, monitored pest and beneficial species in groves and identified a number of previously unreported pests and diseases.

This project was funded from RIRDC Core Funds which are provided by the Australian Government, and funding support was also provided by Southern Highlands Olive Growers Association.

This report, an addition to RIRDC's diverse range of over 1000 research publications, forms part of our New Plant Products R&D program, which aims to facilitate the development of new industries based on plants or plant products that have commercial potential for Australia.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/fullreports/index.html
- purchases at www.rirdc.gov.au/eshop

Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

Acknowledgments

I gratefully acknowledge the contributions made by the following people:

Members of the project team
Len Tesoriero NSW DPI
Barbara Hall SARDI
Frank Page QDPI
Stewart Learmonth WA Dept Agriculture

Damian Conlan, Dick Taylor, Dan Ridley and Susan Sweeney for providing assistance in workshop organisation and for other project support

Staff of the diagnostic laboratories in PHDS (in particular Dr Vera Sergeeva), and SARDI for undertaking much of the laboratory work associated with pathogen diagnoses.

Barbara May for conducting much of sample inspections from the field monitoring and Rosalie Laing for assisting in communicating results to co-operating growers.

Oleg Nicetic and Mary Cannard for assistance with field work on black scale and lace bug.

Dr Michael Priest (Mycologist, OAI NSW DPI) for confirming fungal species identifications, Dr Ric Cother and Dorothy Noble (Bacteriologists, OAI NSW DPI) for bacterial identifications and Dr Andre Drenth (QDPI, Indooroopilly) for confirming species identifications for *Phytophthora*.

The Southern Highlands Olive Growers Association (SHOGA) for funding support for this project.

Growers for cooperating in grove monitoring: Peter and Jayne Bentivoglio, Marcelo Berlanda, Dennis Bishop, Mark and Maggie Edmonds, Tony and Jill James, Keith MacIntosh, Lisa and Lachlan Rountree.

Various growers, horticulturists and crop consultants for the supply of diagnostic samples.

Abbreviations

AOA- Australian Olive Association
APVMA- Australian Pesticides and Veterinary Medicines Authority
IPDM- Integrated pest and disease management
IPM- Integrated pest management
NRA- National Registration Authority

Contents

Executive Summary

This project is the first to comprehensively address pests and diseases in Australian olives. The rapid expansion of the olive industry together with its relatively young stage of development provided the opportunity to develop a clearer picture of the pest and disease complex in major olive-growing districts, as well as to provide education on sustainable options for their management.

It aimed to achieve these objectives through three major activities.

1. Surveying districts throughout Australia for incidence and severity of olive pests and their impact on production.

2. Developing and undertaking field monitoring systems for key pests and diseases

3. Conducting workshops on pest and disease recognition, monitoring and sustainable management.

A national survey conducted in late 2001-early 2002 with over 200 respondents provided a useful overview of olive growers' thoughts on their major pests and diseases, their current pesticide use in olives and their understanding and implementation of IPDM. This survey indicated that black scale was the most important and widespread olive pest throughout Australia, although other pests and diseases were important in particular regions.
A total of 13 workshops were conducted throughout mainland Australia, primarily in the first two years of the project, focussing on olive pest and disease recognition and strategies for their management including biological control and beneficial species in groves, cultural controls such as sanitation, quarantine and correct irrigation, safe and effective pesticide use and IPDM. These workshops were well attended (with a total number of over 600 and mean workshop attendance of 46). A number of additional workshops and grower presentations were conducted during the life of the project. These activities also provided the project team with growers' perspectives of pest and disease issues.

To monitor olive pest and disease incidence in the field, two strategies were adopted. The first involved growers or consultants submitting samples of suspected disease or disorders for free diagnosis to New South Wales Department of Primary Industry's Plant Health Diagnostic Centre. The Centre received over 200 samples, with several new pathogens being recorded on olives in Australia for the first time, including *Agrobacterium* sp., *Botryosphaeria sp.*, *Burkholderia caryophyllii*, *Cercospora cladosporioides*, *Macrophomina phaseolina*, species of *Phytophthora* (viz. *P. cryptogea,* and *P. nicotianiae*), *Pseudomonas savastanoi* and *Ralstonia solanacearum*. In addition, the survey also indicated the importance of the root rot disease *Rhizoctonia*, and the necessity for accurate diagnoses of olive disorders.

The second strategy involved continuously monitoring eight groves in five mainland states, ranging in size from 4-2100 ha, for the last two years of the project (2003-2004). This employed yellow sticky traps which attracted a number of pest and beneficial species, and collection of branch samples, both of which were submitted fortnightly for identification and enumeration of pests and/or damage. The monitoring program confirmed the status of black scale as the most important and widespread pest, but also suggested that its activity on olives may be greater than on citrus, the host from which we have based much of our previous scale pest recommendations in Australia. If this is so, it could pose problems for timing of effective oil spray applications against black scale, as only the young crawler stage is susceptible to suffocation by oil. Another important outcome of the monitoring was the frequent observation of high levels of black scale parasitism, particularly by the small wasp *Scutellista caerulea*, although the impact of this species on scale populations has still to be evaluated. Two other pests identified as important were armoured scales in Queensland and

Western Australia, and olive lace bug in New South Wales and Queensland. There was little evidence of fruit fly activity in olive groves except for central Queensland, and no sign of fruit damage. Thrips were the most numerous pest on sticky traps, but it is likely that their primary hosts are grove understorey plants. However, during the project, several growers in northern New South Wales and southern Queensland expressed concern about possible thrips damage to olive fruit. Subsequent monitoring of groves with yellow sticky traps, and examination of samples of flowers and young fruit did not identify the serious pest western flower thrips, nor was it able to confirm any fruit damage associated with thrips.

Investigations assessing petroleum oil sprays against black scale were conducted in 2004 in two of the monitored groves. These trials demonstrated effective control of even heavy scale infestations could be achieved after two or three timed applications, and should provide data to assist in registration of petroleum oil for black scale control in olives. The project generated more detailed studies on integrated management of black scale, and biology and ecology of olive lace bug, both of which are being conducted at UWS via two PhD projects.

The project has also generated a number of images and other information suitable for publication in a field guide booklet on Australian olive pests and diseases.

1. Introduction

The Australian olive industry needs production systems that are both profitable and environmentally sustainable, to survive and compete with its overseas counterparts. Arthropod pests and diseases are often key constraints to economic industry production via their effects on both yield and quality. Pest and disease control has relied extensively on the use of synthetic pesticides. These not only pose problems for human health, but also for environmental contamination. In the field, their continued use results in development of resistance by pests, and the disruption of agro-ecosystems with resultant pest resurgence. A more sustainable approach has been the development of integrated pest and disease management (IPDM) programs, in which an ecological perspective is taken and a range of strategies used in a systemic way to protect plants and their products from significant damage.

Although the Australian olive industry is 150 years old, recent rapid industry expansion in all mainland states has led to increased problems with pests and diseases not previously encountered. At the commencement of this project, while Australia appeared to be free of many cosmopolitan olive pests such as olive moth (*Prays oleae*), olive fly (*Bactrocera oleae*) and olive knot (*Pseudomonas savastanoi* pv. *savastanoi*) some pests such as scale insects and peacock spot (*Spilocea oleaginea)* appeared to be widely distributed. The recent discoveries of the exotic pest olive bud mite, *Oxycenus maxwelli* (Knihinicki 2000), and the native olive lace bug, *Froggattia olivinia*, in South Australia in 1999 by RSH, together with reports of olive fruit attack by the native Queensland fruit fly, *Bactrocera tryoni*, (D Conlan, personal communication; F Page, personal communication) and occasional bacterial galls recorded on stems (L Tesoriero, personal communication) further illustrated the importance of elucidating key pests and diseases in Australian olive production. Little is known about a number of these pests, in particular their distribution and ecology in Australian olive groves. For instance, the only scientific reference to olive lace bug is by Froggatt in 1901 (this reference was subsequently cited in Hely et al. 1982).

By comparison, research of pests and diseases in other olive growing countries in Europe and the USA is much more advanced, and many aspects of their sustainable management, including classical biological control (eg. Alberola et al 1999; Orphanides 1993) and use of semiochemicals (eg. Haniotakis et al. 1991, Mazomenos et al. 1997) have been investigated. Conferences reporting on IPM in olives have been conducted (eg Haskell, 1992) and a manual on olive pest management in California has been published (Sibbert et al.1995). Both of these confirm the importance of field monitoring and pest and disease recognition in the development of sustainable pest and disease management systems. However, most research has been targeted at individual pest species, with surprisingly little effort invested in conducting surveys of the distribution of pests and their natural enemies, or investigating the complex of organisms in olive agroecosystems. Where these surveys have been conducted (such as Belcari and Dagnino, 1995) they have presented a remarkable complexity of entomofauna. Another study (Morris et al. 1999) demonstrated the important role played by spiders in controlling olive moth in Spanish groves.

The first stage in developing sustainable pest and disease management is field monitoring. While detailed field examination of individual plants is preferred, it is time-consuming and necessarily restricted to, at best, a few specific sites. Even so, a sampling program is the only practical means of examining large areas such as agroecosystems. Other sampling methods include lures and traps. For general monitoring, chromotrophic traps, Malaise and pitfall traps are the most frequently used. Belcari and Dagnino (1995) reported that chromotrophic and Malaise traps were complementary for many groups of entomofauna in the canopy of olive groves. Field plant inspection and chromotrophic (especially yellow) traps are most consistent with grower practice.

To date there has been no systematic approach to investigating the olive pest and disease complex in Australia, although *ad hoc* responses have been made to specific pest problems. This includes application to the APVMA (formerly NRA) for permit registration of pesticides for a number of olive pests, many of which are unfortunately not compatible with a sustainable (IPDM) approach.

The development of integrated pest and disease management (IPDM) programs in perennial horticultural production systems in Australia such as citrus (Smith et al. 1997), grapes (Milne 1991; Patrick 1991) and pome fruit (Bates 1993; Thwaite 1997) provides evidence to support the likely development and adoption of similar approaches for olives.

The team for this nationally-focussed project comprised the key entomology, plant pathology and olive industry development personnel from five states who had already been providing advice on olive pest and disease recognition and control.

2. Objectives

The objectives of this project were to provide growers with a clear picture of the pest and disease complex in Australian olive ecosystems and an increased understanding of sustainable approaches to their control. These objectives were to be achieved by the following:

1. Surveying districts throughout Australia for incidence and severity of olive pests and their impact on production.

2. Developing and undertaking field monitoring systems for key pests and diseases.

3. Conducting workshops on pest and disease recognition, monitoring and sustainable management.

3. National Pest and Disease Survey

3.1 Materials and methods

A written survey was developed with input from members of the project team and Dr Paul Horne who had previously conducted a survey on IPM adoption in Australian potatoes (Horne et al. 2002). One thousand copies of the industry pest and disease survey with reply-paid envelopes were sent to the Australian Olive Association (AOA) and distributed with the Summer 2001 issue of "The Olive Press". Another article on the project and the survey was published in the November edition of the Australian Olive Grower, and an additional 200 survey forms were provided for non-members of the AOA, particularly those attending project workshops in early 2002.

By June 2002, 206 usable survey forms had been received, with the state break-up of 40 % New South Wales, 19% South Australia, 18% Western Australia, 10% Queensland, 6% Victoria and 5% Tasmania. The data were collated and analysed. A summary of the survey results was presented at the AOA's National Conference in October 2002 and a summary of responses to key questions is provided in Table 3, with the complete survey results presented in Appendix 1. The data were based on the number of respondents rather than number of trees, and the results reflect this bias. Unfortunately, several of the large olive plantations did not reply to the survey. The survey is also biased in favour of states with higher response rates (eg. New South Wales).

3.2 Results and discussion

Arthropod pests

From the survey, the four most important arthropod pests were (see Table 1a):

1. Black scale *Saissetia oleae* (Hemiptera: Coccidae) with associated ants, was by far the most common pest, with more than two-thirds of respondents rating it as one of the five major insect pests. The common application of oil sprays (Table 1c) is indicative of their widespread use for scale control. Methidathion, for which there is also a current permit for scale control, was overall the fourth most commonly used insecticide in olives.

2. Olive lace bug *Froggattia olivinia* (Hemiptera: Tingidae)
The native olive lace bug was the second most common arthropod pest, particularly in the eastern states. Dimethoate was the most commonly used insecticide for lace bug, followed by methidathion and neem (neither of these latter two are registered). These were more frequently used than the other permitted pesticides, fenthion and potassium soap, the latter an organically acceptable input.

3. Grasshoppers (Orthoptera: Acrididae)
Grasshoppers, (or more commonly locusts) were the third most common insect pest, especially reported from Western Australia.

4. Weevils (Coleoptera: Cucurlionidae)
Weevils were most frequently cited as a pest by the Western Australian respondents, then South Australian respondents. The relatively widespread use of α-cypermethrin as a butt spray for weevil control placed it as the third most common insecticide used, although a number of respondents also indicated they used chlorpyrifos for this and other pests. An effective alternative to insecticide application was the use of mechanical trunk barriers such as dacron to prevent weevils climbing trees.

5. Other insect pests
Other insect pests less frequently mentioned in the survey were (in order) light brown apple moth, African black beetle, armoured scales (such as red, oleander, parlatoria), sucking bugs, fruit flies, olive bud mite, vine hawk moth and cicadas. This is not to suggest that these were not important pests in individual districts or groves, but rather that they were not widespread problems.

Pathogens

In general, pathogens were generally considered to be less important than insect pests (Table 1b).
1. Peacock spot (*Spilocaea oleagina*)
Peacock spot was the most commonly reported disease, and seems to be widespread throughout Australia with the exception of Western Australia. Copper sprays were the most widely used fungicides in olives, and peacock spot was the prime target. Peacock spot is probably under-represented in samples submitted for diagnosis (see Section 3.2) because of most growers' ability to recognise symptoms of this disease.

2. Phytophthora root rot (*Phytophthora* spp.)
The most common root rot pathogen named by respondents was *Phytophthora* although subsequent diagnoses by plant pathologists appear not to confirm this (see PHDS report, Appendix 2). The use of phosphonic acid (Agrifos) was reported by several respondents for field control.

3. Anthracnose (*Colletotrichum* spp.).
Anthracnose was the third most important disease reported in the survey, and the most common fruit disorder. Copper oxychloride and copper hydroxide were cited as the fungicides applied against this disease.

4. Rhizoctonia root Rot (*Rhizoctonia* spp.)
Rhizoctonia was reported as the second most important root rot pathogen. Although there are currently no fungicides permitted for use against Rhizoctonia in olives, several growers used PCNB (Terrachlor).

5. Other diseases
Other diseases less frequently mentioned in the survey were (in order) *Verticillium* wilt, leaf spots other than peacock spot, nematodes, fruit diseases other than anthracnose and galls.

Other Pests
Several vertebrate pests, particularly rabbits, kangaroos and birds were also mentioned in the survey.

Use of pesticides in Australian olive production

This national survey reflects the number of respondents rather than the area of production. In addition, many groves were yet to come into full production. Never-the-less, it is clear (Table 1d) that Australian growers are generally interested in minimising pesticide use. Only 16% rated pesticides as their main control, and 32 % had not applied pesticides at all. Two-thirds were interested in reducing their use/reliance on pesticides.

By far the most widely used pesticide in olive production was petroleum spray oil (or white oil) with 66 % of respondents reporting they used it, targeting black scale and occasionally lace bug (the latter pest it is not registered for and probably not highly effective against). The second most commonly used pesticide was copper (copper oxychloride and copper hydroxide almost equal), for peacock spot and anthracnose. This was followed by dimethoate (for olive lace bug), then chlorpyrifos (lace bug, grasshoppers, weevils and African black beetle), α cypermethrin (weevils) and methidathion (black scale and other pests). The latter four insecticides are quite disruptive to agroecosystems, and should only be used with caution and within the limits of their permits. Phosphonic acid (Agrifos) was used for control of Phytophthora, and PCNB (Terrachlor) was occasionally used against *Rhizoctonia.*

While both of these products are likely to be efficacious, they are currently not permitted in olives. Other non-permitted chemicals reported were neem and pyrethrum. Neither neem nor any of its constituents are currently registered for use in Australia, and pyrethrum is a botanically-derived but broad-spectrum insecticide that is disruptive to agroecosystems.

The most common method for aerially applying pesticides was by hand-held applicator, followed by booms, air blast sprayers and oscillating boom. This is likely to be a reflection of the small grove size of many of the respondents, the stage of the industry (ie. recent plantings and small trees) and/or the generally low level of pest incidence in groves (and thus the common practice of spot spraying using hand wands).

Knowledge of and interest in Integrated Pest and Disease Management (IPDM)

Over 80% of respondents reported they knew little or nothing about IPDM, and less than 10% reported they knew the topic well (Appendix 1). This latter group had received their information from a wide variety of sources. It should be pointed out that at the time of the survey, only a few IPM project workshops had been conducted. While few growers were certified organic or in conversion, over two-thirds indicated they had an interest in organic production. Of those growers practicing IPDM, the most common strategy employed to monitor pest and diseases was plant inspection, followed by using weather data to predict field disease incidence, and yellow sticky traps (for insects). A number of growers used consultants to monitor their groves. Pests and diseases most commonly monitored for were black scale, lace bug, peacock spot fruit rots and root rots.
Only one third of growers indicated that beneficial organisms were present in their groves, with the majority being unsure. This response appears to be related to their ability to recognize common pests, diseases and beneficial species. While just over half of respondents believed they could recognize insect pests, and over 40% were able to recognize diseases, less than one quarter felt they could confidently recognize beneficial organisms.

Table 1a. Major olive insect pests reported to national survey

Pests in order of importance	Mention of pests by respondents (%)
Black scale	69
Ants	35
Olive lace bug	34
Grasshoppers	29
Other (pests)	20.5
Curculio beetle/apple weevil	18
African black beetle	8.5
Light brown apple moth	8
Red scale	8
Rutherglen bug	8
Green vegetable bug	6
Olive bud mite	6
Queensland fruit fly	5.5
Other (scale)	5.5
Other (mites)	5
Grape vine hawk moth	5
Cicadas	4
Mediterranean fruit fly	2.5
Parlatoria scale	2

Table 1b. Major olive diseases reported to national survey

Diseases in order of importance	Mention of diseases by respondents
Peacock spot	22.5
Phytophthora root tor	15
Anthracnose	7.5
Rhizoctonia root rot	5
Verticillium wilt	5
Other (leaf diseases)	2
Other (root and stem diseases)	2
Nematodes	2
Other (fruit diseases)	1.5
Galls	1

Table 1c. Insecticide and fungicide use reported to national survey

Pesticide use in groves	Users (%)
Insecticides	
Petroleum/Mineral Spray Oil	66
Dimethoate	19.5
Alpha-Cypermethrin	17
Chlorpyifos	17
Methidathion	15.5
Fenthion	8.5
Neem	5
Natrasoap	4
Maldison	4
Pyrethrum	2
Bacillus thuringiensis	2
Imidacloprid	2
Carbaryl	2
Plant-derived oil	1.5
Fenitrothion	1
Omethoate	1
Soluble sulphur	0.5
Soda ash	0.5
Socusil copper snail control	0.5
Fungicides	
Copper Hydroxide	17.5
Copper Oxychloride	10
Phosphonic acid	3.5
Terrachlor	2
Metalaxyl-M	1

Table 1d. Grower attitudes to pesticide use

Question	Respondents Yes (%)	Respondents No (%)
Interested in reducing pesticide use	67	10
Currently use IPDM	37.5	60
Registered organic grower	1	
Organic in conversion	14	
Interested in organic but currently conventional	68.5	
Not interested in organic production	15	
Able to identify common pests	56	41
Able to identify common diseases	42	55
Able to identify common beneficial species	24	71

4. National IPM Workshops

Altogether, during the project there have been 20 grower workshops, seminars and presentations.

Consistent with the project objectives, an initial series of 13 workshops were conducted in 2001 and 2002 (workshop presenters in brackets: RSH - Robert Spooner-Hart; LT - Len Tesoriero; FP - Frank Page; DC - Damian Conlan; BH - Barbara Hall, SL - Stewart Learmonth).

Queensland: Inglewood 10th November 2002 (RSH, LT, FP)
Murgon 11th November 2002 (RSH, LT, FP)

New SouthWales: Inverell 24th November 2001 (RSH, LT, DC)
Grenfell 1st April 2002 (RSH, LT, DC)
Picton (SHOGA, a project funding supporter) 4th May 2002 (RSH, LT)
Mudgee 13th Sept 2002 (RSH, LT)

South Australia Mypolonga 2nd February, 2002 (RSH BH)
Roseworthy 3rd February 2002 (RSH, BH)

Western Australia Perth (mainly WA Dept Agriculture) 14th February 2002 (RSH, BH)
Margaret River 15th February 2002 (RSH, BH, SL)
Gin Gin 16th February 2002 (RSH, BH, SL).

Victoria: Euroa 3rd August, 2002 (RSH, LT)
Boort 4th August 2002 (RSH, LT)

The workshops (sometimes called field days) were organised in collaboration with the local olive associations and relevant state Departments of Agriculture/Primary Industries. They were widely advertised, and total workshop attendance was over 600 (individual workshops participation varied from 30 to 78, with a mean of 46).

The workshops comprised a combination of theory and practical activities and were generally run for a half day. They were designed to be interactive, with grower discussion and activities encouraged. Presentations were given by the project team on concepts of IPM, olive pests, diseases and disorders (including damage symptoms and identification), and sustainable methods of pest and disease management including monitoring, biological control, cultural control strategies and safe and effective use of chemicals. Speaker notes were distributed to all participants.

Where appropriate, field collected or preserved specimens were set up under stereomicroscopes to enable growers to more closely examine organisms and damage. Following the presentations and discussion, a grove walk was normally conducted with participants provided with hand lenses (x10). In the field component of the workshop practical monitoring, identification of pests, diseases and disorders (including stages of pests and parasitism) and practical control options were discussed. We also took the opportunity to discuss quarantine and sanitation procedures, especially in the context of visitors from other groves. When required, field specimens were further examined under the stereomicroscopes. We received very positive participant feedback at all of the workshops. At a number of them, the local association or department organiser also sought independent written feedback, which confirmed the verbal feedback.

In addition to the above workshops, reports on the project and its development have been presented to olive growers at the Olive Harvest Workshops at the Rylstone Olive Press, New South Wales in September, 2003 and 2004 and at the Australian Olive Association (AOA) Conference, Adelaide in October 2002, the organic workshop at the AOA Conference in Brisbane 2003 and at the AOA Conference and workshop in Perth and Gingin 2004. Specific workshops have also been conducted by RSH in Perth Western Australia in September 2002 in relation to an incursion of olive lace bug in that state, a project progress report to the Southern Highlands Olive Association in August 2003 and by Oleg Nicetic (a PhD student of RSH investigating black scale management in olives) in Victoria in December 2004 on black scale control.

A presentation on this work was made to the New South Wales Entomological Society in August 2002, and papers were also presented at the International Plant Pathology Congress, Auckland, New Zealand in January 2004 (Huda et al. 2004) and the International Congress of Entomology, Brisbane in August 2004 (Cannard et al. 2004; Spooner-Hart et al. 2004).

5. Pest and disease monitoring

5.1 Disease diagnoses

5.11 Methodology

A key component of the project was surveying for olive diseases, which was coordinated by Len Tesoriero through the NSW Department of Primary Industries' (formerly NSW Agriculture's) Plant Health Diagnostic Service (PHDS) at the Elizabeth Macarthur Agricultural Institute, Camden. Diagnoses were provided free to all olive growers and consultants from any state who submitted specimens, with a highly discounted (internal rate) diagnostic fee paid to PHDS from project funds. A diagnostic plant pathologist, Dr Vera Sergeeva, was initially employed by the PHDS to support this work. Dr Sergeeva was subsequently located at UWS to undertake further pathological investigations and to complete write-up of scientific and industry papers.

A second plant pathologist, Barbara Hall, SARDI Adelaide was a key member of the project team, participating in workshops in South Australia and Western Australia and collaborating in disease diagnoses. She was integral to the discovery of olive knot in Australia (Hall et al. 2004) and provided timely advice to the project team on developments of this serious incident.

5.12 Results

A complete list of sample diagnoses of olive diseases and disorders primarily from eastern Australia from the PHDS conducted just prior to and during the project is provided in Appendix 2. The PHDS received nearly 200 olive submissions for pathogen testing over the three years 2001-2004. Samples originated principally from New South Wales (60%), Queensland (23%) and Victoria (13%). Approximately 40% of these samples had foliar symptoms such as leaf yellowing, leaf drop and dieback of shoots or the main trunk. These symptoms occurred in the absence of insect and mite infestations or any significant root rots. A further 16% of samples may have displayed foliar symptoms described above, but also had root injury suggesting the problem originated below the ground. Fruit rots and fruit disorders made up 20% of samples, while stem galls accounted for a further 6%. Ten percent of samples appeared to have nutritional problems or odd disorders that were not suggestive of any particular cause. Mite and insect damage was concluded as the cause in the remaining 8% of cases. Although accurate information on the age of plants for all these samples was not always obtained, the bulk of them were younger than five years old. Clearly this collection of samples reflects diseases and disorders in establishing olive groves and is likely to be biased against common and recognisable diseases such as peacock spot, as evidenced by the grower survey.
A general summary of the Australian olive diseases and disorders situation in olives largely derived from data generated from this project was compiled by Barbara Hall, Len Tesoriero and Peter Wood [1] and is given below. This was presented by Barbara and Len at the 2004 AOA Conference workshop in Gingin, Western Australia.

Many different organisms have been recovered from olive plants in Australia, however only some are known to cause diseases of olives. It is possible that these diseases have been around for many years, but are only becoming noticed because of the increased interest in olives as a commercial crop.

Below are groupings for common symptoms and possible causes determined from laboratory studies and supplied case history data. Please note that the following list includes some pathogens that have not been confirmed as the primary cause of the diseased tissue from which they were isolated. Although they are known to be plant pathogens and were isolated from affected tissue, they may be incidental or opportunistic invaders of tissue damaged by other agents. In particular, some of the root rot, stem dieback and fruit rot symptoms may have been primarily due to abiotic disorders that have

[1] Peter Wood is a plant pathologist in the WA Department of Agriculture, but not an official member of the project team

allowed entry of these fungi and bacteria. Scientific method dictates that these potential olive pathogens are reinoculated into healthy plants, observable symptoms are reproduced and the organism is reisolated from that affected tissue. This task is sometimes difficult because disease establishment and development may require specific environmental conditions that are not known at the time of conducting these trials. Some of the diseases and the associated organisms listed below are yet to be confirmed by such pathogenicity tests on olives.

Leaf yellowing, leaf drop, shoot dieback, vascular wilts and root rots

Fungal diseases

Peacock spot (*Spilocaea oleagina*).
Also known as olive leaf spot and bird's-eye spot, peacock spot develops with high humidity and rain. It first appears as small sooty blotches on the leaves that later become muddy green to black, often with a yellow halo. Often the leaves drop prematurely. This disease has not yet been recorded in Western Australia.

Cercospora leaf mould (*C. cladosporioides/Pseudocercospora cladosporioides*).
The first signs are grey blotches on the underside of the leaves, the top of the leaves will yellow, and defoliation occurs. This often occurs together with peacock spot, and can be managed the same way. *Cercospora* has been identified on trees in New South Wales, Queensland and South Australia only at this stage.

