Phase II: Native vegetation to enhance biodiversity, beneficial insects and pest control in horticulture systems

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FINAL REPORT

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HAL Project VG06024

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This is the final report for VG06024 titled 'Phase II: Native vegetation to enhance biodiversity, beneficial insects and pest control in horticulture systems' which summarised the key findings and outlines plans for future research and industry adoption of integrating native vegetation in vegetable systems. This project was funded for one year, conducted and completed in collaboration with Anna Marcora, Mark Wade, Felix Bianchi all of CSIRO, Bronwyn Walsh, Samantha Heritage and Dave Carey all of DPI&F, and The Emericks and Andrew Johannson of Mulgowie Farms.

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MEDIA SUMMARY

With increasing pest problems, planned changes to land management legislation around water courses and continuing pressure from urban encroachment, an integrated approach to vegetable production and land management is required. Furthermore, trend forecasting is showing that consumers are becoming more conscious of environmental sustainability of food production. These trends combined with information on the crucial role of non-crop habitats (eg. fragments of remnant native vegetation) for maintaining pest control services are highlighting the importance of considering pest problems beyond the crop boundary. However, when discussing pest control and native vegetation with vegetable growers they frequently ask, 'why should I maintain / create areas of native vegetation – (how will it benefit me), and how do I know it won't add to my pest problems?'

Conducting extensive literature review, field experiments and grower survey, we answer these questions and show that:

- There are numerous species of native plants that pose low risk of creating pest problems and are suitable for integrating with vegetable pest management.
- Beneficial insects move from remnant vegetation into crops, some pests do as well, particularly when remnants are weedy.
- The majority of growers have a high regard for native vegetation, are interested in the concept of 'Revegetation by Design', but need guidelines, and demonstration to move forward.

These findings suggest that there are numerous species of native plants to use for revegetating weedy degraded areas on-farm, and that these plants will pose less of a risk for insect pest problems, particularly in comparison to weeds. Furthermore, remnant native vegetation can support pest control services and should be valued and maintained. Managing the edges to minimise weeds may reduce pest problems. Finally, linking vegetable production with environmental stewardship aligns with the demands of consumer expectation and possibly offers an opportunity to develop a marketing edge through product differentiation.

TECHNICAL SUMMARY

The Problem

In the Lockyer Valley, Queensland, vegetable production is concentrated along the alluvial flats of several creeks which contain some of the last remnants of native vegetation. There is wider recognition of the need to consider pest problems beyond the crop boundary, and the crucial role of non-crop habitats in agricultural landscapes.

Past work in QLD, VG05014, showed that beneficial predators and parasitoids were found on a wide range of native vegetation, with several species spending a lot of time in the edge habitat between native remnant vegetation and crops, and a jassid pest to be associated with exotic grasses.

Building on the findings of VG05014, this project aimed to answer the most frequently asked questions by growers when discussing native vegetation, 'why should I maintain / create areas of native vegetation – (how will it benefit me), and how do I know it won't add to my pest problems?' This work is a continuation of the Revegetation by Design concept.

The Project Science

- Literature review and risk assessment exploring when native vegetation is a risk for pests to vegetable crops in Australia.

- Field trials in two landscapes, one with < 1% remnant vegetation the other with >60% remnant vegetation, to determine whether beneficial insects and pests move from remnant vegetation (remnant and riparian remnant) into the crop.