Verticillium wilt (*V. dahliae*).
This is a soil borne fungus, which affects the roots and attacks the vascular tissue of the tree. Initially one or more branches will wilt, usually early in the growing season, however the tree will eventually die. This disease is more prevalent when olives are planted in ground where crops susceptible to *Verticillium* have been grown, eg. cotton, stone fruit, brassicas, potatoes and tomatoes. *Verticillium* has not been recorded on olives in Western Australia.

Phytophthora root rot (*Phytophthora* spp.).
Phytophthora spp. cause root rots, stem and crown cankers, and will kill tress if untreated. Seven different species have so far been identified as causing problems with olives. The presence of *Phytophthora* was consistently correlated with evidence of excessively wet soils, clay-panning or poor drainage. It should be noted that excess soil moisture for as little as one day (particularly when combined with higher temperatures) can cause root death.

Rhizoctonia root rot (*Rhizoctonia* spp.).
Rhizoctonia has been consistently recovered from browned and rotted roots of young plants. Above ground symptoms include tip death, defoliation or death. While *Rhizoctonia* has been identified in roots of mature plants, it does not seem to cause a problem in otherwise healthy trees.

Charcoal rot of roots (*Macrophomina phaseolina*).
Unlike *Phytophthora*, this fungus appears to like drier soil conditions. It is found associated with root rots where plants have been water-stressed during summer. Affected roots have typical black speckles on their surface.

Stem cankers (*Botryosphaeria* sp.)
This fungus is occasionally detected on branches of trees, resulting in yellowing of foliage above the affected area. In Western Australia, the same fungus has been detected on apple and stonefruit trees, which may be responsible for cross-infection of nearby olives.

Minor root rots (*Pythium* spp., *Fusarium* spp.).
These fungi are common in all soils, but are more prevalent in wet, poorly drained areas. They are not considered to be a major problem with mature trees, but will seriously affect young trees and those weakened by other stresses.

Bacterial diseases

Stem cankers and dieback (*Pseudomonas syringae*, *Pseudomonas* sp., *Xanthomonas campestris, Ralstonia solanacearum, Burkholderia caryophylli*).
These bacteria were likely to have entered plants through pruning wounds or where frost/cold injury had caused stem tissue to crack or peel. In many instances, bacteria had entered the vascular tissue of the main trunk and moved in both an upwards and downwards direction. For some unknown reason bacteria did not appear to move down into the root systems, but were limited at a point some ten centimetres above ground level. In many cases, affected plants would develop new shoots from below this point.

Pseudomonas syringae was found in one grove to cause significant stem damage, and consequently trees were removed as unprofitable. However it is usually of minor importance.

The detection of *Ralstonia solanacearum* is interesting in that it is an important pathogen of many other plant species (e.g. potatoes and tomatoes) causing a disease known as bacterial wilt. It has only been previously recorded on olives from Asia where it is endemic in soils.

There have been no bacterial problems identified on olives in Western Australia.

Nematode Disorders

Galling of roots caused by root knot nematode (*Meloidogyne* sp.) has occasionally been observed on young trees in Western Australia. Root damage by this nematode can cause stunting of top growth.

Abiotic Disorders

The following disorders have been recorded:
- tip dieback, which occurs randomly with no apparent ill effect to the tree
- frost, cold and hail injury to stems
- sunscald injury to stems
- waterlogging, under-watering, and claypan restriction to roots
- plating of roots due to being held for too long in small containers prior to planting
- chemical injury to foliage
- herbicide injury (spray drift & uptake via roots).

Fruit Rots, blemishes and markings

Fungal diseases

Anthracnose (*Colletotrichum acutatum*).
This disease causes soft circular rots on the fruit, usually on the shoulder, and at high humidity produces an orange slimy mass of spores on the fruit surface.

Fruit Rots (*Botryosphaeria* sp., *Alternaria* spp., *Coleophoma oleae*).
Usually occur on fruit already damaged by other causes, particularly in wet and humid weather.

Abiotic Disorders

The following abiotic fruit disorders have been recorded:

- apical end desiccation, also known as “soft nose”, is apparently caused by sudden changes in temperature and humidity, which produce partial dehydration of olive fruit, particularly at the apical end
- hail injury
- sunscald
- bird injury.

Galls and stem swellings

Bacterial Diseases

Olive Knot (*Pseudomonas savastanoi* pv *savastanoi*)
Olive knot has been detected on seven properties (five confirmed, two yet to be confirmed) in South Australia, and one in Victoria. So far it has only been detected on cv. Barnea; there are many susceptible varieties grown in Australia, and people should be vigilant when inspecting trees. Plants should be inspected carefully upon receipt for any unusual lumps or galls on the stem or at ground level. If symptoms are observed, the supplier should be notified and plants should be tested for disease.

Crown Gall (*Agrobacterium* sp.).
So far this disease has only been detected in potted nursery stock, but could be serious if it establishes in the field.

Abiotic Disorders

Sphaeroblasts are rounded swellings on the main trunk or on secondary branches. They form at attachment sites of branches after they are pruned.

New olive pathogens

The following pathogens were recorded for the first time on olives in Australia during the project: *Agrobacterium* sp., *Botryosphaeria sp., Burkholderia caryophyllii*, *Cercospora cladosporioides*, *Macrophomina phaseolina*, species of *Phytophthora* (viz. *P. cryptogea,* and *P. nicotianiae*), *Pseudomonas savastanoi* and *Ralstonia solanacearum*.

5.2 Grove monitoring

Eight groves located in all mainland states growing olives were selected following advice from AOA and regional olive associations, from the Western Australian west coast to the east coast (see details following page), varying in size from four to 2100 ha. Monitoring commenced in the 2002-2003 season and continued until winter 2004.
Each grove set up a centralised monitoring station comprising a block of 20-50 trees typifying the grove or selected because of previous history of pest and disease problems. Some large groves set up more than one monitoring site. Sampling protocols were provided to all co-operators to ensure consistency of monitoring and data provision. At each site, yellow chromotrophic sticky traps, double sided, dimensions 16 x 10.2 cm (Bugs for Bugs, Integrated Pest Management Pty Ltd Bowen Street Mundubbera Qld 4626) were set up, as well as fruit fly traps (plastic Q Fly traps, dimensions 13cm diameter 10.5 cm high) (Bugs for Bugs Integrated Pest Management Pty Ltd Bowen St Mundubbera Qld 4626) baited with Q lure Fly Wick (for eastern states including SA) or Medlure in WA (the latter provided by Dick Taylor, WA Dept Agriculture). Traps were set up in the monitoring sites consistent with instructions provided by the trap suppliers. Yellow sticky traps were replenished in groves every two weeks, with the collected traps covered in plastic sheeting and sent by prepaid mail to UWS for counting and identification. Any insect specimens in fruit fly traps were also collected and returned for identification. Fruit fly wicks were replaced every six months. In addition, twenty branch and leaf samples approximately 15 cm long were cut from trees within the monitoring area and sent every fortnight for detailed inspection. This method is similar to that described for black scale monitoring on olives in Europe (Lopez-Villalta 1999). Growers were encouraged to also sent specimens from outside the monitoring area with damage symptoms or specimens of pests, particularly scale insects.

Yellow sticky traps and branch samples were examined under a stereomicroscope to identify pests, pest damage and beneficials present. For each branch sample, incidence of damage or pest species was recorded as presence/absence, whereas for the sticky traps, total number of organisms was recorded. Thus for scales, lace bug, bud mite, weevils and grasshoppers, results are recorded as number of branches infested or damaged per 20 branch sample (Appendix 3). Stage of scale development was recorded as crawler, juvenile (2nd and 3rd instars) or adult female. Scales were examined for parasitism, and where appropriate, retained for parasite emergence. Emergent parasites were identified to species where possible, using Smith et al. (1997) and Malipatil et al. (2000). Where pathogens were suspected, specimens were sent to the PDHS and are included in their results (Appendix 2).

Collaborating growers were contacted by email or facsimile with results immediately after samples had been examined.

An additional monitoring site at Menangle Park New South Wales (32° 41’ S, 152° 04’ E) was included in October 2002 for visits by RSH and LT, but this site was abandoned in February 2003 because of severe tree stress due to the drought and difficulties encountered in monitoring with regular pesticide applications.

5.2.1 Grove locations

The location of groves monitored, together with grove details provided at the commencement of the monitoring period are given below (order is based on longitude).

Margaret River WA	33°58'S, 115°04'E 2002-3 Area 4 ha, 1100 trees, 6 years old, all bearing Varieties: WA Mission, Frantoio, Leccino 2004 Area 8 ha, 1200 trees, 2-5 years old, 75% bearing Varieties: WA Mission, Frantoio, Leccino, Pendulino
Gingin WA	34°20'S, 115°54'E Area 10 ha, 2500 trees, 4-6 years old, all bearing Varieties: Manzanillo, Frantoio, Kalamata, Leccino
Coonalpyn SA	35°42'S, 139°51'E Area 20 ha, 7200 trees, 3-5 years old, 50% bearing Varieties: Barnea, Picual
Boort VIC	36°07'S, 143°43'E Area 2100 ha, 715000 trees, 1-3 years old, 75% bearing Varieties: Barnea, Picual, Frantoio, Leccino
Darlington Point NSW	34°35'S, 146°00'E Area 22 ha, 6000 trees, 5 years old, all bearing Varieties: Paragon, Corregiola, Pendalino
Rylstone NSW	32°48'S, 149°58'E Area 32 ha, 8000 trees, 1 and 4 years old, 75% bearing Varieties: Frantoio, Picual, Coratina, Leccino, Pendulino, Barnea
Millmerran QLD	27°54'S, 151°16'E Area 800 ha, 210,000 trees, 1-4 years old, 20% bearing Varieties: Manzanillo, Paragon, Kalamata, Barnea
Murgon QLD	26°14'S, 151°56'E Area 61 ha, 15,600 trees, 1-4 years old, 75% bearing. Varieties: Manzanillo, Corregiola

5.2.2 Results

Results for the arthropod monitoring are summarised in Tables 3, 4 and 5 and graphs for individual groves are presented in Appendix 3.

Scales

Black scale incidence and parasitism rates recorded from the sampling regime are summarised in Table 3. Black scale was the most frequently recorded insect pest and was located in all grove monitoring sites, with heavily infested samples being submitted from Millmerran, Margaret River, Rylstone and Boort. This result is consistent with the national grower survey and our earlier project field workshops, in which black scale was sometimes the only pest present in the grove. Scale crawler activity was observed on samples from most locations, especially in summer and late autumn-winter. In Rylstone, crawlers were active even in July 2003, which indicates that the current recommended monitoring period in citrus (viz. November to March) is likely to be unsuitable for olives. In Queensland, even early in the season, overlapping generations were observed, which makes timing of effective oil applications difficult.

Parasitism of black scale was recorded from most sites with *Scutellista caerulea*, a parasite and egg predator, by far the most common. In many samples, parasitism in mature adult scales by *S. caerulea* was high, and reached 100% in several. Unfortunately, *S. caerulea* tends to be density-dependent (Altmann J pers. comm.) and thus common only in heavy infestations. *S. caerulea* was imported from California in 1904 (Wilson, 1960), and appears to have spread widely into olive-growing districts. Only one other adult parasite was recorded from black scale, namely *Coccophagus* sp., probably *C. semicircularis,* which was imported to control soft brown scale *Coccus hesperidium* (Smith et al. 1997). There was surprisingly little parasitism of immature scales observed, and these were mainly recorded from the Western Australian sites (Margaret River and Gingin) and one site in Queensland (Millmerran). The parasite species recorded at these sites was *Metaphycus lounsburyi*, a soft scale parasite imported from South Africa in 1902 (Wilson 1960). In heavy black scale infestations, the scale-eating caterpillar *Catoblemma dubia* was occasionally recorded, with samples from Rylstone New South Wales most common. However, this predator is highly density dependent and while of interest, is not likely to impact significantly on scale infestations.

Other scales recorded from samples were the armoured scales, in particular red scale, *Aonidiella aurantii*, from both Queensland sites and Ross's black scale, *Lindingaspis rossi*, from Western Australia. These do not produce honeydew and are not associated with ants or sooty mould. Armoured scale incidence and parasitism rates are summarised in Table 5. The red scale infestation in Millmerran in particular was severe, and in late summer, fruit of cv. Jumbo Kalamata was severely infested. Red scale parasitism was surprisingly low, and when it was observed, *Aphytis* spp. and *Comperiella bifasciata* were the only species present. At the Millmerran site, *A. lingnanensis* a mass-reared commercially available red scale parasite, was released by the grower during our monitoring period. Although they were recorded on the yellow sticky traps, evidence of their successful establishment was not obvious from branch and fruit samples. In two samples from Millmerran, we also recorded low numbers of circular black scale, *Chrysomphalus aonidum*, and oleander scale, *Aspidiotus nerii*. Ross's black scale from Western Australia showed some parasitism from an unknown species.

Fruit flies

Traps were set up in all groves, in the eastern states for Queensland fruit fly (QFF) and in Western Australia for Mediterranean fruit fly. Fruit flies were only recorded in three groves, and all of these were QFF (Table 5). The highest numbers and most frequent occurrence were recorded in Murgon, Queensland, with only one QFF recorded from the other Queensland site. Interestingly, several flies were collected from Darlington Point in the Murrumbidgee Irrigation Area, a fruit fly exclusion zone. Microscopic examination of these specimens indicated they were not marked sterile males used in the tri-State fruit fly strategy. No fruit fly damaged fruit was recorded. These data collected during the monitoring period suggest that fruit flies are unlikely to be a widespread problem in olives.

Olive Lace Bug

Lace bug damage was only recorded from Queensland and New South Wales, but was present at all of these sites, where mild to severe leaf damage was recorded, the latter particularly from the Rylstone site. However, lace bugs were only observed in samples from the two New South Wales sites (Table 5). These data seem to confirm that lace bug, while not widespread in all olive-growing districts can cause severe damage where major infestations occur.

Thrips

Thrips (Thysanoptera) were the most commonly recorded pest on yellow sticky traps (Table 5 and Appendix 3). They were recorded at all sites from late spring to autumn. They were therefore present during the period of olive flowering. While there were too many specimens on the traps for individual identification, the most abundant species was plague thrips *Thrips imaginis*. This species is common throughout Australia and has been reported to be an occasional serious pest attacking flowers and developing fruit of summer fruit (Thwaite et al. 2002; Western Australian Department of Agriculture 2003). Flower samples sent as part of the project occasionally contained thrips, but microscopic examination of flowers and developing fruit failed to identify evidence of thrips damage. We examined a number of yellow sticky traps and inflorescences from groves not part of the project monitoring sites with suspect western flower thrips, but expert examination by NSWDPI confirmed the thrips were not *F. occidentalis*. There are a number of species of thrips that are predatory, and we recorded several of these. A number of thrips species are also omnivorous so may feed on other small invertebrates as well as on plants.

It is likely the high numbers on sticky traps reflect major thrips flights as grove floor vegetation dries off during the hot dry months of the year.

Olive bud mite

Bud mite was recorded in one grove in South Australia, together with symptoms of damage. Two sites in Western Australia submitted branches with damage symptoms typical of budmite, but no mites were detected by microscopic examination. Subsequently, budmite was detected at one of these sites (Gingin). This situation is typical of eriophyoid mites such as olive bud mite, when by the time damage is noticed, mite populations have already declined. However, there are other causes of witches' broom symptoms which should also be considered, including severe infestation by young black scale, which is probably the cause of damage in the second West Australian site.

Rutherglen bug

This pest was only recorded at one site (Victoria) during the monitoring period, and only in low numbers. This pattern is typical of Rutherglen bug, as it only causes problems when conditions are conducive to high populations. Similarly to thrips, the bugs swarm into olive trees when the grove floor vegetation dries off.

Leafhoppers/Psyllids

Members of the Homoptera, in particular leafhoppers and psyllids, were commonly recorded on yellow sticky traps at most sites. These are not likely to be olive pests and are probably associated with the grove floor vegetation or other nearby crops, although the olive psyllid, *Euphyllura olivina*, is common in Mediterranean countries (Lopez-Villalta 1999). We included the homopterans in our counts so that growers were able to identify them as "incidentals" in trap catches.

Beneficial species

While we observed some beneficial organisms (especially scale parasites) on branch samples, the majority of the beneficials were recorded from the yellow sticky traps (see Appendix 3). The most abundant beneficial species on the traps were wasps (Hymenoptera), which were divided into large (> 2 mm) and small (micro) ($\leq$ 2mm). Micro-hymenoptera were by far the most numerous, and were consistently recorded in high numbers throughout the warmer months in all locations. These wasps were primarily from the superfamily Chalcidoidea, particularly the families Aphelinidae, Chalcididae, Encyrtidae and Pteromalidae. Most members of these diverse families are parasitic on small arthropods, including scales, aphids and insect eggs. While we were able to identify some species that were common parasites of scale insects, we were unable to find a taxonomist to identify the majority of specimens collected, as this is highly specialised and probably not very rewarding work. The larger hymenoptera were primarily from the families Braconidae, Ichneumonidae and Sphecidae. Braconids and ichneumonids are large diverse families which prey on larger insects, particularly caterpillars (Lepidoptera). Sphecids, commonly known as flower wasps, have adults which feed on nectar or honeydew. Females commonly hunt a range of insects or spiders for larval food, and some are fossorial, predating on soil-dwelling arthropods such as scarabs (CSIRO 1991).

Adult ladybirds (Coccinellidae) were the second most frequent beneficial species recorded on the sticky traps. The most common species were white collared ladybird, *Hippodamia variegata*, transverse ladybird, *Coccinella transversalis,* the striped ladybird, *Micraspis frenata*, and the minute two-spotted ladybird, *Diomus notescens*. Larval and adult stages of ladybirds are generally predatory on soft-bodied insects, although the latter may also feed on nectar and pollen. Other important predators detected from sticky traps were spiders, green and brown lacewings (Chrysopidae and Hemerobiidae respectively), and predatory flies, mainly hover flies (Syrphidae) and stilt flies (Dolichopodidae). While these species predate on a range of arthropods, their role and impact in olive ecosystems is yet to be determined.

5.2.3 Discussion

The grove monitoring for two seasons was limited in that only one or several sites were monitored in detail in each grove location, via branch samples and yellow sticky traps. However, co-operating growers were encouraged to submit specimens to UWS or the PHDS from trees outside the monitoring area, an option which was taken up by most growers. This enabled a broader picture of pest and disease activity in the groves, as well as a clearer picture of scale parasitism, to be determined. A number of limitations associated with use of the yellow sticky traps were identified. One grower complained that the sticky polybutene “tanglefoot” on the traps damaged leaves and fruit with which they came into contact, so traps were moved off trees to posts between trees. Microscopic examination of traps and identification of captured arthropods was time consuming. However, we recorded images of specimens on traps to assist growers and consultants for future identification in monitoring programs. We recorded a number of incidental species of arthropods as well as beneficial species. Apart from common scale parasites, we found identification of other trapped micro-hymenoptera very difficult. As previously reported in 3.2.2, most of them belonged to the Chalcidoidea families Aphelinidae, Chalcididae, Encyrtidae and Pteromalidae, and we assumed they were parasitising various species of scales, aphids and insect eggs. This is a highly specialised taxonomic field and we had neither the time nor the ability to undertake this work. We were also unable to find suitable taxonomists available to conduct the identifications.

A summary of the status of pest and beneficial arthropods in Australian olive groves based on the grove monitoring and other project work is provided in the following section (3.2.4).

Table 3. Black scale monitoring: samples and levels of parasitism

Grove location	Months Recorded on samples	Stage(s) of scale	Parasitism
Margaret River - WA 2003	November	All stages	Nil
Margaret River - WA Jan-August 2004	January to August	January – heavy infestation – juveniles	1 adult parasitised with *Scutellista*
		February – adults First & second instar juveniles	1 adult parasitised by small black wasp to be identified
		March – crawlers and second instar juveniles	Nil
		April – crawlers Second instar juveniles	One *Coccophagus* sp.? *semicircularis*
		June – crawlers Second and third instar juveniles	Some juveniles by *Metaphycus*
		July - juveniles	Nil
		August juveniles	Nil
Gingin - WA	Mainly December to February. Slight outbreak in April	January – juveniles	33% *Metaphycus*
		February – juveniles	100%
		February – adults	Nil
		April – adults	100%
Coonalpyn - SA	December to May	December – juveniles	Nil
		February – adults & juveniles	Nil
		March – juveniles	3% by unknown parasite
		April – juveniles	Nil
		May – juveniles	Nil

Grove location	Months Occur	Young or Mature	Parasitised
Boort - VIC	January to December	January – adults with eggs & some settled crawlers	50% adults by *Scutellista*
		February – adults & second and third instar juveniles	60% adults by *Scutellista*
		March – adults with eggs	Nil
		April – heavy infestation – adults with eggs & crawlers	Few adults by *Scutellista*
		May – juveniles	Nil
		June – juveniles	Nil
		July – juveniles	Nil
		August – juveniles	Nil
		November – adults with eggs plus juveniles	Nil
		December – heavy infestation – adults with eggs, some crawlers plus juveniles	Nil
Darlington Point - NSW	November to September	November – juveniles	Nil
		December – adults with eggs & crawlers	
		January – adults & crawlers	100% adults by *Scutellista* Nil crawlers
		February – adults with eggs & juveniles	Nil
		March – juveniles	Nil
		April – adults with eggs, juveniles & crawlers	Nil
		May – juveniles	20%
		June – juveniles	33%
		September – adults	1 adult by *Scutellista*
Rylstone - NSW	November to July	November-December – adults, & crawlers	Nil
		February – juvenile	Nil
		April – juvenile	Nil
		May – juvenile	Nil
		July – adults, juveniles & crawlers	70% adults by *Scutellista*, *Catoblemma* caterpillar present

Grove location	Months Occur	Young or Mature	Parasitised
Millmerran - QLD	Present all year with overlapping generations for most of the year	January - all stages including crawlers	30% adults by *Scutellista*
		February – adults and mature juveniles	30% to 90% adults by *Scutellista*
		March – adults and juveniles	100% adults by *Scutellista*
		April – some mature adults with eggs, few juveniles	30% to 100% adults by *Scutellista*
		May – all stages including crawlers	40% to 100% adults by *Scutellista* (larvae also observed)
		June – young females and juveniles present	50% to 100% adults by *Scutellista*
		July – young juveniles, no new adults	Nil
		August – few new adults, young juveniles	Little parasitism
		September – small number adults	Little parasitism
		October – adults with eggs some crawlers and juveniles	Little parasitism
		November – adults, juveniles and crawlers	20% to 40% adults by *Scutellista*
		December – all stages including crawlers, some juveniles	30% adults by *Scutellista*
Murgon - QLD	November, February to June (heavy infestation in March)	November – not known	Nil
		February – juveniles & adults	16% adults by *Scutellista*
		March – juvenile & adult & newly hatched crawlers	50% adults by *Scutellista*
		April – juveniles	Few
		May – not known	Nil
		June – juveniles	Few

Table 4. Scale species other than black scale monitoring: samples and levels of parasitism

Grove location	Red Scale	Parasitism	Circular Black Scale/Ross's Black Scale	Parasitism
Margaret River -WA 2003	Nil	-	November to May	January, February, June
Margaret River- WA 2004	Nil	-	Nil	-
Gingin - WA	February, April On fruit in May	April – some parasitised by *Aphytis* sp.	January, March, May	Nil
Coonalpyn - SA	Nil	-	Nil	-
Boort - Vic	Nil	-	Nil	-
Darlington Point - NSW	Nil	-	Nil	-
Rylstone - NSW	Nil	-	Nil	-
Millmerran - QLD	March April with eggs May, September, October	Several by *Aphytis lingnanensis*	February Oleander scale	Nil
Murgon- QLD	November to July – eggs in April/May – peak in February/March	Few in February 1 *Comperiella bifasciata* (June)	Nil	-

Table 5. Olive pests other than scales monitoring

Grove Location	Fruit Fly	Lace Bug	Rutherglen Bug	Thrips	Leafhoppers/Psyllids	Bud Mite
Margaret River - WA 2003	Nil	Nil	Nil	November to July peak January	November to July peak March	Nil
Margaret River - WA 2004	Nil	Nil	Nil	Small numbers peaking in January	Small numbers peaking in February/March	"stunting" – no mites present
Gingin - WA	Nil	Nil	Nil	October to October peak November	December, January and March to May	January, February
Coonalpyn - SA	Nil	Nil	Nil	November to May One predatory thrips in May	March to May	January
Boort - VIC	Nil	Nil	January to April – small numbers	All months – peak April	November to May	Nil
Darlington Point - NSW	October and November – one or two QFF plus one other in October	Two adults in November	Nil	All months – peak November and December	September to June	Nil
Rylstone - NSW	Nil	Common. Adults Nov to June Nymphs November, April and May	Nil	All months – peak January	November to May	Nil
Millmerran – QLD	June	Nil Damage only	Nil	October to October peak November	September to April	Nil
Murgon - QLD	1-19 QFF all months peak April	Nil Damage only	Nil	All months peak March	December to September	Nil

5.2.3 Summary of status of arthropod pest and beneficial species

Based on the grower survey, workshops and grove monitoring, the following summarises the arthropod pests and beneficial species of olives in Australia.

Black scale: *Saissetia oleae* (Hemiptera: Coccidae)
This cosmopolitan species is widely distributed in Australian olive production areas, and can cause severe problems in some groves resulting in leaf drop, reduced tree vigour and twig dieback in heavy infestations. The presence of ants and sooty mould associated with the honeydew produced by this scale can also compound problems of tree health and management. In Australia, there are between two and five scale generations per year, with first generation crawler emergence common in late spring.
Natural enemies of black scale include the small wasps *Metaphycus* spp., which are true parasites of immature stages, and are being considered for commercial rearing and release (Smith *et al.* 1997; J Altman, personal communication), and *Scutellista caerulea,* which is primarily an egg predator. Field parasitism by the latter species can be very high, with >80% parasitism of adult scales recorded in some olive groves (Spooner-Hart, unpublished data). Unfortunately, *Scutellista* is prey density-dependent and only reaches these high levels later in the season. In addition, with heavily ovipositing female scales, egg-predation by *S. caerulea* may be insufficient to prevent a serious infestation the following season. Other predators include several species of ladybird beetles (Coleoptera: Coccinellidae), lacewing larvae (Neuroptera: families Chrysopidae and Hemerobiidae) and the scale-eating caterpillar *Catoblemma dubia* (Lepidoptera: Noctuidae).
The use of horticultural spray oils has been strongly encouraged for scale control in olives and citrus crops. While this has been primarily application of narrow-range petroleum spray oils with high efficacy and low phytotoxicity, there is also strong interest, particularly by organic growers, in a canola oil spray formulated with extract from the Australian native tea tree, *Melaleuca alternifolia*. However, correct timing of applications to coincide with scale crawler emergence and ensuring adequate tree coverage are both critical factors in the success of all oil sprays. There is also a permit for methidathion, although this is generally only recommended for severe infestations, and a more recent permit for the insect growth regulator buprofezin.

Armoured scales: (Hemiptera: Diaspididae)
Several species of armoured scales have been reported causing economic damage in some Australian olive groves (Hely et al. 1982; Spooner-Hart et al. 2002). These include red scale, *Aonidiella aurantii*, oleander scale, *Aspidiotus nerii*, Ross's black scale, *Lindingaspis rossi*, circular black scale, *Chrysomphalus aonidum* and parlatoria scale, *Parlatoria oleae*. Damage is primarily to leaves and twigs, although occasional fruit infestations have been observed. Honeydew, sooty mould and ants are not associated with these infestations.
Natural enemies of armoured scales are commonly parasites, including *Aphytis melinus* and *A. lingnanensis*, both of which are mass reared and commonly released into citrus orchards; C*omperiella bifasciata* and several *Encarsia* spp. (Smith et al. 1997). However, predators can play an important role in scale control, particularly the ladybirds *Rhizobius lophanthae*, *Chilocorus circumdatus* and *Halmus chalbeus*, and to a lesser extent some species of lacewings and predatory mites.
Oil sprays, as discussed previously for black scale control, are also encouraged for use against armoured scales as a component of ecological pest management in olive groves, although methidathion and buprofezin also have permitted use.

Olive lace bug: *Froggattia olivinia* (Hemiptera: Tingidae)
Olive lace bug is an Australian native species first described feeding on the native olive *Notelaea longifolia* in New South Wales (Froggatt, 1901), and has also been recorded in Queensland and Tasmania. Froggatt also reported lace bug severely attacking European olive, and remarked "..if the olive is ever largely cultivated in Australia this might become a

very serious pest" Froggatt (1901). This prediction has now occurred, with lace bug being recorded as a serious pest in a number of locations in eastern Australia (Hely et al. 1982). It has spread from its original distribution, probably with movement of plant material, and was reported for the first time in South Australia in December 1999 (Spooner-Hart, unpublished data), followed by a confirmed infestation in Western Australia in April 2002 (Botha et al. 2002)

Adult lace bugs are mottled brown, 3mm in length, with large clubbed antennae and a highly punctured upper body surface. Eggs are laid on the underside of leaves in clusters close to the mid-vein and are commonly covered with tar-like excrement. Highly spined nymphs emerge in spring, piercing the leaf surface and feeding on cell contents. This results in yellow spotting on leaves, which become highly chlorotic and abscise in heavy infestations. Twig dieback may occur in severe infestations. There are five nymphal instars which can complete their life cycle in as little as 5- 6 weeks, depending on climatic conditions (Spooner-Hart, unpublished data). In many parts of Australia, there appears to be four or five generations per season. Adults feed in a similar manner to nymphs.

Current recommendations (permits) for control have been given for the organophosphorus insecticides dimethoate and fenthion, although a permitted organic alternative is insecticidal potassium soap (Natrasoap®). We observed field predation of lace bug nymphs by larvae of green lacewings (Chrysopidae), and also recorded high predation rates of lace bugs by the commercially available native green lacewing, *Mallada signata*, in laboratory investigations. It appears there may be resistance or tolerance to lace bug in olive cultivars and in different tree culturing systems. Identification of effective control strategies for lace bug will be central to achieving sustainable olive production in a number of regions.

Fruit flies: (Diptera: Tephritidae)

Two fruit fly species, Queensland fruit fly, *Bactrocera tryoni*, and Mediterranean fruit fly (Medfly), *Ceratitis capitata,* have been reported damaging olive fruit in Australia, although to date this damage has not been widespread. *B. tryoni* is endemic to Queensland and the coastal parts of New South Wales. Most of inland New South Wales, together with the states of Victoria and South Australia, are free of *B. tryoni*. *C. capitata* only occurs in Western Australia. With both species, fruit are damaged by oviposition, which can prematurely ripen fruits or cause them to fall. This damage also predisposes the fruit to fungal rots.

While natural enemies of Queensland fruit fly have been recorded, primarily braconid parasites (Hymenoptera: Braconidae), the assassin bug *Pristhesancus plagipennis* (Hemiptera: Reduviidae) and birds, these rarely achieve economic control (Smith et al. 1997). Although attempts at biological control of Medfly have been tried, these have been unsuccessful. Sterile insect technique (SIT) however, has been used with some success against both species, particularly the tri-State strategy in south-western New South Wales, Victoria and South Australia. Current permitted insecticides for fruit fly control in olives are dimethoate and fenthion.

Cuelure and trimedlure are used to monitor for presence of adult male flies of Queensland fruit fly and Medfly respectively in many crops. Baiting with yeast autolysate mixed with an insecticide is recommended in areas of high fruit fly activity in other tree crops, although it is not currently recommended for olives. There is evidence that oil spray deposits may protect fruit from damage by inhibiting oviposition by fruit flies (GAC Beattie, personal communication).

Weevils: (Coleoptera: Cucurlionidae)

Curculio beetle (= apple weevil), *Otiorhynchus cribricollis*, damages olive leaves in inland New South Wales, South Australia and Western Australia, whereas garden weevil, *Phlyctinus callosus,* has only been reported as a pest in Western Australia. In both species, adults are nocturnal and emerge from soil, leaf litter and weed stubble to feed, and climb olive trees and chew the outer leaf margins. Minor damage results in ragged leaves, but heavy infestations can severely damage growing tips and may remove leaves entirely, especially in young trees. The soil-dwelling larvae may also damage tree roots. A permit for butt spraying of non-bearing olive trees with α-cypermethrin is current. No natural enemies of weevils have been identified, although free-range poultry have been used for weevil control in apple orchards. An effective alternative to insecticide application to butts of trees is the application of either a sticky or a fibrous barrier to the tree trunk. In the latter case, weevils become enmeshed in the fibres.

Caterpillars: (Lepidoptera)
There are a number of caterpillar species recorded attacking olives in Australia. Of these, the most important is light brown apple moth *Epiphyas postvittana* (Tortricidae), a native species of leafroller. It primarily damages growing tips in olives, tying them together with silken threads to form a protected area within which it feeds. Other caterpillars identified on olives include native hawk moths (Sphingidae), heliothis and cutworms (Noctuidae). Most leaf-feeding caterpillars, including *E. postvittana*, are readily controlled by applications of the biological insecticide *Bacillus thuringiensis*.
An as yet unidentified species of *Cryptoblabes* (Family Pyralidae) has recently been recorded feeding on fruit in Queensland (F Page, unpublished data).

Olive bud mite: *Oxycenus maxwelli* (Acari: Eriophoyidae)
Olive bud mite was first detected in New South Wales in 2000 (Knihinicki 2000), but had possibly been present in this country for some time. This small (0.1 to 0.2 mm) mite preferentially feeds on developing buds, shoots and leaves. While this species does not generally cause major damage, it is most severe in young trees in favourable conditions (warm temperature and high humidity).

Other sucking bugs: (Hemiptera)
Generally, these are of minor importance, although they may be prevalent in some districts in favourable seasons. These include lygaeid bugs (Lygaeidae), particularly Rutherglen bug *Nysius vinitor*, which can be a serious pest on new plantings in South Australia and the wheatbelt areas of Western Australia (D Hardie, personal communication), green vegetable bug *Nezara viridula*, and cicadas (Cicadidae). Cicadas have been recorded in Central Queensland heavily ovipositing in olive twigs, causing severe damage.

Grasshoppers: (Orthoptera: Acrididae)
There are four major species of grasshopper (or locust) that may attack olives in Australia, the plague locust, *Chortoicetes terminifera*, the spur-throated locust, *Austacris guttulosa*, the migratory locust, *Locusta migratoria*, and the wingless grasshopper, *Phaulacridium vittatum*. Of these, plague locust is the most devastating, although *P. vittatum* has been a serious pest in the wheat-belt regions of Western Australia (D Hardie, personal communication) as well as other areas of southern Australia. In the non-gregarious phase, grasshoppers primarily feed on terminal leaf margins. However, in the locust phase, they devour most green plant material, stripping trees rapidly. Under these conditions, immediate action is essential. There are no permitted pesticides for controlling grasshoppers in olives, although several pesticides permitted for use in olives are registered for grasshopper control in other tree crops. Additional permits for pesticide use are usually made in locust plague outbreak years.

Thrips: (Thysanoptera)
Thrips, particularly plague thrips, *Thrips imaginis*, are one of the most common insects recorded on sticky traps in olive groves. They have also been frequently found in olive flowers, and have been implicated with causing fruit damage, although without proof.

6. Other activities

6.1 Integrated black scale control

Black scale is the most common and widespread pest of olives in Australia as evidenced by the data presented earlier in this report from the national survey, grove monitoring and field day observations. In fact, every olive grove associated with this project (either through monitoring, field days or project team member visits) had some black scale infestation. These data emphasise the importance of black scale management for sustainable olive production. In citrus however, black scale is regarded as “occasionally important” in the south-eastern states of Australia and a minor pest elsewhere (Smith et al. 1997). In fact it is rare to see heavy infestations in citrus causing sooty mould and blackened trees, especially in coastal areas (GAC Beattie personal communication), although these symptoms are common in many olive groves throughout Australia. It is unclear which factors contribute to this apparent difference in black scale incidence. Our observations suggest that black scale is active on olives in northern Australia for most of the year. It is possible that there are differences in scale predation or parasitism, related to the different microclimate in olive and citrus orchards (especially oranges, *Citrus sinensis*, which have a dense canopy and maintain a relatively higher humidity conducive for epizootics of the entomopathogen *Verticillium lecanii*). There are also recent suggestions that these differences may be a result of *S. oleae* biotypes with distinct host preferences (O Nicetic personal communication).

Most recent black scale research in USA (Weppler 2003) and other countries relate to release of *Metaphycus* species for its biological control. In collaboration with Biological Services Ltd. South Australia, we released small numbers (<2000) in each batch, of *Metaphycus helvolus* and in one case also *M. lounsburyii*, onto trees infested with most stages of black scale. Blocks of 20 to 40 trees, depending on the level and distribution of the scale infestation, were selected in groves of a number of project co-operators for *Metaphycus* release. Parasites were supplied by Biological Services in punnets, which were checked for good wasp emergence prior to opening for release. Release trees were tagged and examined three months later to assess parasite establishment. Releases were made in Gingin (Western Australia) in September 2003, Margaret River (Western Australia) in October 2003, Millmerran (Queensland) in 2004, and Rylstone (New South Wales) in May 2004. There was little sign of parasite establishment in all release locations, although parasitism by *Metaphycus* spp. was recorded from Millmerran and Gingin samples. However, although no quantitative data were collected, our visual observations and grower feedback indicated reduced black scale activity in the release site compared to non-release sites in both Rylstone and Gingin.

We were not able to undertake any further *Metaphycus* releases during the project period, because Biological Services was unable to supply parasites. However, black scale populations in olives continue to be monitored in Rylstone and Millmerran as part of a newly commenced PhD project. In Rylstone, discrete generations make timing of controls, particularly oil sprays, easier than at Millmerran, where heavy crawler emergence was recorded in October and by mid-season, all stages were present on trees (Table 3).

6.2 Oil sprays for black scale control

Permits are current for petroleum spray oils (PSOs, white oil), methidathion (Supracide) and buprofezin (Applaud) against scale insects in olives. During the project, we heard that a number of growers were experiencing difficulty controlling black scale with PSOs. We therefore conducted, as an extension of this project, field trials to assess PSO efficacy when properly timed and applied. We also aimed to generate efficacy data for registration, where appropriate. For this work, we received support from SACOA Pty Ltd, Perth, Western Australia.

6.2.1 Materials and methods

Experimental sites
Two experiments were conducted to evaluate the efficacy of a narrow range PSO (SK EnSpray 99, SK Corporation, Korea). The first experiment (Experiment 1) was conducted from November 2003 until March 2004 at Australian Olives, Millmerran (Queensland) and the second experiment (Experiment 2) was conducted at Bentivoglio Olives, Rylstone (New SouthWales) from December 2003 until May 2004.
Experiment 1 was conducted on cv. Manzanillo trees planted in 1999 on a 8x5m grid. The trees were 3.5-4 m high. In Experiment 2 cv. Barnea trees were used, spaced at 8x5m and planted in 2001. Trees were 2-2.5 m high. In Experiment 1 trees were drip irrigated and in Experiment 2 irrigation was not applied and trees were water stressed.

Experimental design
Both experiments were designed as completely randomised blocks with only one fixed factor: black scale control treatment. Block was included as random factor. Black scale treatments were different for each experiment.

In Experiment 1, treatments were:
1. Water treated control
2. PSO (*n*C24) SK EnSpray 99 at 1%
3. PSO (*n*C24) SK EnSpray 99 at 1.8%
4. Insecticide comparator methidathion (Supracide 400 SC) at 0.125%

In Experiment 2, treatments were:
1. Water treated control
2. PSO (*n*C24) SK EnSpray 99 at 1%
3. PSO (*n*C24) SK EnSpray 99 at 1.8%
4. Oil comparator PSO (*n*C24) D-C-Tron Plus (Caltex Australia Pty Ltd) at 1.8%

Both experiments comprised 6 blocks (=replicates) and each block comprised four trees, one tree for each of the treatments.

Spray application
In Experiment 1, sprays were applied using a mist-blower Silvan sprayer fitted with 12 solid cone nozzles (6+6) on each side with diameter of 2 mm. Output per nozzle was 8 L/min and tractor speed was 2 km/hour. This resulted in trees being sprayed to the point of run-off with spray volume of 10 L/tree.
In Experiment 2, sprays were applied using a Hardi wheelbarrow sprayer fitted with a 100 L tank, a 2.5 kW petrol engine and an extension wand with one solid cone nozzle 1.8 mm diameter. Sprays were applied to runoff at a spray volume of 4 L/tree.

In Experiment 1, three sprays were applied on 13/11/ 2003 and 10/12/2003 and on 20/1/04. In Experiment 2 only two sprays were applied on 22/12/2003 and on 29/02/2004.

Benchmark treatments
In Experiment 1, methidathion (Supracide 400 SC) was used as the industry standard treatment since it has a permit for use in control of black scale in olives and is widely used. For Experiment 2, another petroleum spray oil was used as a comparison since that orchard is certified for organic production and no synthetic pesticide could be used. D-C-Tron Plus has been widely used within the horticultural industries for scale control and it is the benchmark against which new oil products should be compared.

Assessments
The samples were collected in the field from each sprayed tree. Each sample consisted of four, 0.2m long twigs, one from each of four cardinal points of the tree. Twigs were cut randomly at approximately 1.8-2 m above the ground. Twigs were placed in sealed plastic bags and then into an Esky for transport to the laboratory at UWS. In the laboratory they were kept refrigerated at $+4^{o}$ C.
The number of all immature stages of black scales (first and early second instar) on the first five leaves of the new flush was counted with the aid of a stereomicroscope.
Assessments in Experiment 1 were done on 18/1/04 after two sprays were applied, and on 9/02/04 after the third spray was applied.
In Experiment 2 the first assessment was done on 29/2/04 after the first spray, and on 11/03/04 after the second spray.

Data analysis
All presented data were statistically analysed using analysis of variance, general linear model in SPSS for Windows^{TM} Version 12 (SPSS Inc. 2003). Assumption of normal distribution was checked using P-P plot and homogeneity of variance using Levene's test of equality of error variances (Levene 1960).

6.2.2 Results

Experiment 1:
After 2 sprays (1st assessment)
Data were sqrt(x+0.5) transformed to meet the assumptions of normal distribution and homogeneity of variance. There were significant differences in the mean number of black scale between spray treatments ($F_{3,15} = 10.155$, p=0.001). Spray treatment means were separated using Ryan's Q test. All active treatments (both concentrations of oil and methidathion) were significantly better than the water sprayed control. There were no significant differences between treatments. Results are presented in Table 5.
After 3 sprays (2nd assessment)
Data were ln(x+1) transformed to meet the assumptions of normal distribution and homogeneity of variance. There were significant differences in the mean number of black scale between spray treatments ($F_{3,15} = 23.58$, $p<0.001$). Spray treatment means were separated using Ryan's Q test. All active treatments were significantly better than the water sprayed control. There were no significant differences between treatments. Results are presented in Table 6.

Experiment 2:
After 1 sprays (1st assessment)
Data were inverse sqrt(x+0.5) transformed to meet the assumptions of normal distribution and homogeneity of variance. There were significant differences in the mean number of black scale between spray treatments ($F_{3,15} = 23.49$, $p<0.001$). Spray treatment means were separated using Ryan's Q test. All active treatments (both concentrations of SK EnSpray 99 and Caltex D-C-Tron Plus) were significantly better than the water sprayed control. There were no significant differences between treatments. Results are presented in Table 7.

After 2 sprays (2nd assessment)

Data were inverse sqrt(x+0.5) transformed to meet the assumptions of normal distribution and homogeneity of variance. There were significant differences in the mean number of black scale between spray treatments ($F_{3,15} = 11.12$, $p<0.001$). Spray treatment means were separated using Ryan's Q test. All active treatments were significantly better than the water sprayed control. There were no significant differences between treatments. Results are presented in Table 8.

Table 5: Effect of treatment on the number of immature black scale per leaf in Experiment 1 after the 2nd spray

Treatment	Mean[1]	Std. Error of Mean
Water	11.12 a	3.41
1% SK	2.95 b	0.98
1.8% SK	2.11 b	1.06
Supracide	0.18 b	0.08

Table 6: Effect of treatment on the number of immature black scale per leaf in Experiment 1 after the 3rd spray

Treatment	Mean[1]	Std. Error of Mean
Water	3.36 a	0.95
1% SK	0.38 b	0.17
1.8% SK	0.28 b	0.11
Supracide	0.10 b	0.06

Table 7: Effect of treatment on the number of immature black scale per leaf in Experiment 2 after the 1st spray

Treatment	Mean[1]	Std. Error of Mean
Water	1.07 a	0.25
1% SK	0.28 b	0.04
1.8% SK	0.13 b	0.04
1.8% D-C Tron Plus	0.16 b	0.07

Table 8: Effect of treatment on the number of immature black scale per leaf in Experiment 2 after the 2nd spray

Treatment	Mean[1]	Std. Error of Mean
Water	0.82 a	0.29
1% SK	0.20 b	0.10
1.8% SK	0.05 b	0.02
1.8% D-C-Tron Plus	0.05 b	0.03

[1] Means followed by a different letter are significantly different ($P \leq 0.05$)

6.2.3 Conclusions

The PSO (SK EnSpray 99) provided very effective control of black scales on olives at both tested concentrations viz. 1.0% and 1.8% when applied under our experimental conditions. However there was a trend towards more uniform level of control between replicates when the higher concentration was used. The level of control achieved with SK En Spray 99 was similar to that of both industry standard products (methidathion and DCTron Plus). Replacing methidathion with properly applied PSOs for control of black scale will significantly reduce the use of synthetic pesticides in olive groves.

6.3 Olive lace bug incursion in WA

RSH was contacted in his capacity as project leader by Dr John Botha, Western Australian Department of Agriculture's Entomologist Quarantine, Surveillance & Plant Biosecurity & Risk Analysis in July 2002, following detection of olive lace bug in two locations in that state, Margaret River and Busselton. As olive lace bug is endemic only in the eastern states, this incursion was considered a serious threat to the Western Australian olive industry. RSH subsequently provided information on lace bug biology, and discussed protocols for an eradication campaign. Two sprays of fenthion and one of dimethoate were applied at both sites by September, 2002. Later that month, RSH visited the two infestation sites with Western Australian Departmental officers and confirmed the containment and eradication campaign was progressing well. He also gave a presentation to industry and departmental staff on olive lace bug: its biology, damage and control, in Perth on September 26, 2002.

Subsequent communications with Dr Botha confirm the eradication campaign, which was also supported by quarantine restrictions on olive tree imports into Western Australia, has been successful, and no further incursions have been detected.

7. Implications

This project has set a benchmark to support future research and development in olive pest and disease management in Australia. In articulating the pest and disease complex in Australian olives, it has consolidated some previous views (such as the importance of black scale), but has also identified a number of pests and diseases (in particular plant pathogens), previously not reported in Australia on olives. It has provided greater detail on pest and disease distribution. It has also, in our view, improved understanding by the industry participants of olive pests, diseases and disorders, and strategies for their sustainable management. These activities should continue, to support the industry to develop.

Our data reported herein indicate that there are regional differences in pest and disease complexes, in both species distribution and abundance. This has implications for growers and consultants; to take these differences into account by adapting pest monitoring and management programs for specific regions. We used olive tree branch sampling and yellow sticky traps as our main grove monitoring tools, and the monitoring was generally confined to one or several sites on each grove. This was because we were unable to physically inspect all sites fortnightly. The information collected was very useful for our purpose, namely to collect comparative regional data. However, even within our monitoring sites, the data relating to species with clumped distribution such as scales varied even with consecutive samples. A number of co-operating growers sent samples from outside the monitoring site which showed a different pattern of pests and diseases than those collected within the site. This suggests that while branch and sticky traps play a useful role in monitoring, more detailed sampling of groves is required for effective grove management, particularly when there is variability in parameters such as cultivar, age of trees and topography.

It is clear that some growers are mis-diagnosing pests and/or diseases, and are not assessing field parasitism of pests such as scales. In addition, a small number are using unregistered products. These practices can lead to overuse and/or misuse of pesticides, with associated impacts on environmental and human safety and presence of residues in olive products.

Our field trials in Queensland and New South Wales confirmed that narrow-range petroleum oil sprays when correctly timed and applied are highly effective in controlling black scale. We anticipate that the data we generated will assist in registration of PSOs in olives.

It is important to realise that when this project commenced in 2001, most of the industry was in the establishment phase. The pest and disease complex, and grower views and attitudes reported herein are indicative of that. As the industry moves to the production phase, it is likely that the suite of important pests, diseases and disorders will change. Recently adopted agronomic practices such as intensive planting, will also impact on this complex.

Detailed recommendations for further action are provided in the following section. Recommendation 4 is for the production of a field guide book of Australian olive pests, diseases and disorders. During the project, the team members built up not only detailed knowledge but also a series of quality images of the major pest and disease organisms, their associated damage and management. We believe that the production of such a book will be one of the most useful spin-offs from this project.

8. Recommendations

Most Australian olive growers (as evidenced from the surveys, workshops and other interactions with project members) genuinely want to minimise use of pesticides, and there is a small but dynamic section of the industry involved in organic production. However, at the present time, the Australian olive industry is still reliant on a limited number of permits issued by the APVMA, and in our view, the current choice of products is not fully compatible with IPDM. To progress the olive industry's goal of sustainable pest and disease management requires a number of initiatives, which are provided as recommendations below:

1. Registration of IPDM-compatible, and where possible organically acceptable, pesticides targeting key pests and diseases, accompanied by rigorous residue studies.

2. Development of grower-friendly pest and disease monitoring systems, together with a clearer understanding of thresholds for key pests and diseases.

3. The production of a field guide to pests, diseases and beneficials in Australian olive groves. Many growers are currently unable to accurately identify the suite of pests, diseases and disorders that confront them in the grove.

4. Further studies are required to develop integrated management programs for black scale, (the major plant protection problem in Australian olives) based on use of biological control and oil sprays wherever possible. This involves more detailed investigation of black scale phenology in Australian orchards, and of biological control options such as releasing *Metaphycus* spp. and evaluating the role of naturalised agents such as *S. caerulea*, particularly given the latter species' distribution and abundance. These studies will need to encompass biological, strategic and economic issues.
Concerns have been expressed about the "importation and release" of biological control agents such as *Metaphycus* spp. from one part of Australia to another. While some growers are naturally apprehensive about not wishing to create another "cane toad" catastrophe, they should also be aware of the cosmopolitan nature of pests such as scales and that many naturally-occurring predators and parasites, including a number recorded in this project, were previously imported exotic species. There is also a need to better extend to growers the importance of timing and spray coverage by petroleum or plant-derived oils to achieve effective scale control.

5. Further studies are also required on two other insect pests, olive lace bug and thrips. We need to better understand lace bug biology and ecology, its interaction with trees, and strategies for its management, including biological options. Much of this work is currently being pursued via a PhD at UWS.
Thrips are common in olive groves, and they have anecdotally been implicated with fruit damage. However, only preliminary investigations have been conducted to date on their effects on olive fruit set and development.

6. The disorder soft nose is the most common problem in fruit. There is a need to better articulate the relationship between abiotic factors such as weather, agronomic practices such as irrigation and incidence of this condition. Some of these investigations could be conducted in collaboration with studies on organoleptic and chemical parameters of fruit and oil.

7. The present distribution of a number of pests and diseases (such as lace bug and bud mite) can be directly attributed to the supply of infested plants. While state quarantine regulations have prevented a recurrence of the lace bug incursion into Western Australia, this issue also has major implications for regions currently free of particular pests and diseases and, indeed, for individual groves. The importance of quarantine and sanitation, with respect to visitors, contractors and other vehicular access to properties, as well as transport of fruit to processors needs to be extended throughout the industry.

8. The discovery of the serious disease olive knot in Australia and olive fly in California, USA during the life of this project demonstrates the importance of pest and disease vigilance in protecting the Australian olive industry, in particular monitoring for the world’s most destructive olive pest, olive fly.

9. Publications

Botha J, Poole M, Taylor D, Hardie D, Spooner-Hart R (2002) Olive lace bug *Froggattia olivinia* (Hemiptera: Tingidae) Farmnote No 050/2002 Department of Agriculture WA, Australia.

Cannard M, Spooner-Hart R, Beattie G (2004). Olive lace bug, *Froggattia olivinia* (Hemiptera: Tingidae)- an Australian native pest of cultivated olives. International Congress of Entomology. August 2004 Brisbane, Qld, Australia.

Huda A, Spooner-Hart R, Nair N (2004). Using climate information to screen disease risk of olive growing areas in Australia. International Plant Pathology Congress, January 2004, Auckland, New Zealand.

Sergeeva V, Tesoriero L, Spooner-Hart R, Nair N (2005). First report of *Macrophomina phaseoli* (Tassi) Goid. on olive (*Olea europea* L.) in Australia. *Australasian Plant Pathology* (in press).

Spooner-Hart R (2002). Progress towards sustainable and organic pest and disease production in Australian olive production. AOA 2002 National Olive Industry Conference September 2002, Adelaide, SA, Australia.

Spooner-Hart R (2004) Sustainable pest management. 4th Annual Olive Harvest Workshop, September 2004. Rylstone NSW, Australia 119-127.

Spooner-Hart R (2004) Sustainable pest and disease management in Australian olive production: A research update. AOA 2004 National Olive Industry Conference October 2004, Perth, WA, Australia

Spooner-Hart R, Tesoriero L, Hall B, Page F, Learmonth S, Conlan D (2002) Progress towards pest and disease management in Australian olive production. *Advances in Horticultural Science* 16:3-4 218-224.

Spooner-Hart R, Page F, Learmonth S (2004). Arthropod pests of olives. International Congress of Entomology. August 2004. Brisbane, Qld, Australia.

Tesoriero L (2004) Diseases and disorders of olives in eastern Australia. 4th Annual Olive Harvest Workshop, September 2004. Rylstone NSW, Australia 128-131.

10. References

Alberola T, Aptosoglou S, Arsenakis M, Bel Y, Delrio G, Ellar D, Ferre J, Granero P, Guttmann D, Koliaris S (1999). Insecticidal activity of strains of *Bacillus thuringiensis* on larvae and adults of *Bactrocera oleae* (Diptera: Tephritidae) *Journal of Invertebrate Pathology* 74:2 127-136.

Bates V (1993). Broadening the range of pest management tools-integrated pest management in the apple and pear industry. *Plant Protection Quarterly* 8:4 141-3

Belcari A, Dagnino A (1995). Preliminary analysis of insects caught by a Malaise trap in olive groves in Northern Tuscany. *Agricoltura Meditteranea* 125:2 184-9.

Botha J, Poole M, Taylor D, Hardie D, Spooner-Hart R (2002) Olive lace bug *Froggattia olivinia* (Hemiptera: Tingidae) Farmnote No 050/2002 Department of Agriculture WA, Australia.

Cannard M, Spooner-Hart R, Beattie G (2004). Olive lace bug, *Froggattia olivinia* (Hemiptera: Tingidae)- an Australian native pest of cultivated olives. International Congress of Entomology. August 2004 Brisbane, Qld Australia.

CSIRO (1991) *The insects of Australia*. 2nd ed. Melbourne University Press, Victoria, Australia. 1137 pp.

Froggatt, WW (1901). Notes on selected Australian Hemiptera (Plant bugs). *Agricultural Gazette of New South Wales* 12:1 592-601.

Hall B (2001). Olive diseases in South Australia . *The Olive Press*, Winter edition, Australian Olive Association: 15-17

Haniotakis G, Kozryrakis M, Fitsakis T, Antonidaki A (1991). An effective mass trapping method for the control of *Dacus oleae* (Diptera: Tephritidae). *Journal of Economic Entomology* 84:2 564-9.

Haskell B (1992) Research collaboration in European IPM systems. *BCPC Monograph* No 52 BCPC, England. 80 pp.

Hely P, Pasfield G, Gellatley (1982) *Insect pests of fruit and vegetables in NSW.* Inkata Press, Melbourne, Australia.

Horne P, Rae J, Henderson A, Spooner-Hart R (1999) Awareness and adoption of IPM by Australian potato growers. *Plant Protection Quarterly* 14:4 139-142.

Huda A, Spooner-Hart R, Nair N (2004). Using climate information to screen disease risk of olive growing areas in Australia. International Plant Pathology Congress, January 2004, Auckland New Zealand.

Knihinicki D (2000). The olive bud mite: A new mite pest on Australian olives. http://www.agric.nsw.gov.au/Hort/ascu/insects/obudmite.htm

Levene H (1960). Robust tests for equality of variances. In: Olkin I (Ed). *Contributions to probability and statistics.* Stanford University Press. Stanford, California USA, pp278-292.

Llewellyn R (ed.) (2002) 2nd ed. *The good bug book - beneficial insects and mites commercially available in Australasia for biological pest control*- Bugs for Bugs P/L Mundubbera, Qld. Australia. 110 pp.

Malipatil M, Dunn K, Smith, D (2000) *An illustrated guide to the parasitic wasps associated with citrus scale insects and mealybugs in Australia*. Victorian Department of Natural Resources and Environment, Knoxfield, Victoria Australia. 152 pp.

Mazomenos B, Stephanou D, Mazomenos-Pantazi A, Carapati K, Witzgall P (eds.) (1997). Mating disruption field trials to control the olive moth, *Prays oleae*: a four year study. *Bulletin OILB-SROP* 20:1 129-132.

Milne W (1991). Integrated Pest Management in Sunraysia. *Australian and New Zealand Wine Industry Journal* 5:3 236

Morris T, Symondson W, Kidd N, Campos M (1999). Spiders and their incidence on *Prays oleae* in olive plantations. *Boletin de Sanidad Vegetal-Plagas* 25:4 475-89

Orphanides G (1993). Control of *Saissetia oleae* (Hom: Coccidae) in Cyprus through establishment of *Metaphycus barletti* and *M. helvolus* (Hym: Encyrtidae). *Entomophaga*. 38:2 235-9.
Page F (2000). Control of insect pests of olives. QDPI File No: H0176, July 2000. http://www.dpi.qld.gov.au/horticulture/5108.html
Patrick V (1991) Integrated Pest Management in Coonawarra, SA, Australia. *Australian and New Zealand Wine Industry Journal* 5:3 233-5
Sibbert G, Steenwyk R van Teviotdale B, McKendry M, Van Steenwyk K (1995). Olive pest management guidelines. University of California (ANR) Oakland CA USA 20pp.
Smith D, Beattie GAC, Broadley R (1997). Citrus pests and their natural enemies. QDPI Press Brisbane, Australia. 272 pp.
Spooner-Hart R, Tesoriero L, Hall B, Page F, Learmonth S, Conlan D (2002) Progress towards pest and disease management in Australian olive production. *Advances in Horticultural Science* 16:3-4 218-224.
Spooner-Hart R, Page F, Learmonth S (2004). Arthropod pests of olives. International Congress of Entomology. August 2004 Brisbane, Qld, Australia.
Sweeney S, Davies G (1997). The olive industry, pp. 405-411 - In: Hyde, K (ed.) *The new rural industries: Handbook of new rural industries*- RIRDC, Canberra, Australia.
Thwaite W (1997). Australia’s progress in apple IPM. A review of industry pest management in Australian apple orchards. *Bulletin No* 48, 34pp. NSW Agriculture, Orange NSW, Australia.
Thwaite W, Hetherington S, Bright J (2002). *Orchard Plant Protection Guide for deciduous fruits in NSW 2002/3*. NSW Agriculture, Orange, NSW, Australia. 122 pp.
Western Australian Department of Agriculture (2003). *Common pests of summer fruit in Western Australia*. WA Department of Agriculture, Australia. 23 pp.
Weppler R, Luck R, Morse J (2003). Studies on rearing *Metaphycus helvolus* (Hymenoptera: Encyrtidae) for augmentative release against black scale (Homoptera: Coccidae) on citrus in California. Biological Control 28 118-28.
Wilson F (1960). A review of the biological control of insects and weeds in Australia and New Guinea. CAB Technical Communication No. 1, Commonwealth Institute of Biological Control, Ottowa, Canada

Appendix 1: Summary of answers to key questions from national grower survey

Question 1: Contact details (optional)

Question 2: Where is your property?

40% located in NSW
19% located in South Australia
18% located in Western Australia
10% located in Queensland
6% located in Victoria
5% located in Tasmania
0% in the Northern Territory
0% in ACT

Question 3: What varieties do you grow?

Top five varieties

Manzanillo
Frantoio
Correggiola
Barnea
Leccino

Question 4: What are the insect pests in your olive grove?

Ranked from most important pest to least important pest.

Black scale
Ants
Olive lace bug
Grasshoppers
Other (pests)
Curculio beetle/apple weevil
African Black beetle
Light brown apple moth
Red Scale
Rutherglen bug
Green Vegetable bug
Olive bud mite
Queensland Fruit Fly
Other scale
Other mites
Grape Vine Hawk Moth
Cicadas
Mediterranean Fruit Fly
Parlatoria Scale

Question 6: What diseases are present in your olive grove?

Ranked from most important disease to least important disease

Peacock Spot
Phytophthora Root Rot
Anthracnose
Rhizoctonia Root Rot
Verticillium Wilt
Other Spot
Nematodes
Other Fruit Diseases
Galls

Question 7: How important are pesticides to your over all pest-control program?

15% - very important-main control
24% - Quite important
26.5% - Relatively unimportant-minor
32% - Not used at all

Question 8: Which insecticides do you use to control which olive insect pests?

Petroleum Spray Oil/white oil (132) - Black Scale, Red Scale, Olive lace bug

Dimethoate (39)- Olive lace bug, Black scale

Chlorpyrifos (34)- Olive lace bug, Grasshoppers, Curculio Beetle, African Black Beetle

Alpha-Cypermethrin (34)- Weevils, Grasshoppers

Methidathion (31)- Scale insects, Olive lace bug

Question 9: Which fungicides do you use to control which olive diseases?

Copper Oxychloride (35)- Anthracnose, Peacock spot

Copper Hydroxide (20)- Peacock spot

Phosphonic acid (7)- *Phytophthora* Root Rot

Terraclor (4) *Rhizoctonia* Root Rot

Question 10: Do you use any other products to control pests and disease in your olive grove?

Barriers (weevils, hares, kangaroos)

baits (snails, ants)

neem (weevils, lace bug)

pyrethrum (black scale)

Question 11: Which methods of pesticide application do you or your contractor use?

13% - Boom spray
1% - Oscillating Boom
10.5% - Air blast
67% - Hand held applicator (including wand from tractor-drawn sprayer)
1% - Other

Question 12: Are you interested in reducing your pesticide use?

67% - yes
10% - no
5.5% - unsure

Comments for Yes: Economic and environmental perspective
Don't want to kill friendly bugs
Generally dislike chemicals for plants and people
Chemical residue problems and pesticide resistant bugs
Seeking organic accreditation eventually
The less chemicals the better
Marketing considerations

Comments for No: Don't use any pesticides and have no intention of starting
Don't use excessive amounts

Question 13: Are you interested in organic olive production?

1% - Registered Organic grower
14% - In conversion
69% - Interested in growing organically but currently conventional
15% - Not interested in growing organically

Question 14: How much do you know about IPDM?

44% - Nothing
40.5% - Only a little
9% - Quite a lot
7% - Understand it well

Those that answered *Nothing* to question 14 were excluded from the following two questions.

Question 15: Where did you obtain your knowledge of IPDM?

34% - Industry newsletters/journals
25% - Growers field day
22% - Farm chemical user training course
20.5% - IPDM workshops
20.5% - Industry Association
16% - General newspaper/magazines
13% - Dept. of Agriculture
13% - Other growers
4.5% - Internet
3% - Television/radio
2% - Professional consultants
2% - Pest Management contractor
16% - Other - university, TAFE courses, textbooks, specialised olive courses

Question 16: Have you used IPDM?

26% - Yes
45% - No

(Those that answered *No* to question 16 were excluded from the next 4 questions.)

Question 17: How important is IPDM to your overall pest and disease control program?

45% - Very important-main strategy
42% - Quite important
5.5% - Relatively unimportant-minor factor
7.5% - Unimportant-not used at all

Question 18: Against which insect pests do you use IPDM practices?

(87% - Scale Insects
(18% - Ants
39% - Olive Lace Bug
24% - Beetles/weevils/Moths
13.5% - Grasshoppers
5% - Mites
5% - Bugs
0% - Fruit Fly
8% - Other (caterpillars)

Question 19: Against which diseases do you use IPDM practices?

37% - Leaf Diseases
18.5% - Root and Stem Diseases
11% - Fruit Diseases
7.5% - Other

Question 20: Which techniques do you believe are important in IPDM?

89% - Beneficials: predators, parasites
87% - Cultural practices: irrigation/pruning/nutrition etc.
79.5% - Spraying based on monitoring rather than predetermined schedule
76% - Pest monitoring devices/practices
55% - Spot spraying
39.5% - Use of selective pesticides
5% - Other (use of oils)

All surveys were used for the remaining questions.

Question 21: Do you monitor any of the following diseases in your crop?

76.5% - Leaf diseases
38% - Fruit diseases
36% - Root and Stem diseases
5% - Other

Question 22: Is your disease prediction and monitoring based on:

89% - Field Observation
18.5% - Weather
13% - Outside consultants

Question 23: Are you confident you can identify common olive diseases?

42% - Yes
55% - No

Question 24: Do you monitor any of the following insect pests in your crops?

81% - Scale insects
53% - Ants
41% - Olive lace bug
33% - Grasshoppers
32.5% - Beetles/Weevils/Moths
19% - Bugs
13% - Mites
9% - Fruit fly
11.5% - Other (caterpillars)

Question 25: Which of the following methods do you use to monitor insect presence in your crop?

88% - Crop or sample plant inspection
4.5% - Yellow sticky traps
2% - Pheromone traps
2% - Light trap
1% - Blue sticky traps
1% - White sticky traps

Question 26: Do you have beneficial insects in your crop?

34% - Yes
5% - No
59.5% - Unsure

Question 27: Name any beneficial insects that you think are present.

21% - Ladybirds
16% - Spiders
15.5% - Wasps
3% - Bees
3% - Praying Mantis
2.5% - Green Lacewing
2% - Ants

Question 28: Are you confident you can identify common:

Pest Insects?	55% - Yes 43% - No
Beneficials?	24% - Yes 72% - No

Appendix 2: Diagnosis of specimens submitted to PHDS, NSW DPI, as part of the project

Olive Project – PHDS
January 2001 - May 2004
WBS 3954-3

Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
8/01/01	**01/4**		Ringbarking	Undetermined, possibly physical injury	K McIntosh, 'Australian Olives"	Millmerran	QLD
10/01/01	01/5	Manzanillo	Brown spots on fruit, exuding brown sticky substance	Undetermined, fruit: possible hail injury, leaves: poss. lace bug injury	T & C Ellevsen	Mudgee	NSW
11/01/01	01/10	Paragon	Leaves yellowing from tip, Leaf drop, Stem shows signs of collar restriction	Undetermined, poss. physical damage/soil compaction/lace bug damage	Kirkwood Produce Co P/L	Rutherford	NSW
11/01/01	01/27		No bark splitting or red exudate	Undetermined, check soil drainage	M Kennedy	Goulburn	NSW
02/03/01	01/205		Distorted and deformed growing tips	Olive Bud Mite damage	C Shalders, 'Marlborough Olive Nursery'	Lara	VIC
20/03/01	01/270		Yellowing, Dieback, Trunk shrunk at base	Undetermined, possibly herbicide damage	U Frattali	Greensborough	VIC
11/04/01	01/312	Barnea, Frantoio	Canker, Lumpy nodes, Vascular tissue healthy	Undetermined, physical damage, possibly frost/sunscald	Piercefield Estate	Muswellbrook	NSW
19/04/01	01/318			Circular Black Scale	T Duckworth	Quorrobolong	NSW

Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
8/06/01	01/502		White spots on leaves	Undetermined, likely thrips damage	C Shalders, 'Marlborough Olive Nursery'	Lara	VIC
4/07/01	01/573	Manzanillo	Bark splitting, Roots unhealthy	Undetermined, possibly *Fusarium*/Improve soil drainage	G Ballis	Lenitza	NSW
17/07/01	01/660			Insect (likely moth)	K Moran, Narranghi Olive Grove	Braidwood	NSW
20/07/01	01/669			Unsuitable for diagnosis	S Goodchild, Grovrite Aust.	Muswellbrook	NSW
10/08/01	01/770		Gall	Undetermined	B Hall, Plant Research, Hartley Grove	Urrbrae	SA
22/08/01	01/727		Root rot	*Rhizoctonia*	R Spoonerhart, University Western Sydney	Richmond	NSW
6/09/01	01/836	Kalamata, Paragon	Leaf spots	Undetermined, suspected. physiological disorder	R Rothe	Wongavale	NSW
24/09/01	01/954	Vilos, Kalamata	Leaf spot, Black underleaf, Dieback	Peacock Spot - *Spilocaea oleaginea*	GJS Govett	Moss Vale	NSW
25/09/01	01/956	Manzanillo	Root rot	*Phytophthora* & *Rhizoctonia*	Peter Power, C/o D Conlan	Yanco	NSW
5/10/01	01/987		Dieback	Undetermined, possibly cold/frost injury & secondary bacterial	Swan Hill Chemicals P/L	Swan Hill	VIC
9/10/01	01/990	Frantoio	Dieback, Roots healthy	Undetermined, possibly cold/frost injury	W Vochteloo	Cooma	NSW
10/10/01	01/997	Manzanillo	Dieback	Undetermined, possibly waterlogging	RCA Wotton	Gunnedah	NSW
10/10/01	01/989	Picqual, Barnea	Dieback	Undetermined, possibly cold/frost injury	S Goodchild, Grovrite Aust., Pukara Estate	Muswellbrook	NSW

Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
17/10/01	01/1012		Dieback	Undetermined, possibly cold/frost injury	DA & MA Webster	Bungendore	NSW
14/11/01	01/1104		Root rot	*Rhizoctonia*	R Spark, Barambah Olives	Murgon	QLD
14/11/01	01/1105		Fruit abort	Undetermined, possibly environmental stress	A Congreve	Murgon	QLD
14/11/01	01/1106	Frantoio	Dieback, Sooty mould and black scale	Undetermined, possibly environmental stress	B & E Greensill	Kingaroy	QLD
15/11/01	01/1112	Frantoio	Undeveloped root system, Yellow leaf speckling/browning	Undetermined, possibly cold/frost injury	M Tancred, Chatsworth Pastoral Co.	Binda	NSW
19/11/01	01/1125		Fungal fruiting bodies	*Tricholoma*	C Shalders, 'Marlborough Olive Nursery'	Lara	VIC
23/11/01	01/1150	Frantoio	Dieback	Undetermined	G Sanderson	Kenmore East	QLD
28/11/01	01/1165		Leaf spots	Peacock Spot - *Spilocaea oleaginea*	Les ?	Inverell	NSW
17/12/01	01/1214	Kalamata	Dieback	*Rhizoctonia*	A Moller, Burnett Valley Olives P/L	Murgon	QLD
14/01/02	**02/15**		Root galls, No pathogenic nematodes	Undetermined	C Shalders, 'Marlborough Olive Nursery'	Lara	VIC
29/01/02	02/54	Kalamata	Dark blistering on skin of fruit, Dry rot	Undetermined, likely physiological/nutritional	K McIntosh, 'Australian Olives"	Millmerran	QLD
31/01/02	02/58	Frantoio	Dieback	Undetermined, likely physical obstruction to root development	A Moller, Burnett Valley Olives P/L	Murgon	QLD
6/02/02	02/69		Root rot, Bark splitting	*Rhizoctonia* and possibly cold/frost injury	V & A Lee, Hidden Hills	Maryvale	NSW
14/02/02	02/94		Grub burrows in	Possibly Yellow Peach Moth	M & K Melai,	Vacy	NSW

Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
			fruit		Nareeda		
21/02/02	02/120		No mites found	Black Scale and possibly Bud Mite damage	M Edmonds	Gingin	WA
1/03/02	02/158		Moisture stress, Stem bulge, Brown streaks in young phloem	Undetermined, possibly bacterial stem infection. *Pseudomonas* sp. (some *Pythium*, *Rhizoctonia* and *Fusarium.* found associated with roots - not primary)	C de Nantinel	Canowindra	NSW
8/03/02	02/236	Kalamata	Crown and root rot	*Rhizoctonia* and *Pythium*	Y Schietler, Heyden Park Ltd	Talmalmo	NSW
13/03/02	02/248		Symptoms consistent with oedemas	No pathogens detected	C Shalders, Modern olives	Lara	VIC
5/04/02	02/310	Manzanillo	Greyish marking on fruit	Undetermined, possibly Ross's Black scale	N Ellaby, Clarence River Olives	Tabulam	NSW
5/04/02	02/306		Root rot (some lace bug damage to leaves), Dieback, Leaf drop	*Phytophthora*	A Leprince, Terrace Vale Wines	Pokolbin	NSW
6/04/02	02/312		Stem gall, Wrinkled leaves, Tip dieback	Undetermined, physiological, no plant pathogens, some insect injury	C Shalders, 'Marlborough Olive Nursery'	Lara	VIC
12/04/02	02/335	Navadillo blanco	Soft nose on fruit	Anthracnose and *Botryosphaeria* sp. *Colletotrichum* (Anthracnose), Blossom end rot - excess soil moisture	T Wilson, Glenlee Olive Grove	Menangle Park	NSW
17/04/02	02/345	Manzanillo	Sunken lesions on fruit	Undetermined, poss. physical injury	GR & CF Anderson	Emu Vale	QLD

Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
17/04/02	02/346	Manzanillo, Paragon	Necrotic fruit tissue (internal)	Undetermined, likely physiological/nutritional	MJ & RM Carter	Dalby	QLD
17/04/02	02/348		Blistered and split bark on stems	Undetermined, possibly cold/frost injury	C/o J Blight (NSW Ag)	Orange	NSW
18/04/02	02/350	Kalamata	Tip end rot	Undetermined, possibly Blossom End Rot	A Strachan	Willunga	SA
18/04/02	02/351	Kalamata, Katsoulieris, Mediterram	Tip end rot	Undetermined, possibly Blossom End Rot	G Konidis	Sellecks Hill	SA
18/04/02	02/352		Blistered tissue on bark	Undetermined, possibly Physiological	R Spoonerhart, University Western Sydney	Richmond	NSW
1/05/02	02/369	Manzanillo	Sunken lesions on fruit	Undetermined, hail damage	M Buckwell	Grenfell	NSW
1/05/02	02/370		Sunken lesions on fruit	Undetermined, hail damage	M Buckwell	Grenfell	NSW
1/05/02	02/371			Undetermined, high soil moisture	S Rosnay, Rosnay Organic Farms	Canowindra	NSW
7/05/02	02/396		Insect	Olive Lace Bug	B Gagiero	Maldon	VIC
8/05/02	02/404	Kalamata		Undetermined, possibly Blossom End Rot	K Bowtell	Talmalmo	NSW
8/05/02	02/405	Mission	Breakdown of tissue towards blossom end	Undetermined, possibly Blossom End Rot	C/o D Conlan (NSW Ag)	Darlington Point	NSW
15/05/02	02/449	Volos	Rotten fruit	Undetermined, possibly Blossom End Rot	K Bowtell, The Meadows	Talmalmo	NSW
27/05/02	02/489	Kalamata, Frantoio	Discolouration and wrinkles of fruit	Undetermined, possibly physiological	Eleuthera Olive Grove	Exter	NSW
1/06/02	02/522	Volos	Black spots on fruit	Undetermined, possibly physiological	G & I Govett	Moss Vale	NSW

Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
1/06/02	02/523	Correggiola	Black spots on fruit	Undetermined, possibly physiological	G & I Govett	Moss Vale	NSW
1/06/02	02/524	Mission	Yellowing of leaves	Undetermined, possibly physiological	G & I Govett	Moss Vale	NSW
12/06/02	02/543		Fruit rot at stem end	Undetermined, Physiological, no plant pathogens, possibly physiological/nutritional/Blossom End Rot	N Ward	Oberon	NSW
13/06/02	02/548	Azapa, Manzanillo, Hardy's Mammoth	Shrivelled fruit	Anthracnose - *Colletotrichum acutatum*	Twin Tree Cottages	Pokolbin	NSW
26/06/02	02/596	Frantoio	Root and crown rot, Dieback	*Phytophthora* sp. and *Rhizoctonia* sp.	N Champion, Wollondilly Olives	Oakdale	NSW
4/07/02	02/612	Frantoio	Blisters on leaf	Olive Lace Bug	A Perculo	Wollombi	NSW
4/07/02	02/613	Frantoio	Discolouration of young leaves	Undetermined, possibly boron/calcium deficiency	A Perculo	Wollombi	NSW
2/08/02	02/688		Leaf yellowing	Black Scale	N Digiovanni, Red Hill Olive Farm	Marulan	NSW
15/8/02	02/716		Root rot	*Rhizoctonia*	Olive Corp M.Berlanda	Boort	NSW
23/8/02	02/728	Manzanillo	Splits on stem	Undetermined possibly physiological pr. Black Scale	Pengala P/L	Lara	Vic
4/9/02	02/740		Leaf yellowing	Undetermined possibly nutritional deficiency Lace Bug	Hayden Park Olives	Mona Vale	NSW
10/9/02	02/763	Manzanillo 3yr/old	Brown vascular tissue, brown staining around pruning scars. The roots and crown tree-healthy	Undetermined	Konimbla Olives T. Ellevsen	Mudgee	NSW
17/9/02	02/774						

Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
20/9/02	02/787		Unusual pale blotches on leaves	Leaves spot is unknown	R. Spoonerhart	UWS	NSW
20/9/02	02/788		Leaves spot	Scale, Peacock spot	R. Spoonerhart	UWS	NSW
20/9/02	02/789		Brown vascular tissue, brown staining around pruning scars. The roots and crown tree-healthy	Scale, Undetermined, possibly *Pseudomonas syringae*	P Power	Laguna	NSW
25/9/02	02/798						
25/9/02	02/800	Paragon	Brown vascular tissue, brown staining around pruning scars. The roots and crown tree-healthy	Undetermined	M Vest & P Mort	Mudgee	NSW
25/9/02	02/801	Frantoio	Brown vascular tissue, brown staining around pruning scars. The roots and crown tree-healthy	Undetermined	M Vest & P Mort	Mudgee	NSW
11.11.02	02/925		Dieback young olives	Undetermined	P Deakin	Sydney	NSW
14/11/02	02/941	Nevadillo Blanco	Dieback	Undetermined	Australian Olives, Yallamundi	Millmerran	QLD
19/11/02	02/954			Scale, Undetermined, possible *Pseudomonas syringae*	Coonalpyn Olives J Rowntree	Coonalpyn	SA
21/11/02	02/957	Barnea	Lump' is like a hill or 'gall wasp' branch	Undetermined	Olive Australia	Grantham	QLD
20/12/02	02/1000		Dieback	*Rhizoctonia*	Glenlee Olive Grove	Menangle Park	NSW

Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
4/12/02	02/1007		Wood rotting	Undetermined	Australian Olives, Yallamundi	Millmerran	QLD
5/12/02	02/1008		Distorted and kinked stem growth (stem deformities)	Undetermined possible *Pseudomonas* or insect injury	Modern Olives	Lara	Vic
12/12/02	02/1029		Leaves, stem, fruit damage	Hail damage	Austral Olive Yallamundi	Millmerran	QLD
19/12/02	02/1062	Manzanillo	Dieback	Undetermined	Austral Olive Yallamundi	Millmerran	QLD
3/1/03	03/01		Root rot hot, dry conditions.	*Rhizoctonia*	Australian Olives, Yallamundi	Millmerran	QLD
21/1/03	03/52	Correggiola	Dieback	Girdling roots, leaf scorch	Bilbe Agencies P/L	Comboyne	NSW
23/1/03	03/56			Sooty Mould	T James, Forest Grove		
23/1/03	03/58		Root rot	*Fusarium*	Australian Olives, Yallamundi	Millmerran	QLD
3/2/03	03/92			Neg fungi	Modern Olives C Shalders	Lara	Vic
5/2/03	03/97		Root rot	*Macrophomina phaseolina*	Boundary Bend Estate R. Norton	Boundary Bend	Vic
5/2/03	03/98			Undetermined	Wooloomooloo R Sutherland	Gulgong	NSW
5/2/03	03/103	Picqual	Fruit	Undetermined	Olivecorp	Boort	Vic
17/2/03	03/135	Nevadillo Blanco	Blackened, soft regions on fruit	Undetermined, possible deficiency of boron	Glenlee Olive Grove	Menangle Park	NSW
24/2/03	03/152	Barnea 2 year/old	Root rot	*Rhizoctonia, Fusarium, Pythium*	Olivecorp	Boort	Vic
24/2/03	03/153		Root rot	*Rhizoctonia, Macrophomina*	Franland River Olive Co	Frankland	WA

Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
5/3/03	03/196		Fruit rot	*Coleophoma oleae*	Australian Olives, Yallamundi	Millmerran	QLD
11/3/03	03/206	Frantoio/Kalamata	Swollen stem	Neg fungi Foliage damage	N Abela Modern Olives	Lara	Vic
11/3/03	03/208		Fruit	Hail injury or sunscald	Olivecorp	Boort	Vic
17/3/03	03/218	Manzanillo		Environmental injury	Canimbla C Ellevsen	Boort	NSW
18/3/03	03/220	Barnea	Root rot	*Phytophthora nicotianae*	Australian Olives, Yallamundi	Millmerran	QLD
19/3/03	03/227	Correggiola	Dieback	*Pseudomonas syringae*	Mal Bennet	Bathurst	NSW
31/3/03	03/259		Fruit rot			Flemington Market	NSW
31/3/03	03/260		Insect	Weevils	P Hunt	Mudgee	NSW
2/4/03	03/264	Frantoio, Barnea	Root rot	*Macrophomina phaseolina*	Coonalpyn olives	Adelaide	SA
3/4/03	03/267	Manzanillo	Badly discoloured leaves, some leaf drop	Undetermined Girdling roots, scorch	Barambah Estate Olives Dennis Bishop	Wondai	QLD
8/4/03	03/279	Manzanillo	Olive fruit blemished	Birds damage, Neg fungi	N Ward	Manly	NSW
7/5/03	03/332	Manzanillo	Fruit rot	Soft nose	Gooramadda Olives	Gooramadda	Vic
9/5/03	03/337		Fruit rot	*Colletotrichum acutatum*	Australian Olives, Yallamundi	Millmerran	QLD
12/5/03	03/341		Grey mark on base of fruit	*Colletotrichum acutatum*	Northern Rivers Olive Processors P/L	Swinger	NSW
14/5/03	03/350		Fruit rot; Blemishes on leaves and fruit with scale and Sooty mould	*Botryosphaeria* sp. Sooty mould on leaves and scale	Wollaston Holdings P/L	Forest Grove	WA
26/5/03	03/386	Manzanillo, Frantoio	Soft rot	Undetermined	Modern Olives P/L L Ravetti	Lara	Vic

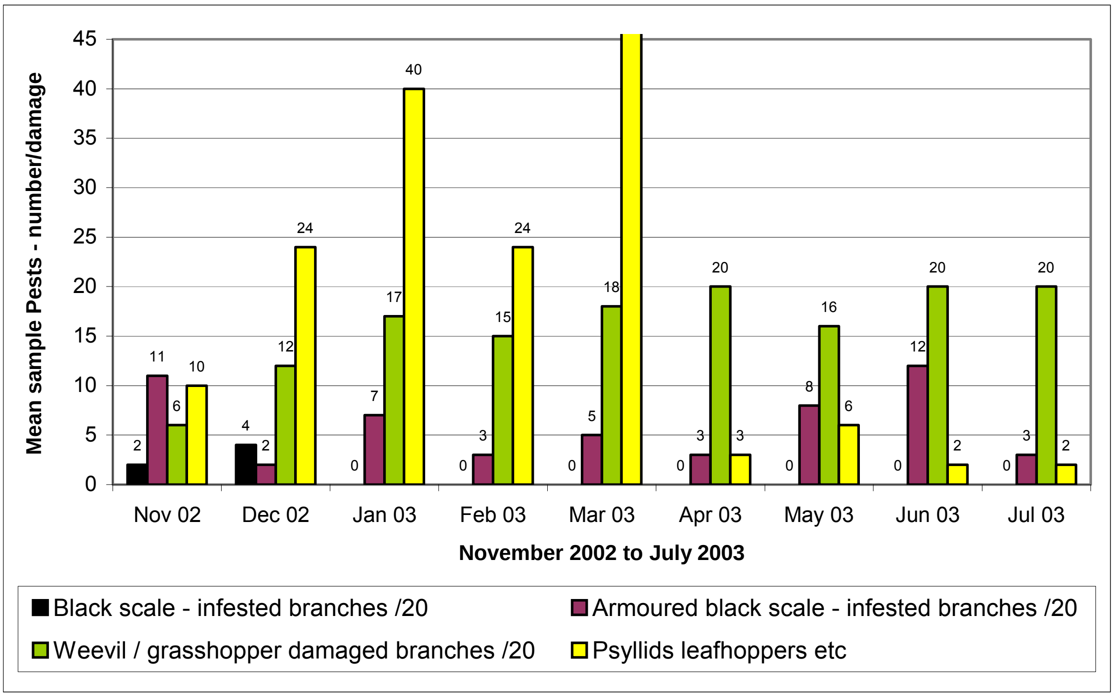
Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
2/6/03	03/426		Brown lesions on fruit	Undetermined poss fungal fruit rot	Nolsser C/O Hawkesbury Campus	Penrith South	NSW
3/6/03	03/430		Scale on leaves; yellowing of leaves	Undetermined	Barambah Olives Dennis Bishop	Wondai	QLD
3/6/03	03/431		Fruit lesions	Fungi negative	Flemington Market C/O V. Sergeeva NSW Ag	Flemington	NSW
18/6/03	03/485	Frantoio	Browning of roots	Undetermined	Australian Olives, Yallamundi	Millmerran	QLD
26/6/03	03/511		Borer type damage	Borer Damage	T Hartmann	Mt Gravatt	QLD
11/7/03	03/554	Barnea	Galls present along branch	Undetermined; negative for Olive Knot bacteria; likely sphaeroblasts	Glenlee olive grove	Menangle Park	NSW
23/7/03	03/586		Brown roots; enlarged lenticels; discolouration of upper stem tissue	Undetermined	Australian Olives, Yallamundi	Millmerran	QLD
29/7/03	03/595		Yellowing of leaves	Undetermined; poss physiological/nutritional injury	Barambah Olives Dennis Bishop	Wondai	QLD
28/8/03	03/665		Stem damage; Stem galls	Undetermined	Modern Olives P/L L Ravetti	Lara	Vic
8/9/03	03/688		Dieback	Bacterial shoot dieback	Barambah Olives Dennis Bishop	Wondai	QLD
22/9/03	03/724	Leccino	Root rot	Undetermined, possible fungal root	M. Wilson	Cessnock	NSW
29/9/03	03/771		Yellowing of leaves	*Cercospora*-like fungus	Barambah Olives Dennis Bishop	Wondai	QLD
7/10/03	03/798		Wood rotting	Undetermined basidiomycete growing on bark	Australian Olives, Yallamundi	Millmerran	QLD

Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
22/10/03	03/840		Root rot	*Macrophomina* Root Rot	Roeta DL & SJ Jones	Hillston	NSW
31/10/03	03/873		Stem lesions, dieback	*Botryosphaeria* sp.	Wooloomooloo R Sutherland	Gulgong	NSW
3/11/03	03/878		Leaf lesions	Undetermined Fungal Leaf Spot	Barambah Olives Dennis Bishop	Wondai	QLD
7/11/03	03/900		Insect	Insect Injury Symptoms - caterpillar	Elmswood P Newell	Via Scone	NSW
20/11/03	03/924	Barnea	Galls present	Negative for Olive Knot; likely sphaeroblasts	Olive Grove	Denman	NSW
25/11/03	03/933	Manzanillo	Leaf lesions, dieback	Undetermined	Lakeland Olives	Cremorne	NSW
27/11/03	03/938	Barnea	Galls present	Negative for Olive Knot; likely sphaeroblasts	S Ponders	Jerry's Plain	NSW
1/12/03	03/953		Leaf spot	Peacock Spot	Oakfield I Newton	Mudgee	NSW
22/12/03	03/1020	Manzanillo	Insect	Possible Thrips feeding damage	Jo-sands Olives D Darby	Inverell	NSW
15/01/2004	04/30	Barnea	Dieback, wilt	Undetermined, hardpan, *Rhizoctonia*	Belinda Wilks, Australian Olives	Millmerran	QLD
15/01/2004	04/31		Dieback, wilt	Undetermined	Xavier Rius, Hortipro	Waikerie	SA
4/02/2004	04/82	Manzanillo, Correggiola	Small brown concave fruit lesions	Undetermined, possibly hail or birds	Jenny Norman, Isaacs Grove	Gunnedah	NSW
11/02/2004	04/110		Yellowing of leaves	Undetermined	Dennis Bishop, Barambah Olives	Murgon	QLD
12/02/2004	04/115	Manzanillo	Scirfing, dimpling, small brown lesions on fruit	Likely thrips and other insect damage	Frank Page, Barkworth Olives	Inglewood	QLD

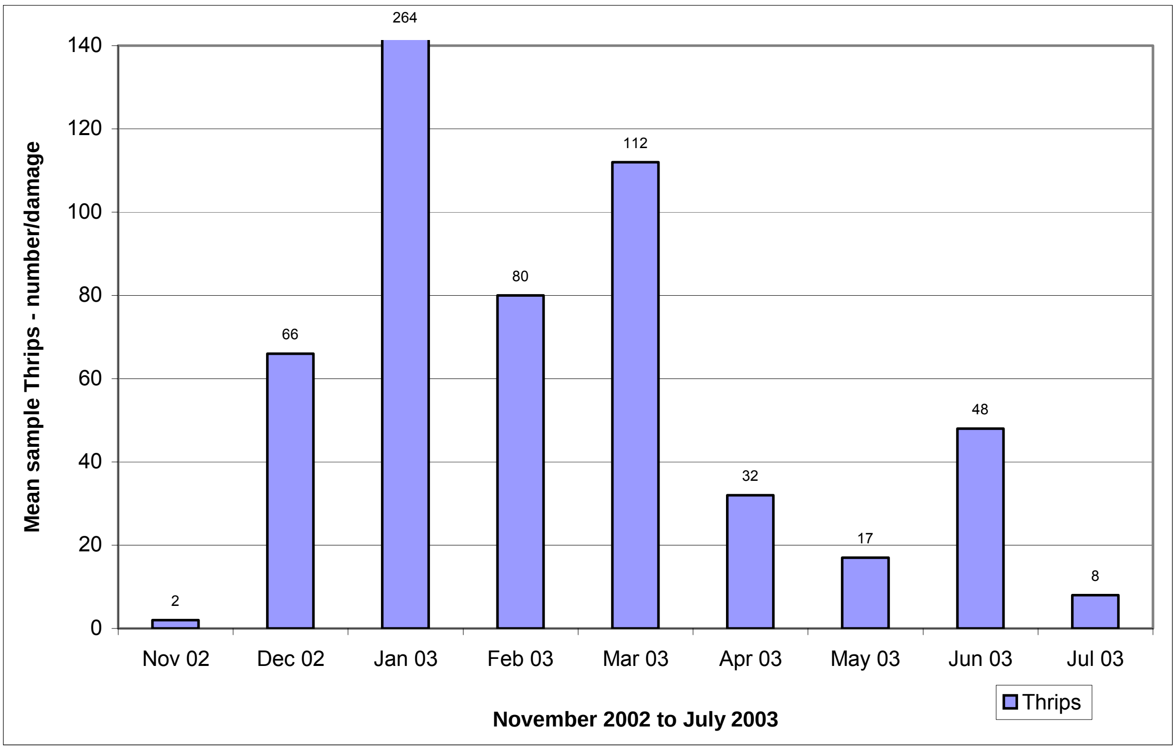
Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
19/02/2004	04/130		Dieback of scattered plants from pruning wounds	Bacterial stem rot	Xavier Rius, Hortipro	Waikerie	SA
27/02/2004	04/149	Manzanillo	Suspect thrips damage	Undetermined	Shane McCulloch, Barkworth Olives	Yelarbon	QLD
2/03/2004	04/152	Manzanillo	Fruit rot	Blossom End Rot	C. Ellerson, Kanimbla Olives	Mudgee	NSW
10/03/2004	04/171	Manzanillo, Barnea	Fruit rot	*Colletotrichum* sp.	Dennis Bishop, Barambah Olives	Wondai	QLD
11/03/2004	04/174	Picqual, UC13A6, Frantoio, WA Mission, Manzanillo	Screening for Anthracnose	Negative for *Colletotrichum* sp.	Mark, Gin Gin Farm	SA/WA	
11/03/2004	04/175	Barouni	Insect damage, caterpillar present	Caterpillar damage	Mike Wilson, Hunter Olive Grove Services	Mt View, Hunter Valley	NSW
11/03/2004	04/210		Pinched leaf tips, sooty mould on leaf under surface	Undetermined, possible environmental stress	Dennis Bishop, Barambah Olives	Wondai	NSW
23/03/2004	04/212		Necrotic vascular tissue, reshooting below diseased wood	Bacterial Stem Rot, *Burkholderia caryophylli*	Craig Shalders, Modern Olives	Lara	Vic
26/03/2004	04/232		Leaf tip dieback	Undetermined	Craig Shalders, Modern Olives	Lara	Vic
29/03/2004	04/236	Barnea, Manzanillo,	Poor root development, galls, brown vascular tissue	Undetermined	John Beet, Harcourt North	Harcourt North	Vic
30/03/2004	04/237		Dieback, stem splitting	Undetermined, possible frost injury	David Kemp, University of	Orange	NSW

Date	PHDS #	CV	Symptoms	Conclusion/Pathogen	Submitter/Grower	Location	Location
					Sydney		
30/03/2004	04/245	Barnea	Necrotic lesions in vascular tissue	Undetermined, possible environmental stress	Keith McIntosh, Australian Olives	Millmerran	QLD
2/04/2004	04/249		Leaf yellowing	*Cercospora* Leaf Blight	Dennis Bishop, Barambah Olives	Wondai	QLD
31/03/2004	04/271		Fruit injury	Undetermined	Australian Olives, Yallamundi	Millmerran	QLD
13/04/2004	04/272	Correggiola	Dieback	Undetermined, possible environmental stress	Australian Olives, Yallamundi	Millmerran	QLD
14/04/2004	04/277		Soil Sample	Root Lesion Nematodes, *Pythium, Rhizoctonia*	SESL		
30/04/2004	04/305		Leaf Yellowing, Leaf Drop	*Cercospora* Leaf Blight	Dennis Bishop, Barambah Olives	Wondai	QLD
6/05/2004	04/321	Barnea, Manzanillo,	Dieback, Fruit Rot	Secondary Fruit Rot	Australian Olives, Yallamundi	Millmerran	QLD
7/05/2004	04/323		Crown Gall	Crown Gall - *Agrobacterium* sp.	Craig Shalders, Modern Olives	Lara	Vic
13/05/2004	04/353		Leaf Yellowing, Leaf Drop	*Cercospora* Leaf Blight	Dennis Bishop, Barambah Olives	Wondai	QLD

Appendix 3: Regional grove monitoring: pests diseases and beneficial species

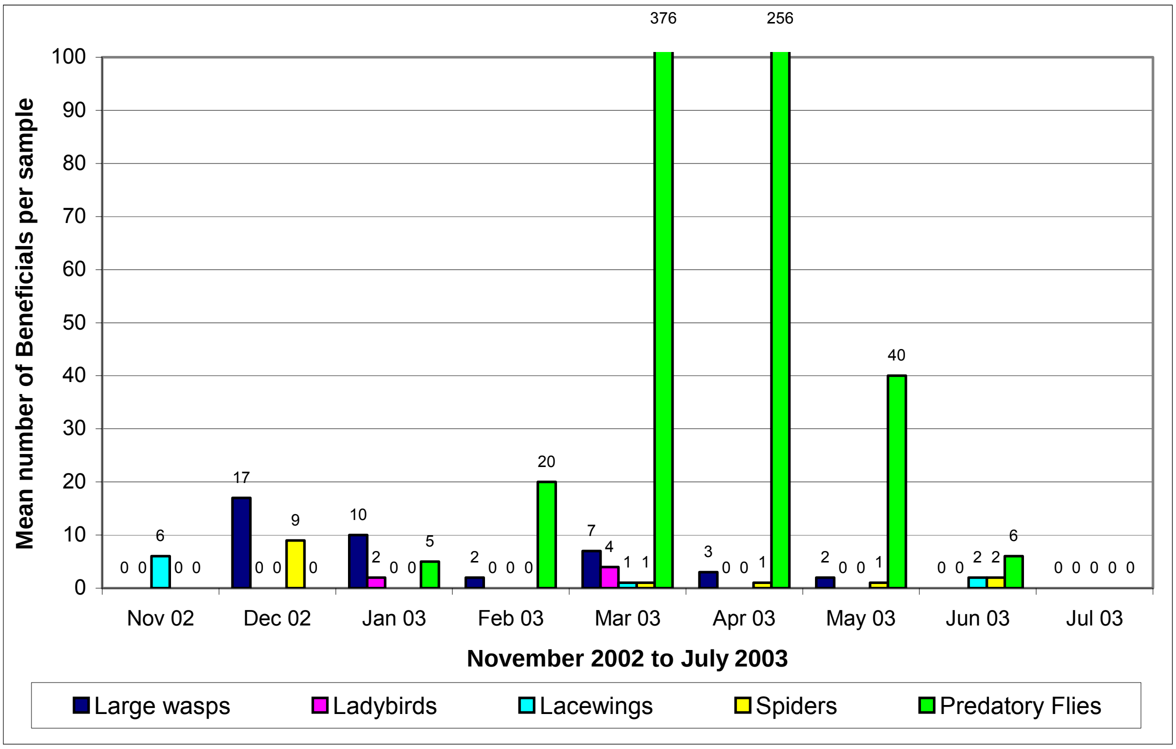


A

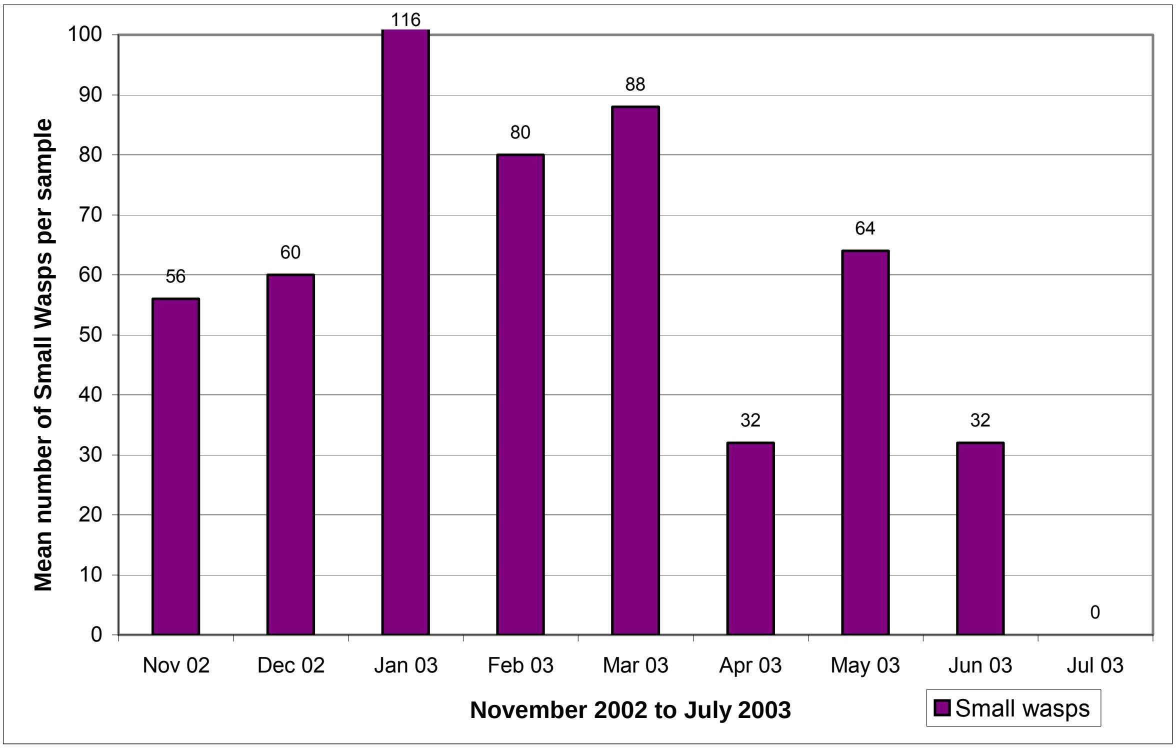


B

Fig 1. Pest species monitoring: Margaret River, WA – 2002 to 2003
A. All pest species excluding thrips
B. Thrips

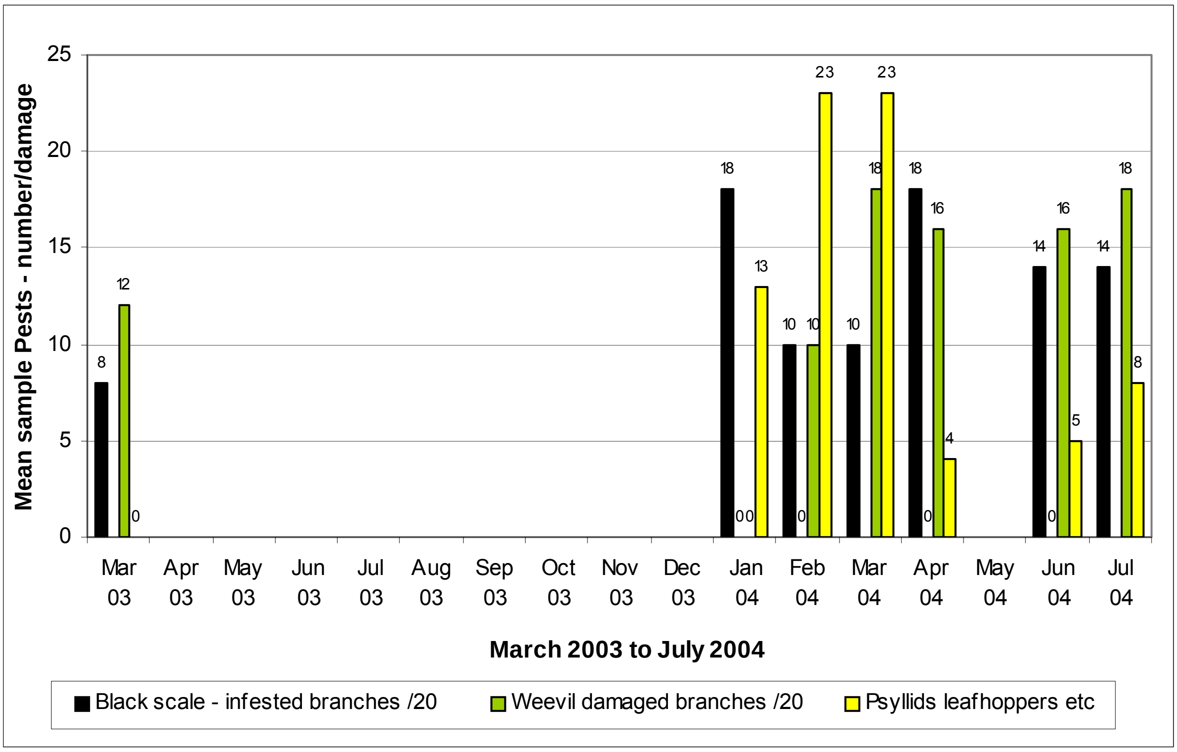


A

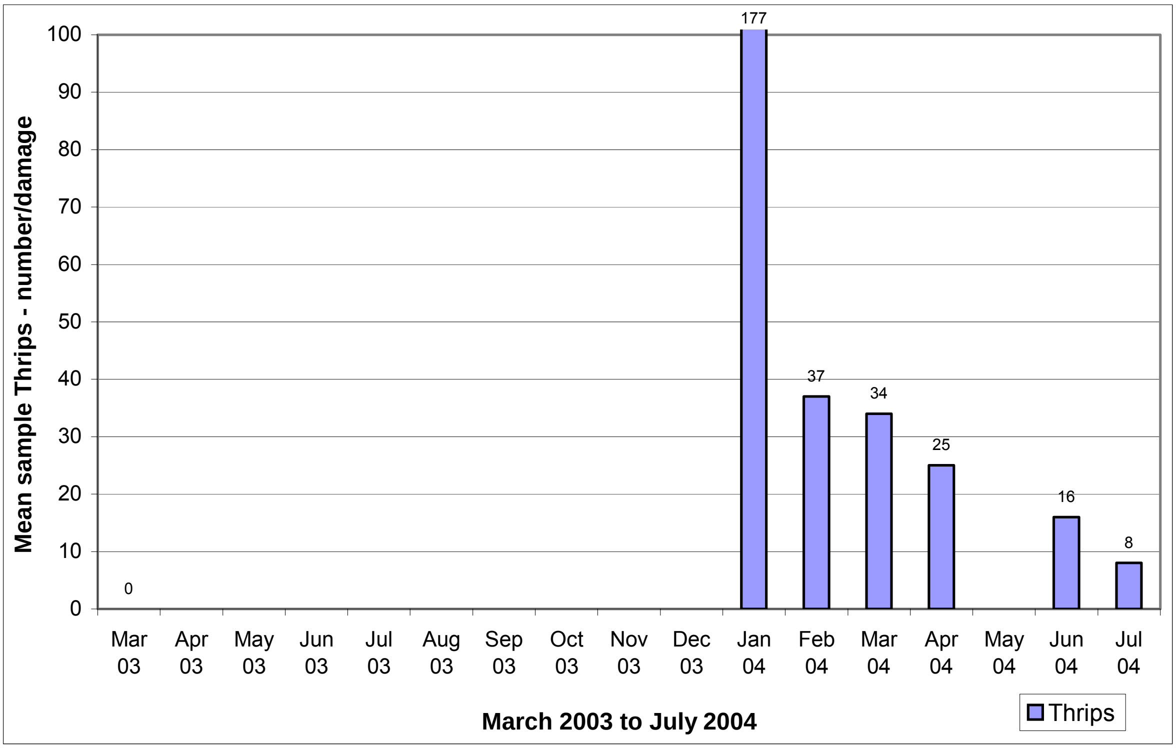


B

Fig 2. Beneficial species monitoring: Margaret River, WA – 2002 to 2003
A. All beneficial species excluding small wasps
B. Small wasps

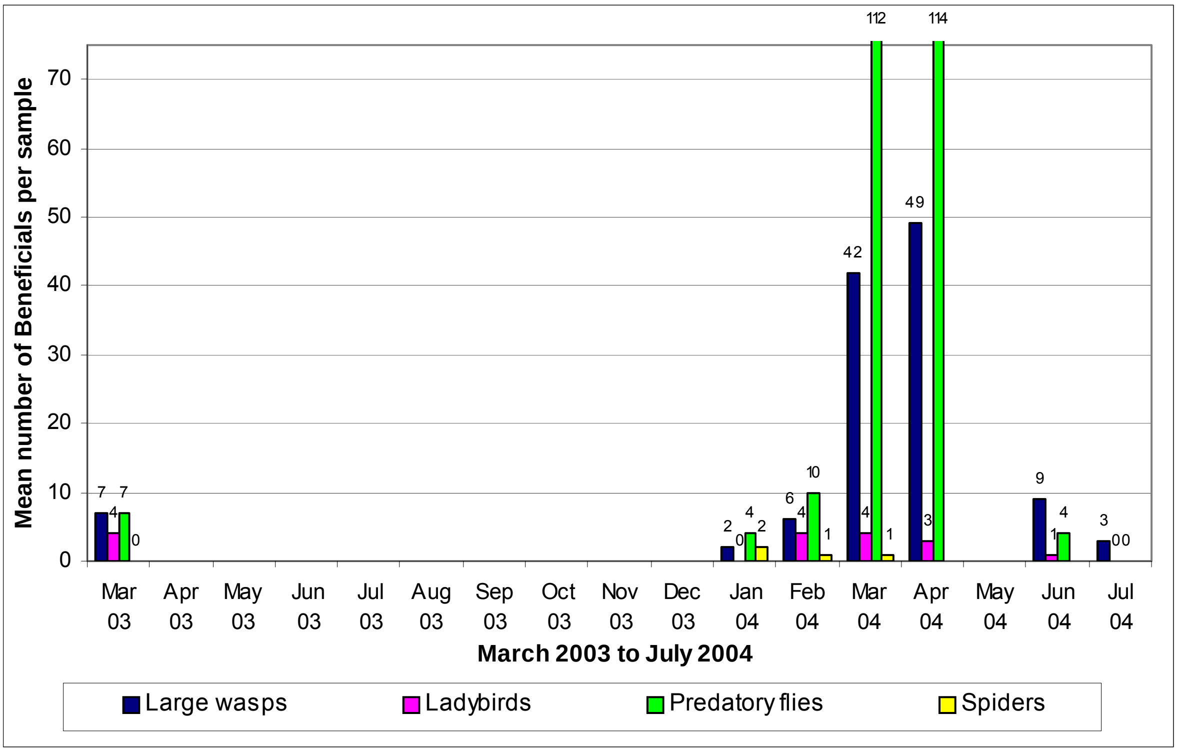


A

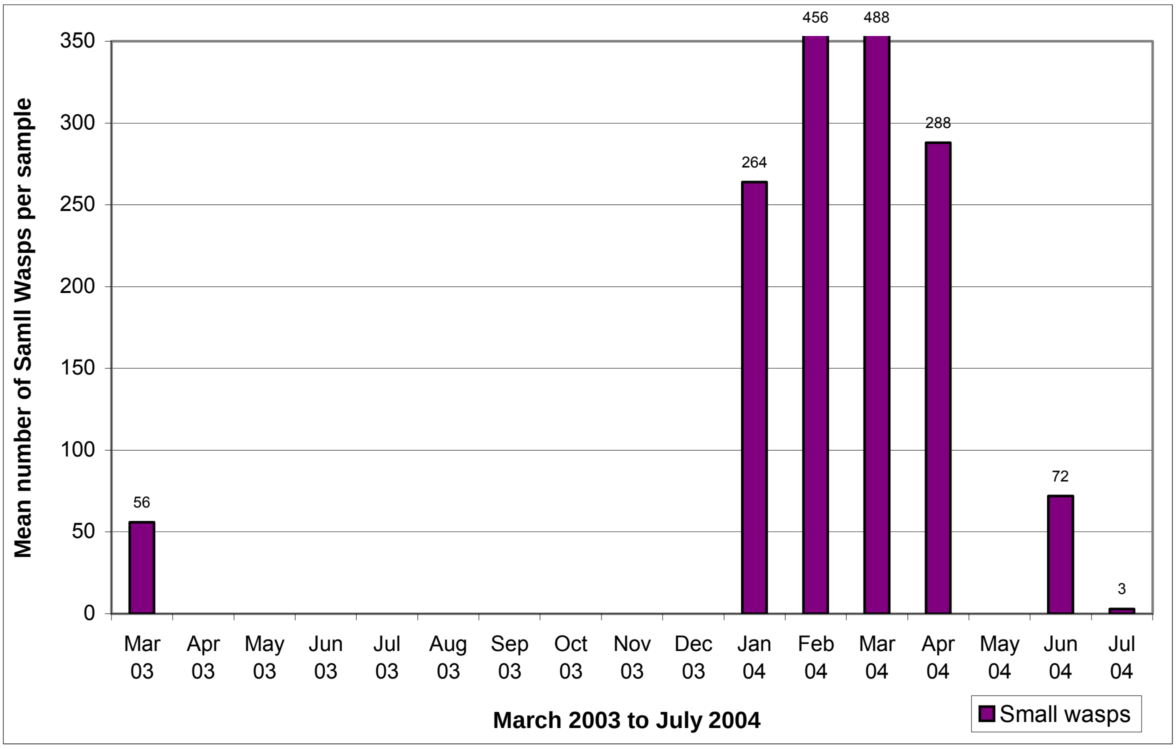


B

Fig 3. Pest species monitoring: Margaret River, WA – 2004
A. All pest species excluding thrips
B. Thrips

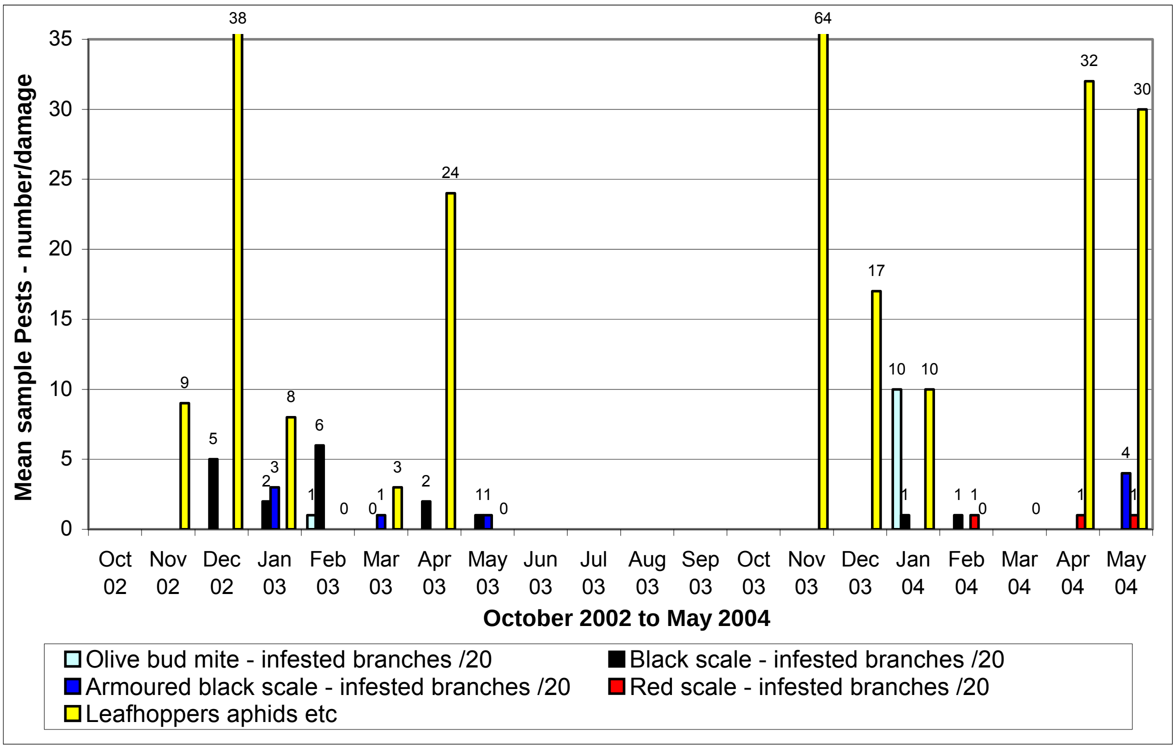


A

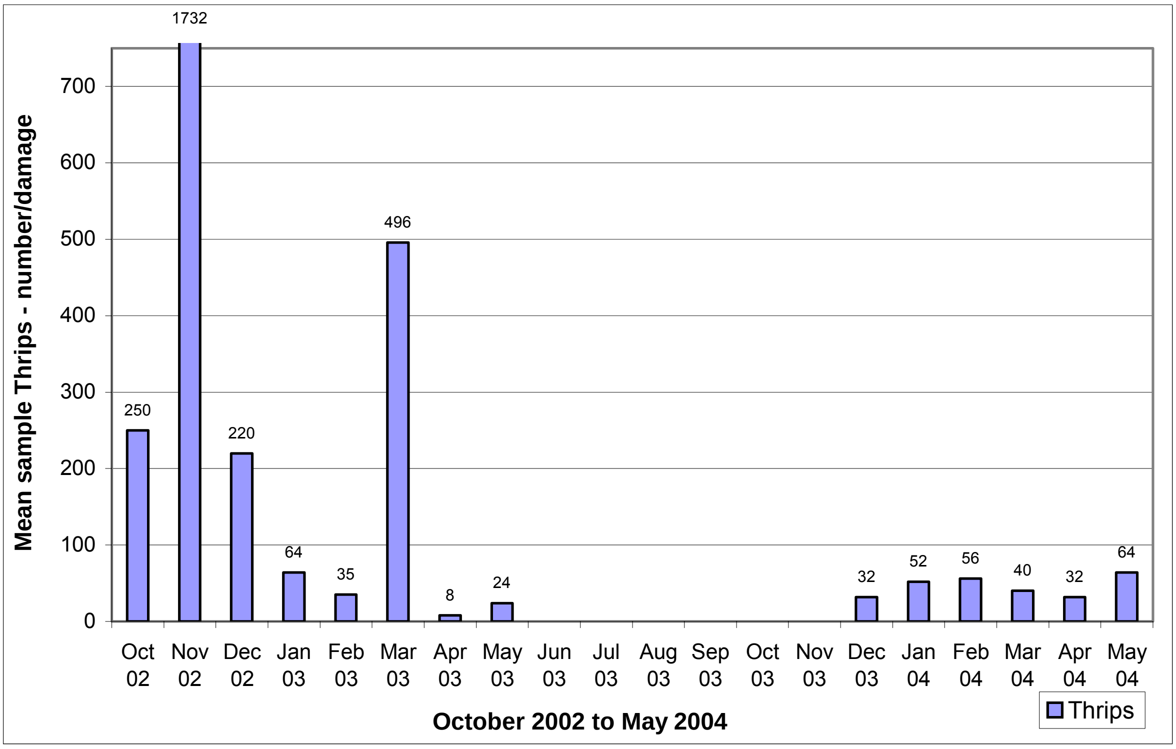


B

Fig 4. Beneficial species monitoring: Margaret River, WA – 2004
A. All beneficial species excluding small wasps
B. Small wasps

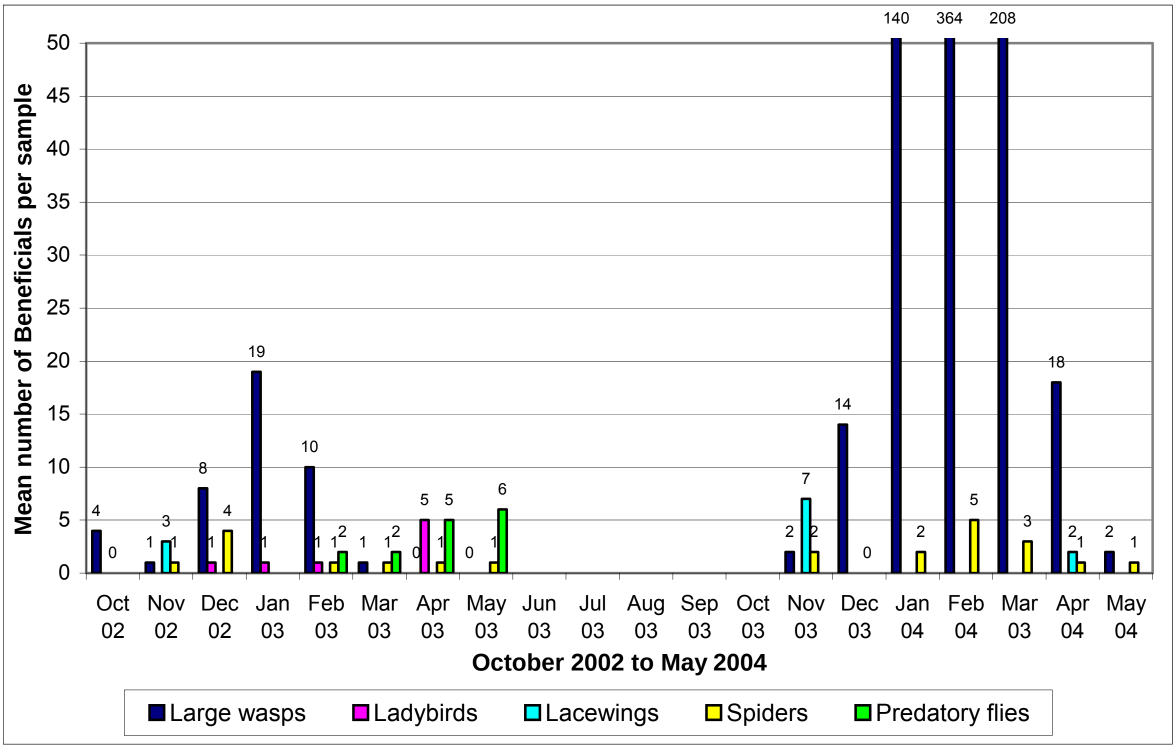


A

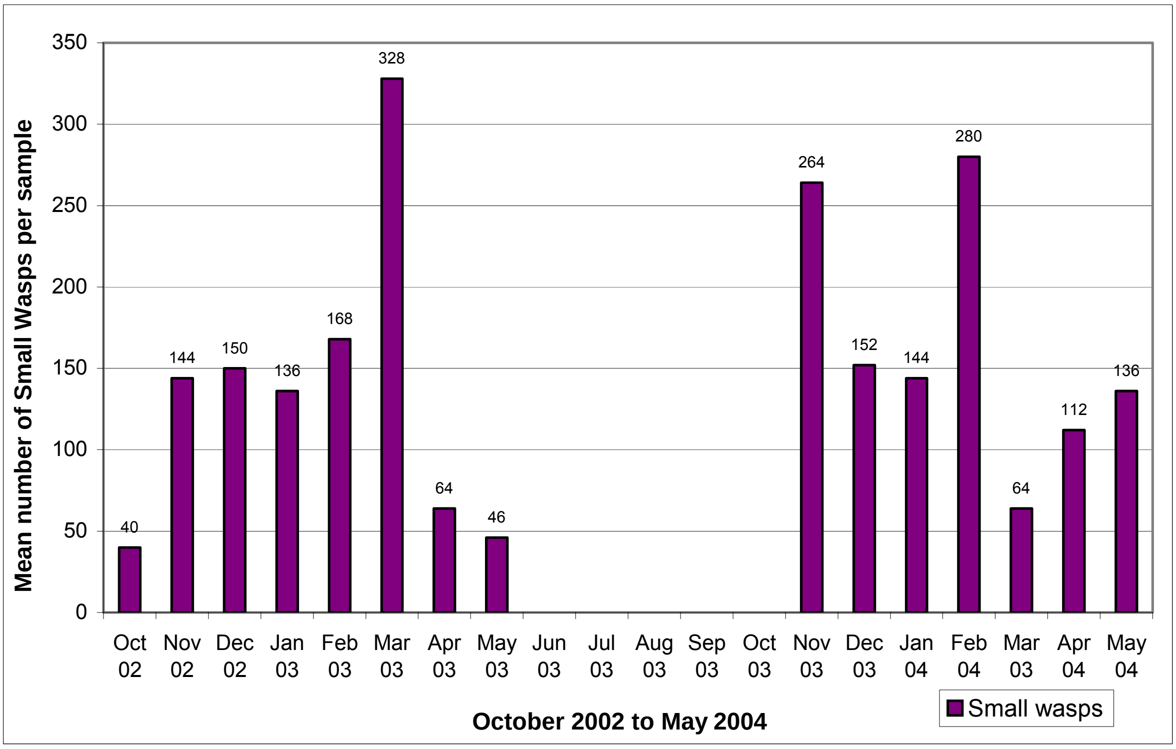


B

Fig 5. Pest species monitoring: Gingin, WA
A. All pest species excluding thrips
B. Thrips

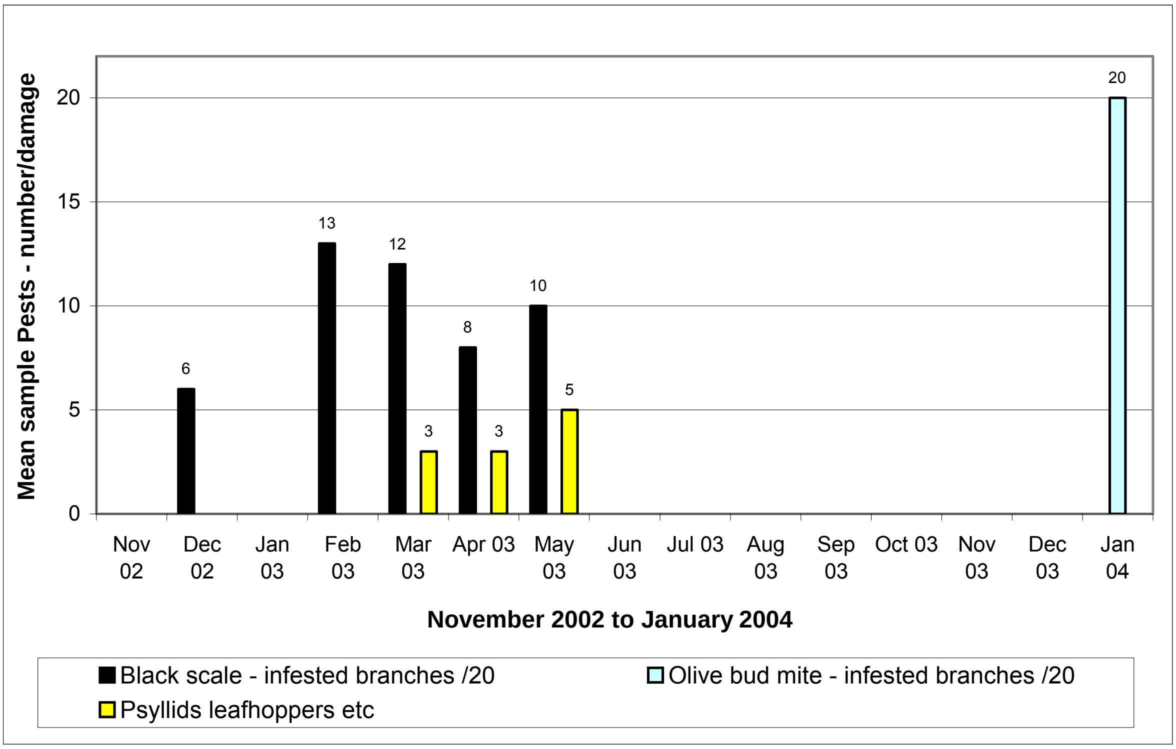


A

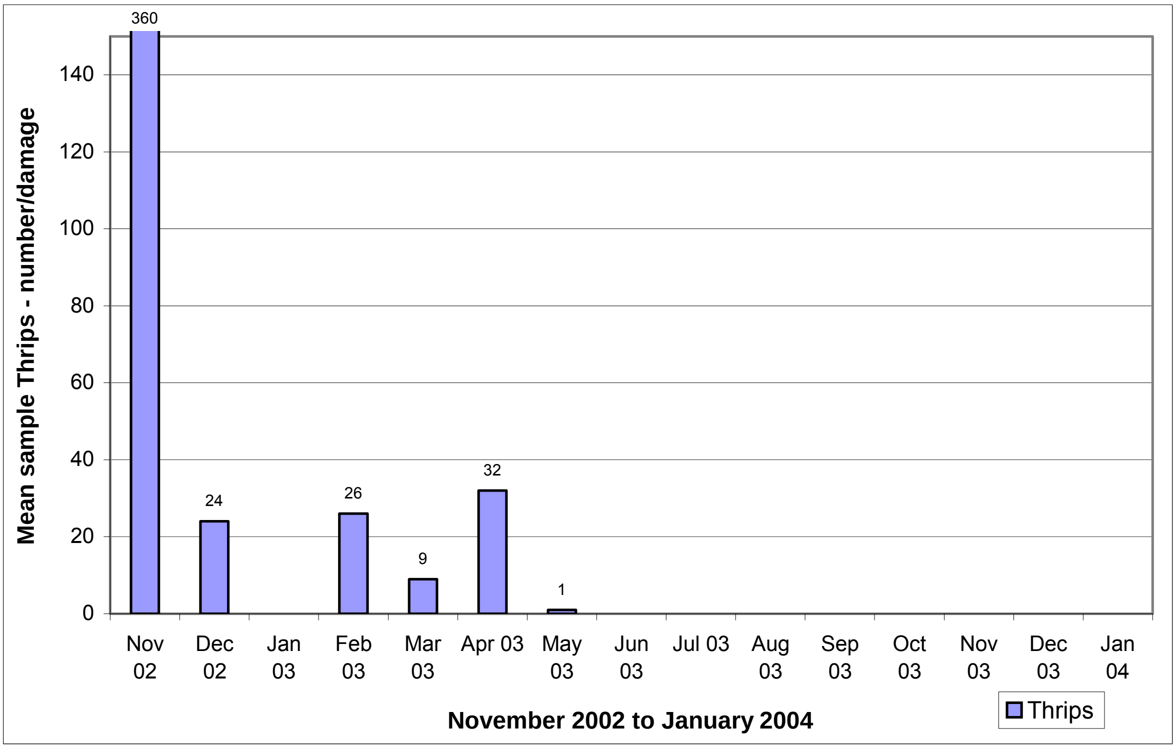


B

Fig 6. Beneficial species monitoring: Gingin, WA
A. All beneficial species excluding small wasps
B. Small wasps

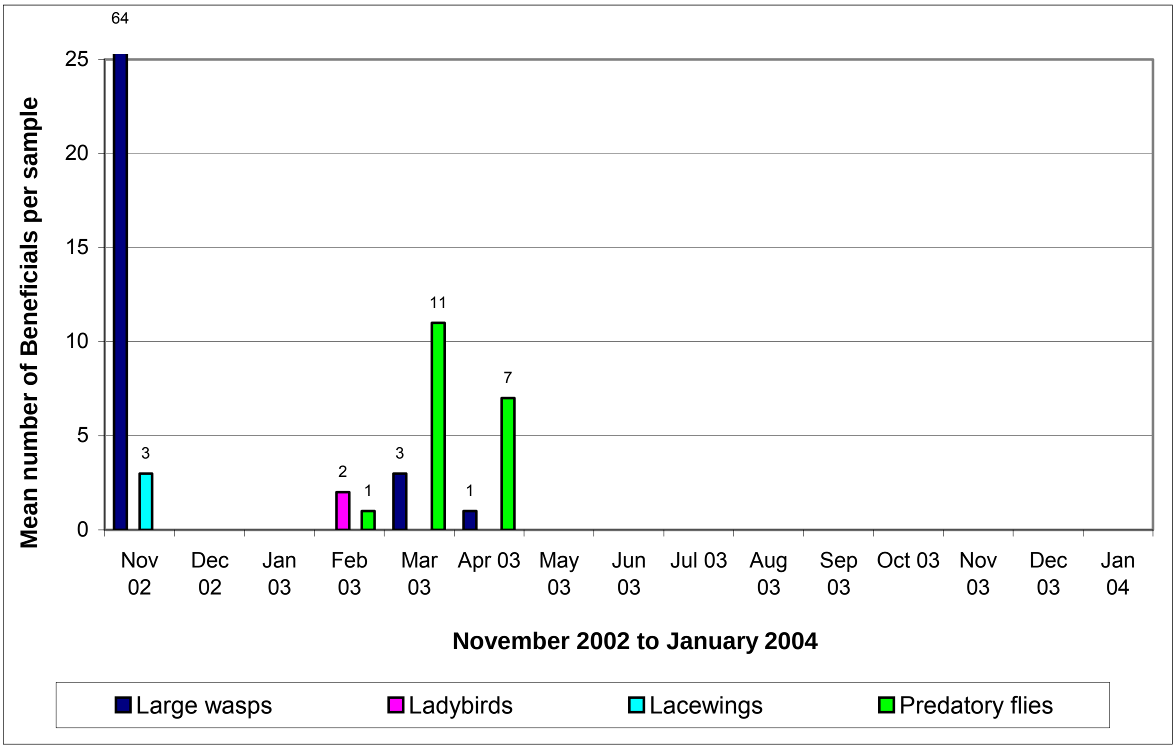


A

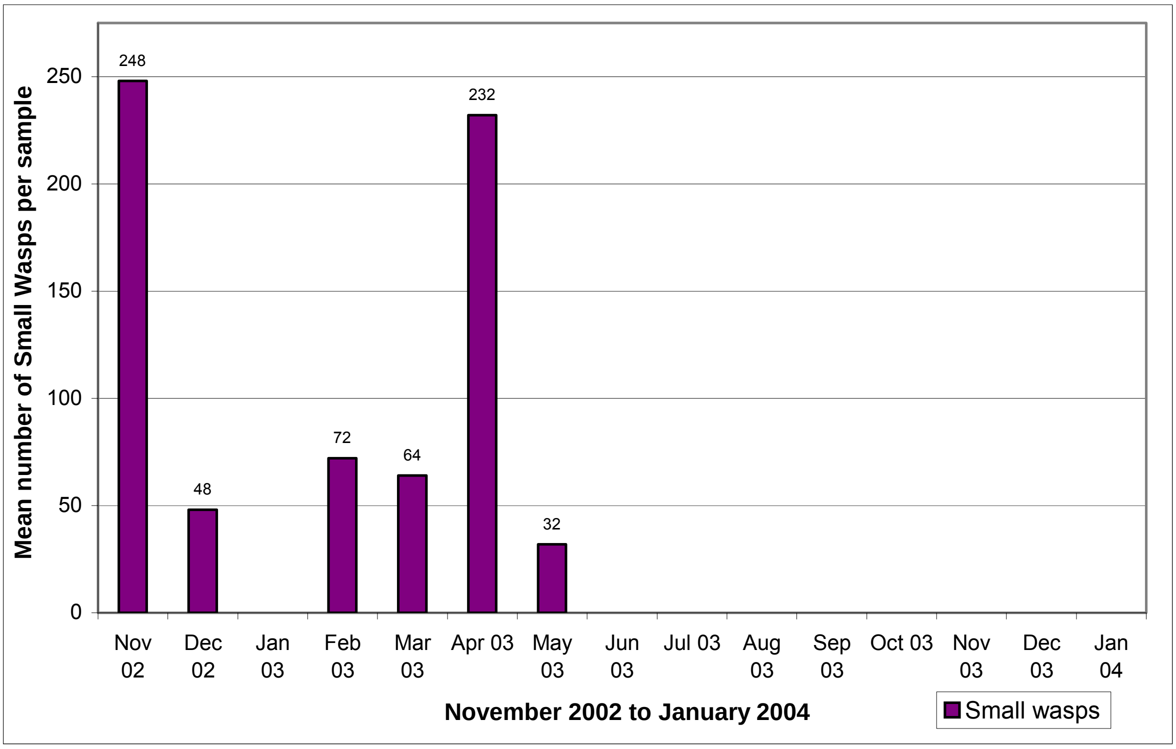


B

Fig 7. Pest species monitoring: Coonalpyn, SA
A. All pest species excluding thrips
B. Thrips

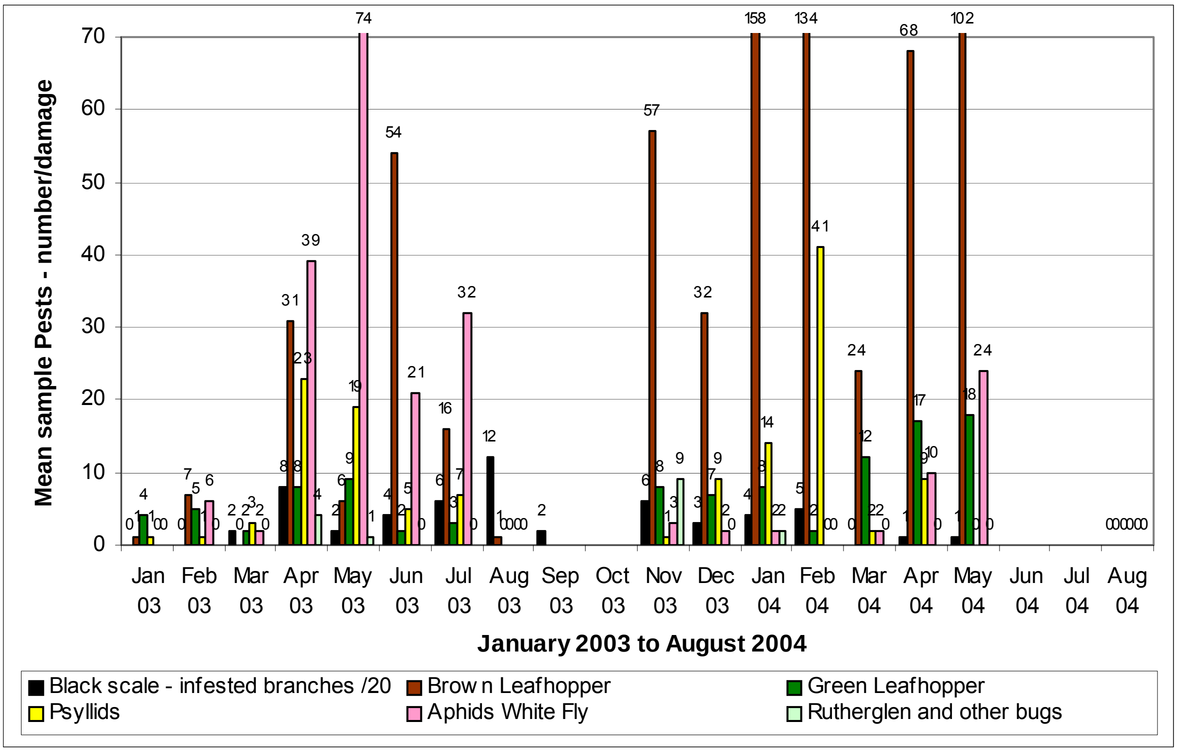


A

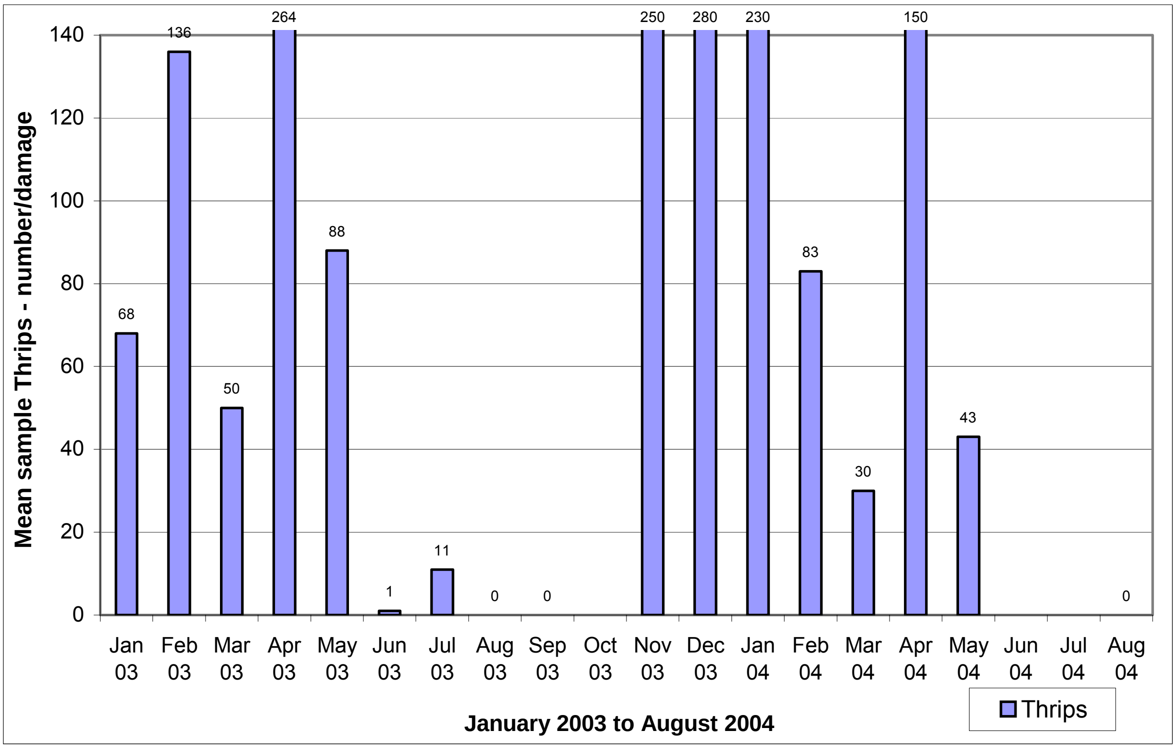


B

Fig 8. Beneficial species monitoring: Coonalpyn, SA
A. All beneficial species excluding small wasps
B. Small wasps

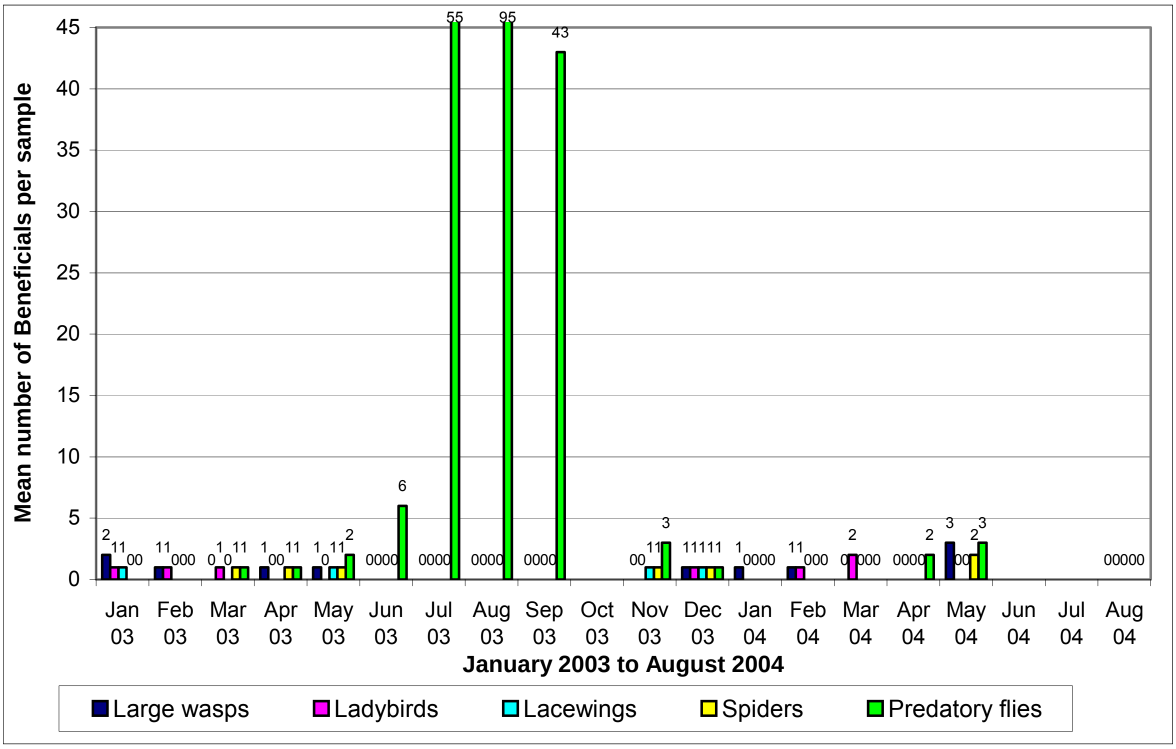


A

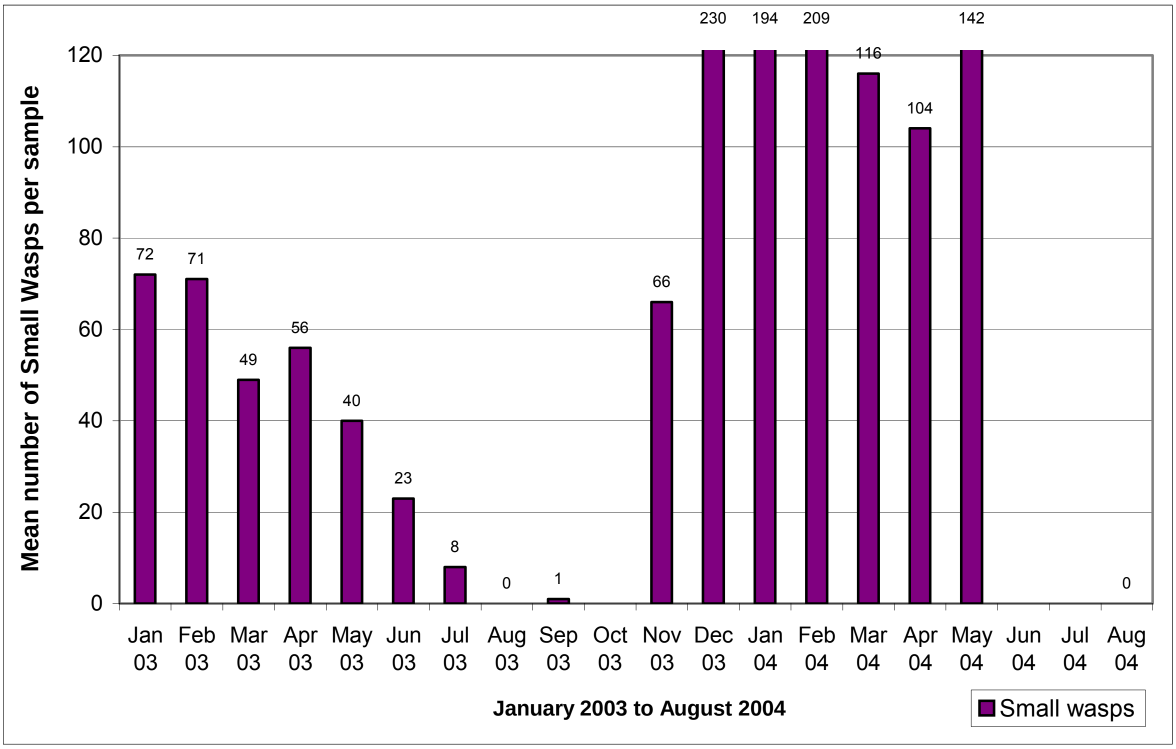


B

Fig 9. Pest species monitoring: Boort, VIC
A. All pest species excluding thrips
B. Thrips

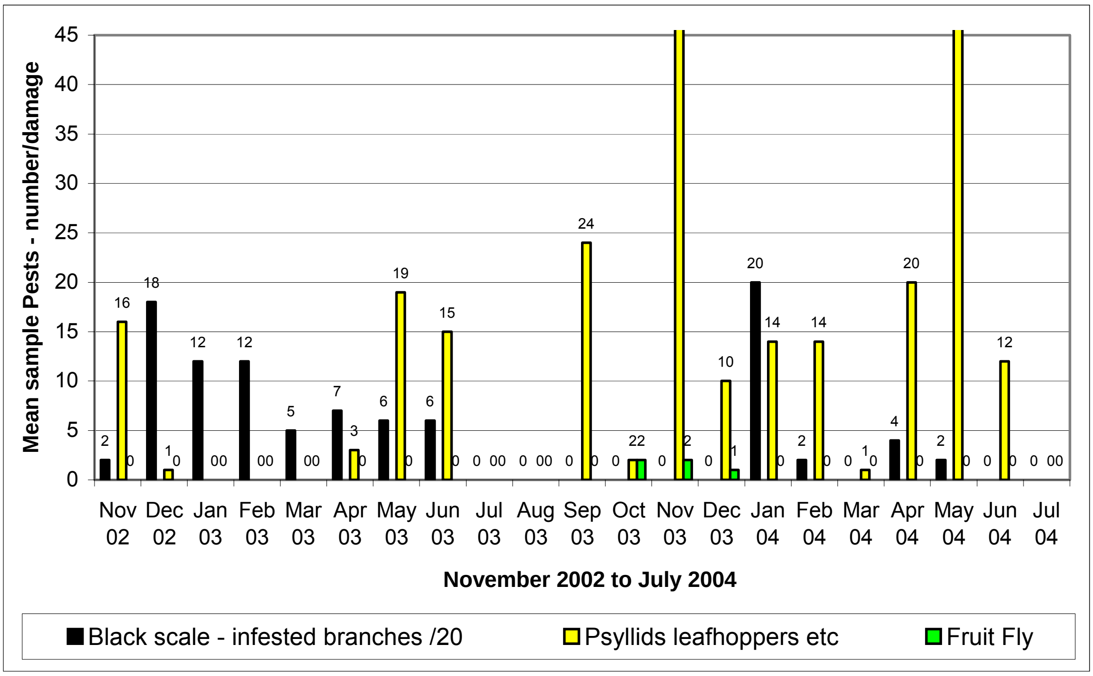


A

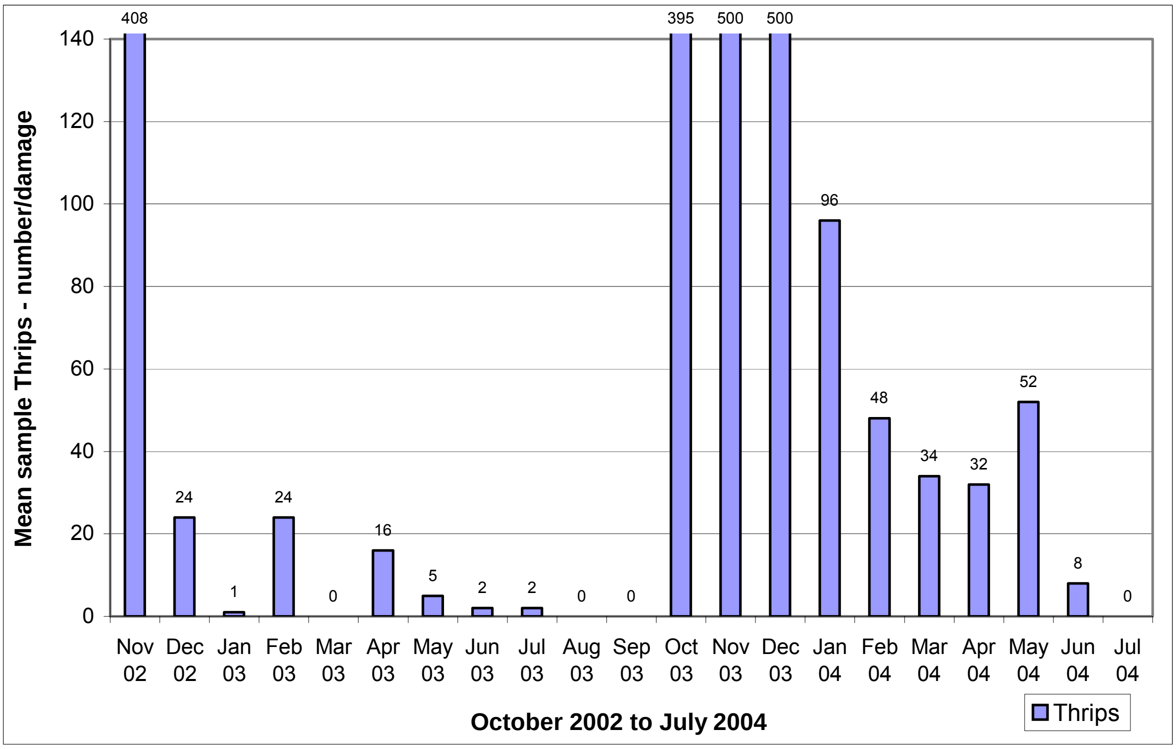


B

Fig 10. Beneficial species monitoring: Boort, VIC
A. All beneficial species excluding small wasps
B. Small wasps

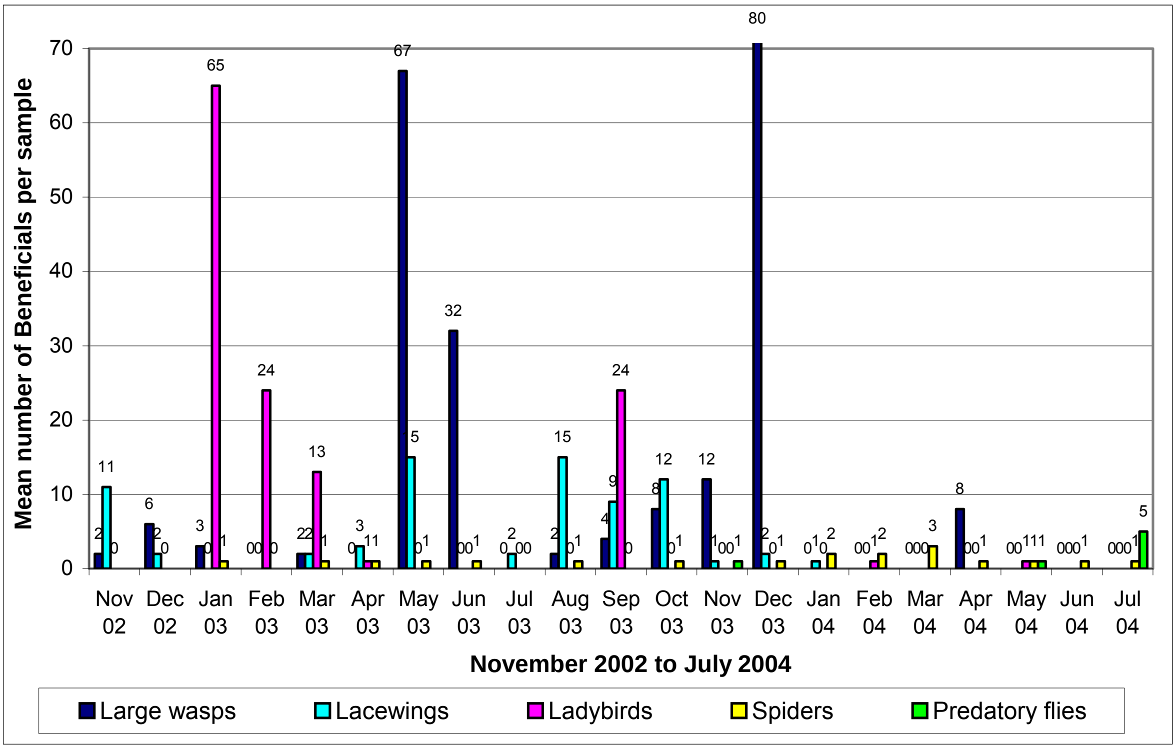


A

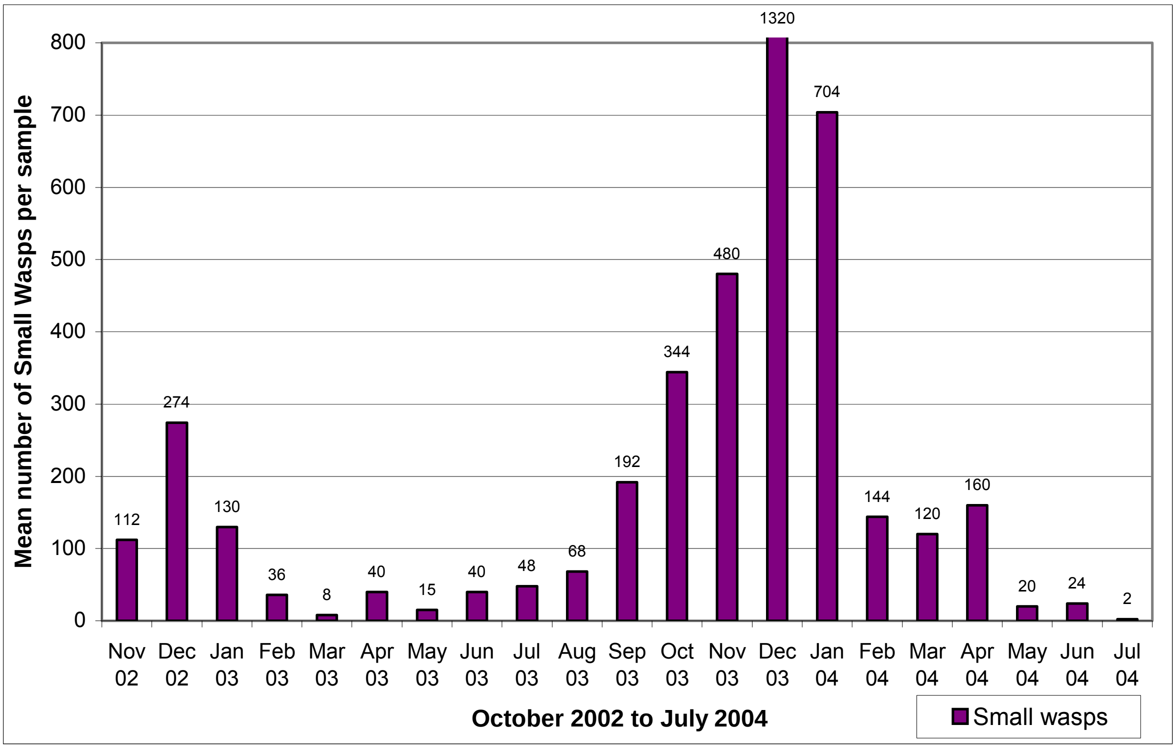


B

Fig 11. Pest species monitoring: Darlington Point, NSW
A. All pest species excluding thrips
B. Thrips

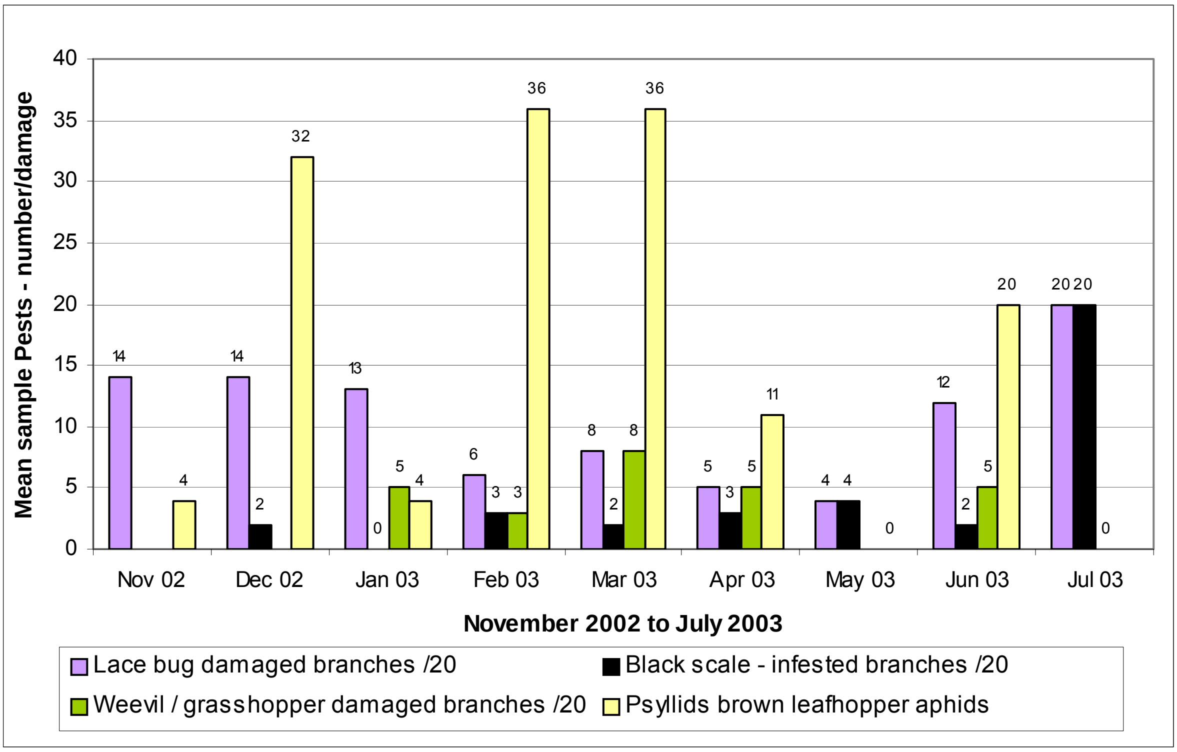


A

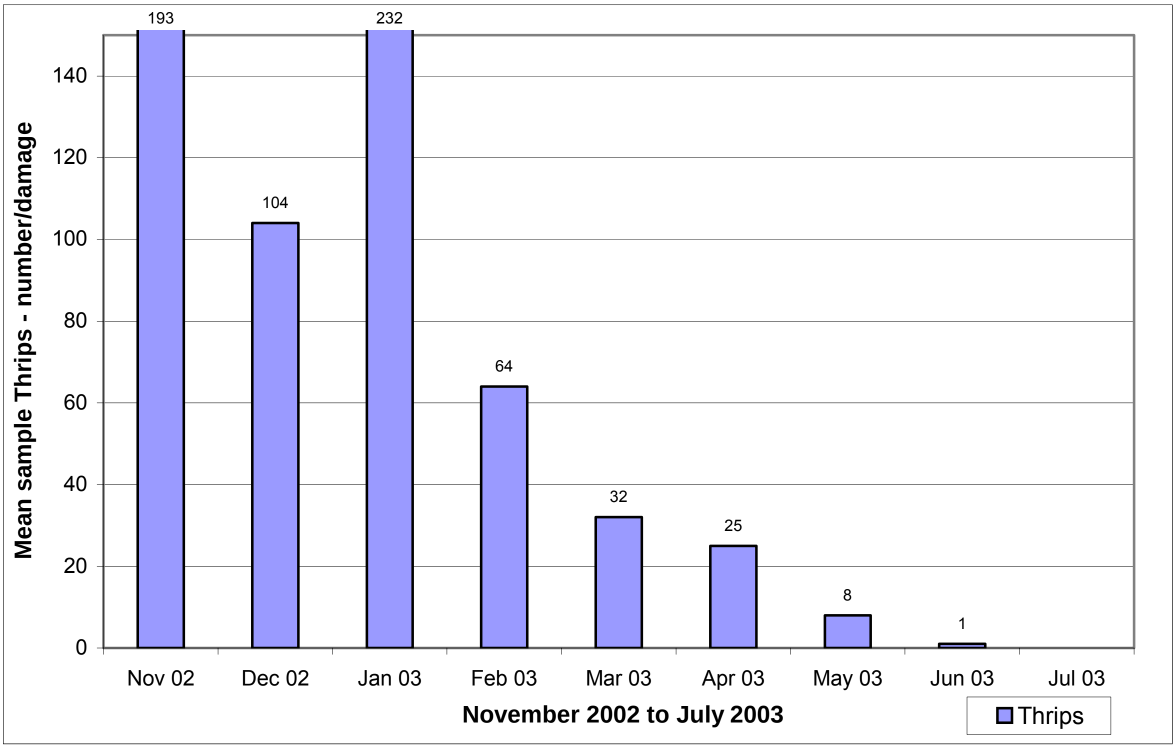


B

Fig 12. Beneficial species monitoring: Darlington Point, NSW
A. All beneficial species excluding small wasps
B. Small wasps

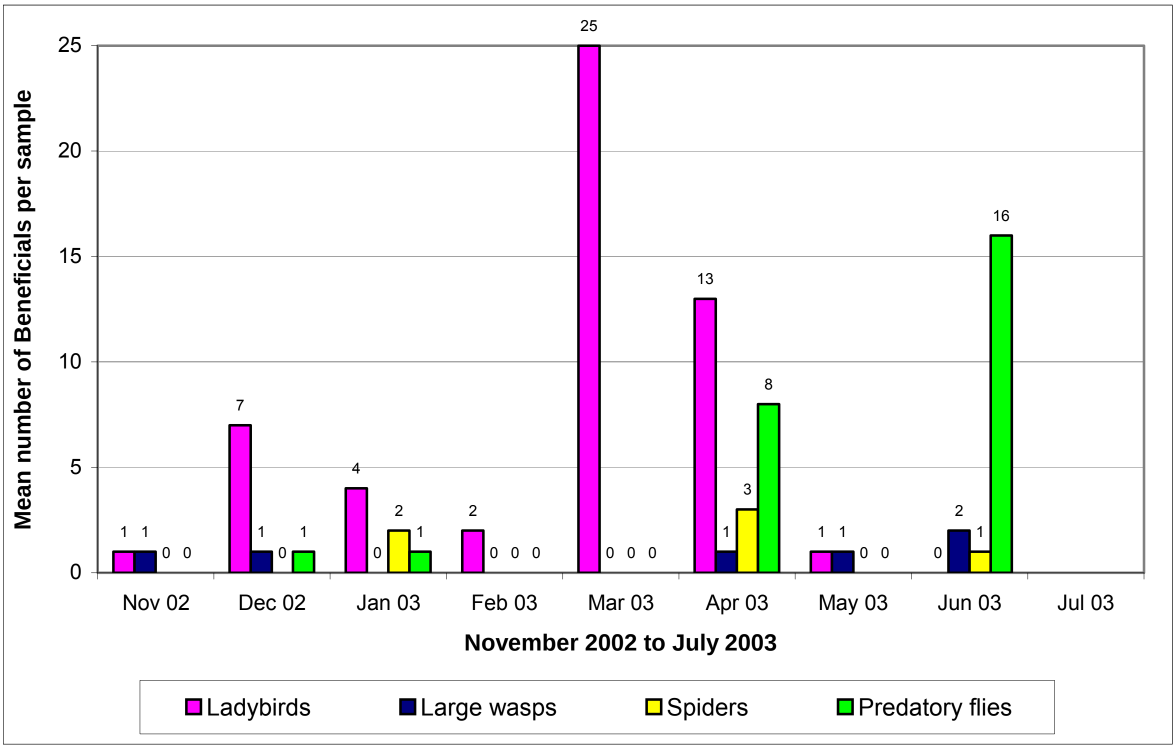


A

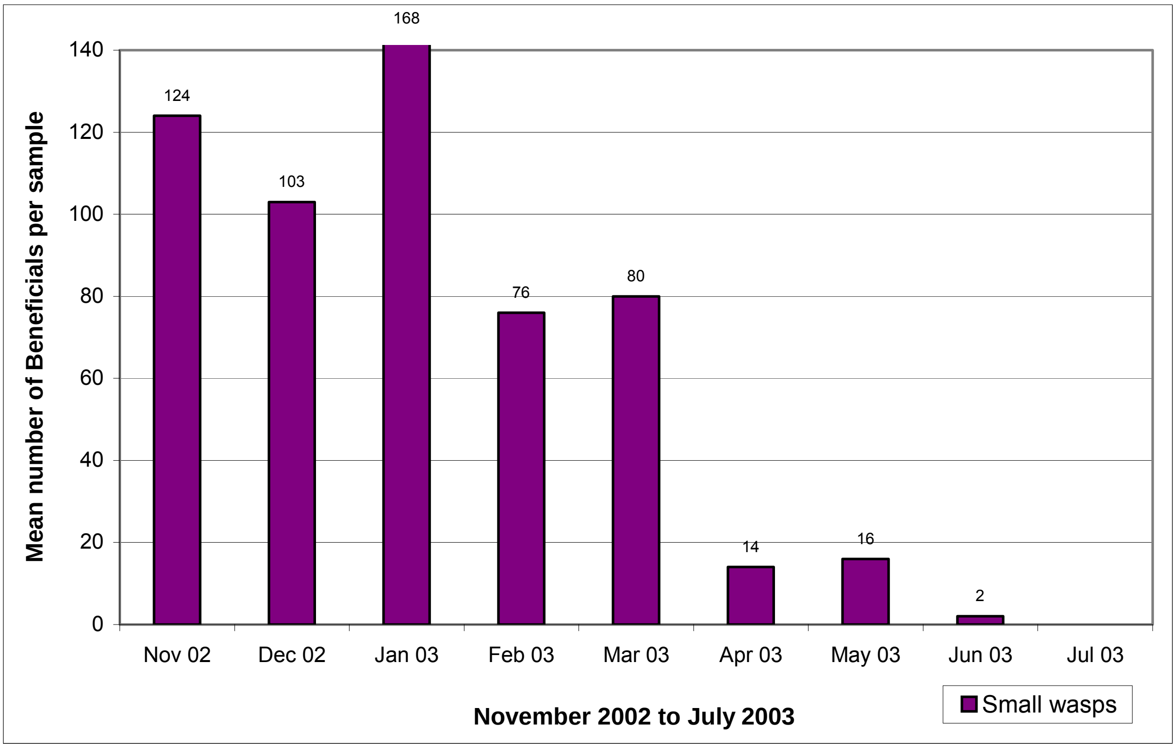


B

Fig 13. Pest species monitoring: Rylstone, NSW
A. All pest species excluding thrips
B. Thrips

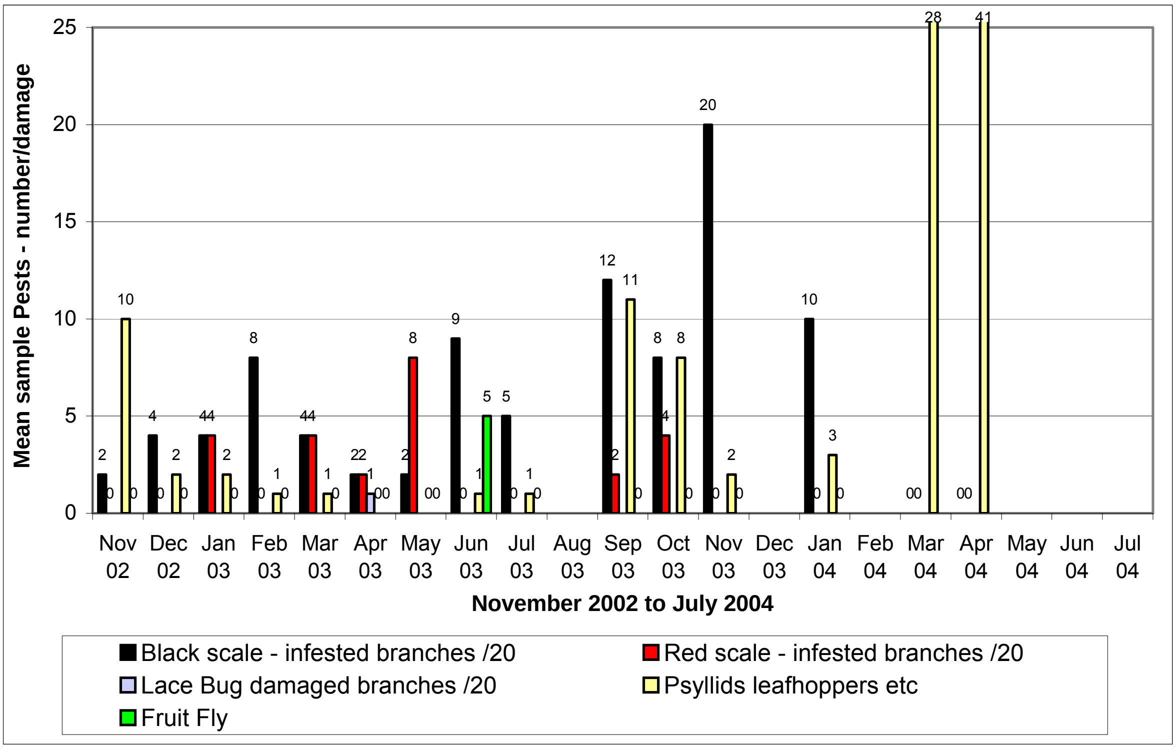


A

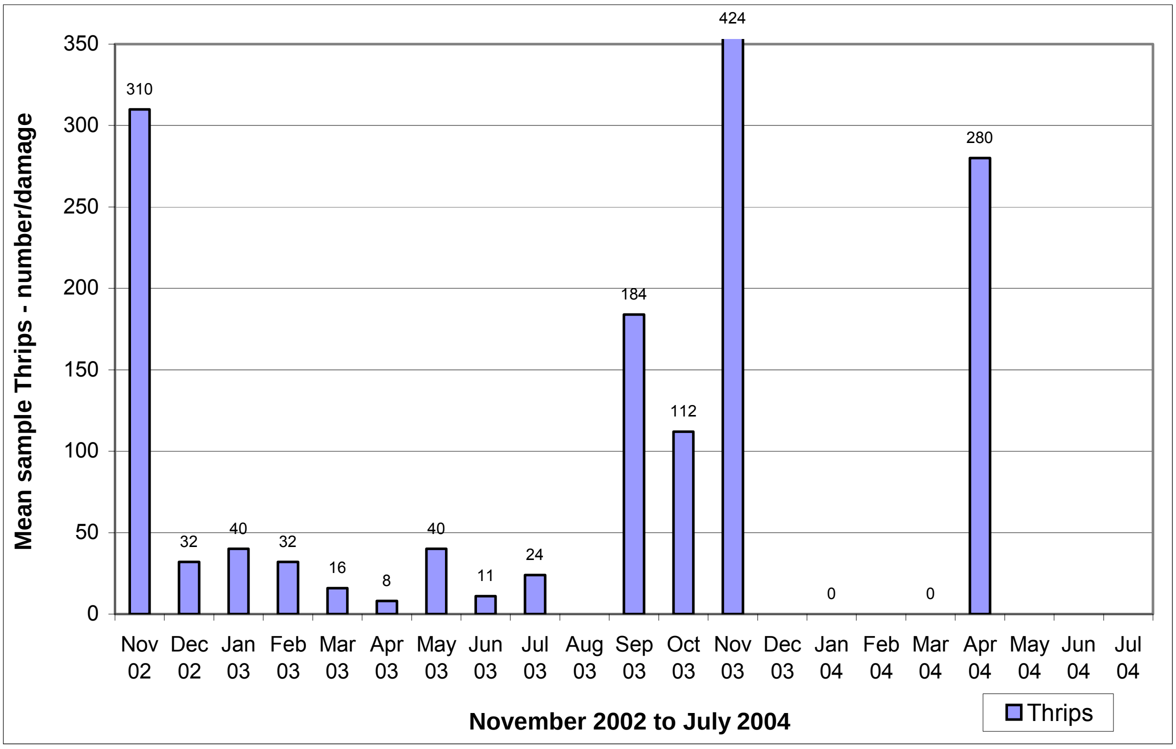


B

Fig 14. Beneficial species monitoring: Rylstone, NSW
A. All beneficial species excluding small wasps
B. Small wasps

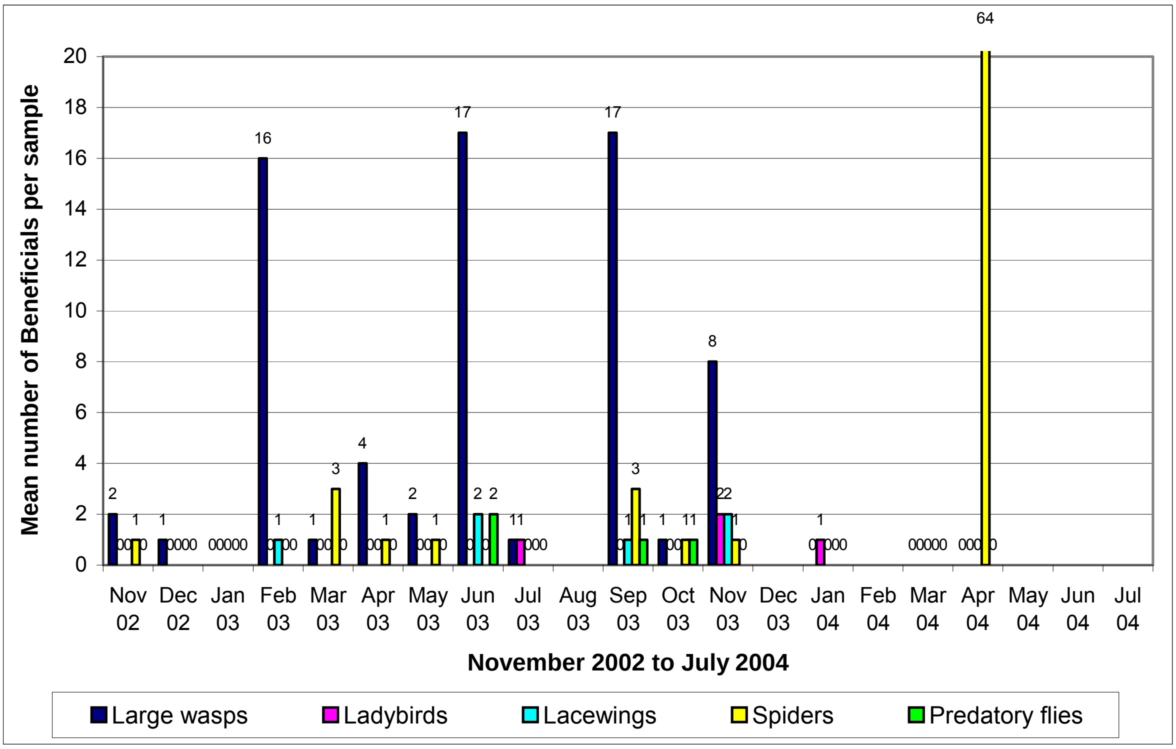


A

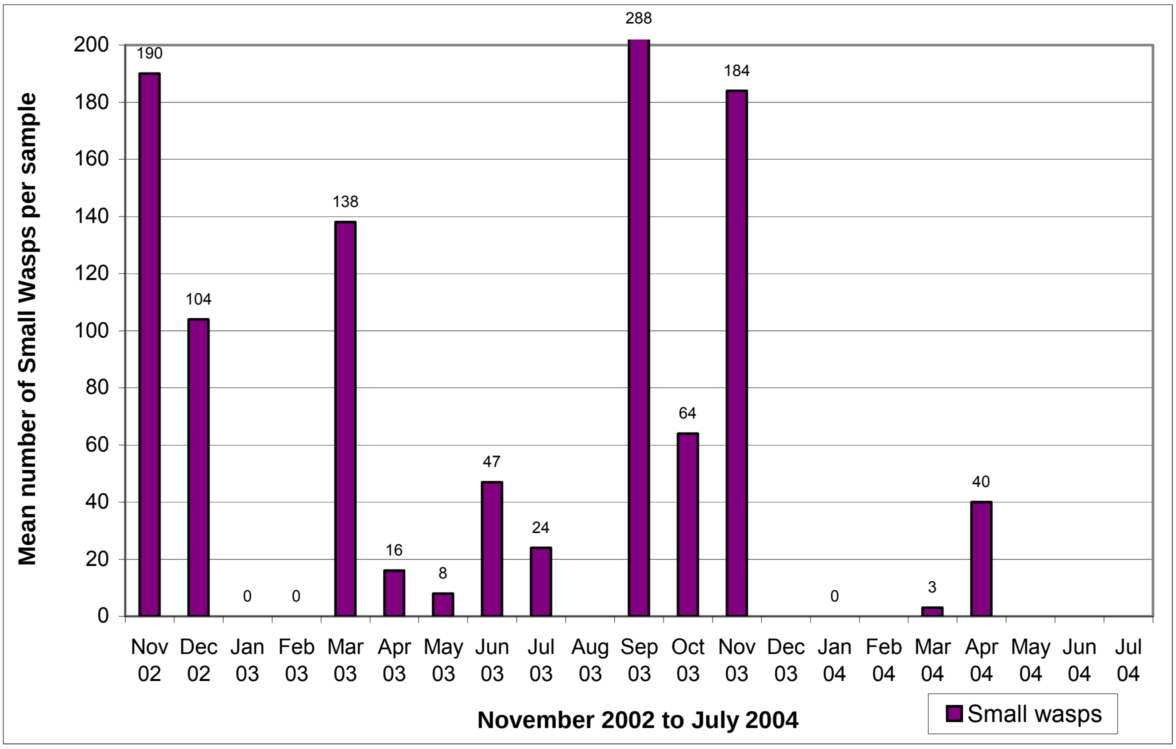


B

Fig 15. Pest species monitoring: Millmerran, QLD
A. All pest species excluding thrips
B. Thrips

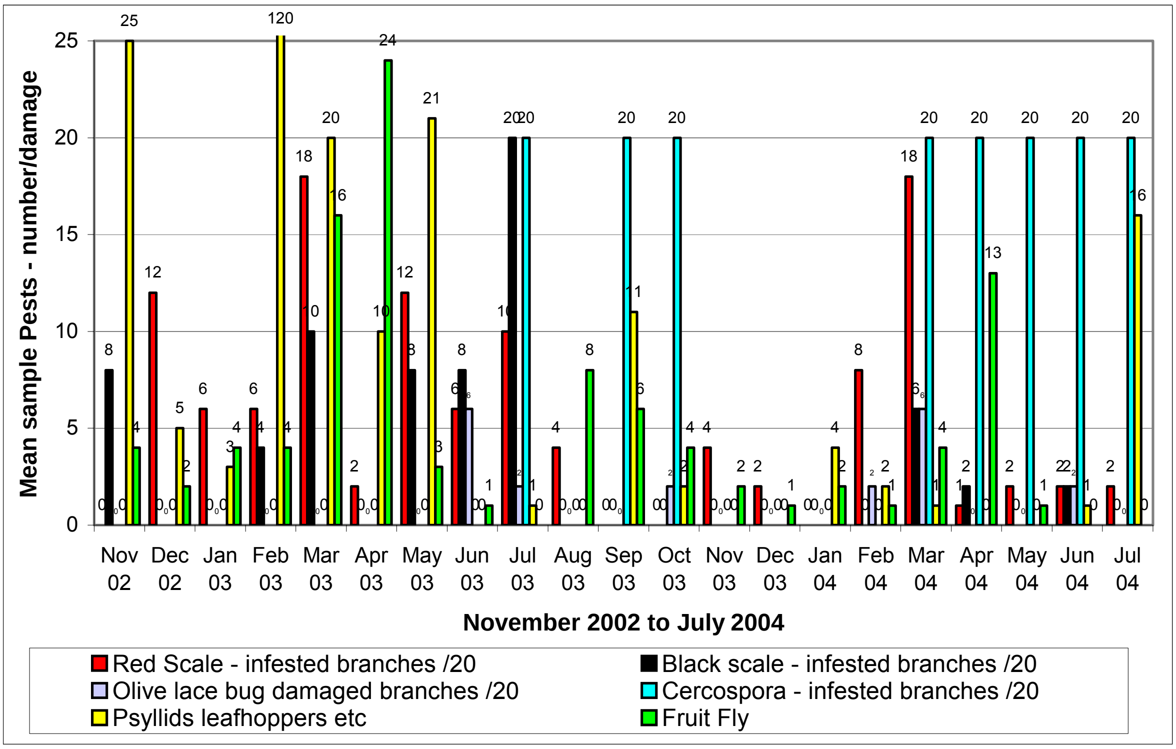


A

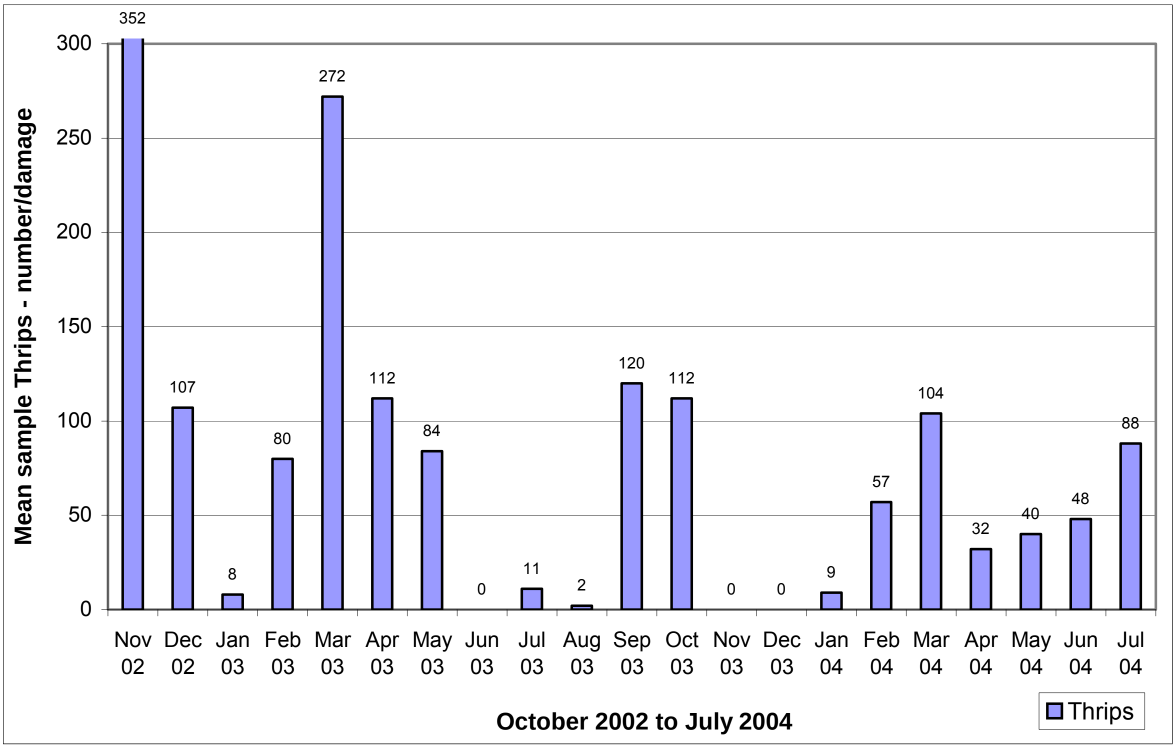


B

Fig 16. Beneficial species monitoring: Millmerran, QLD
A. All beneficial species excluding small wasps
B. Small wasps

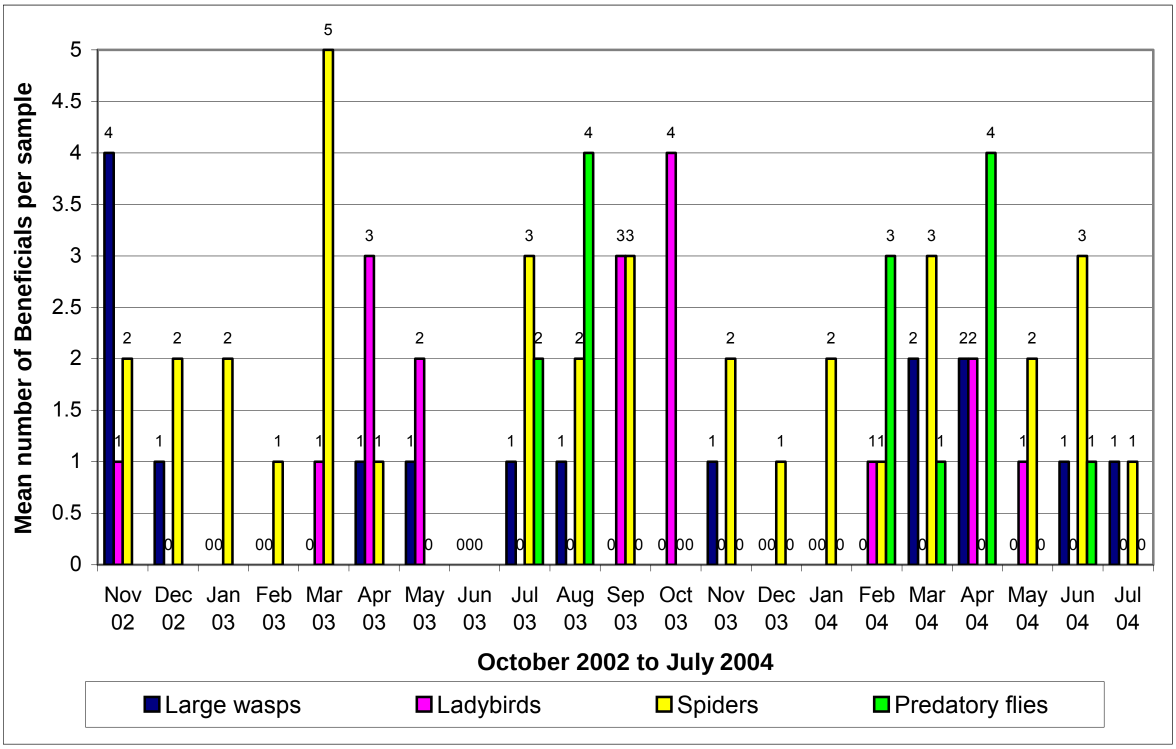


A

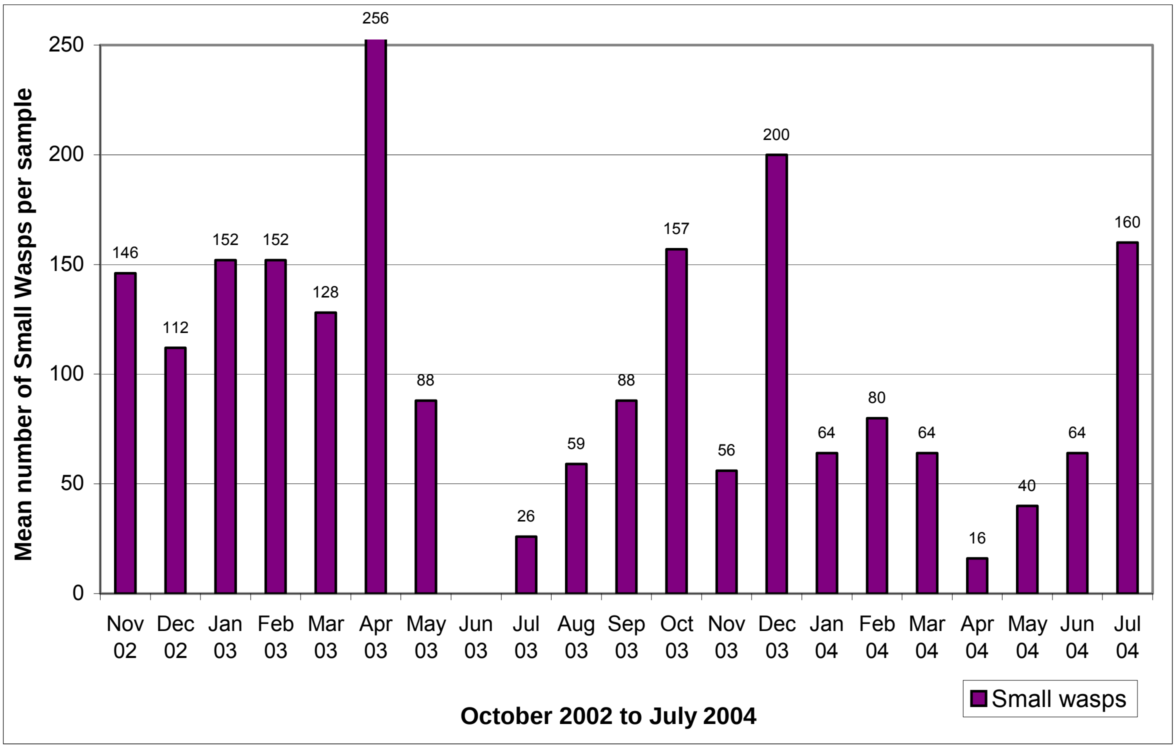


B

Fig 17. Pest species monitoring: Murgon, QLD
A. All pest species excluding thrips
B. Thrips



A



B

Fig 18. Beneficial species monitoring: Murgon, QLD
A. All beneficial species excluding small wasps
B. Small wasps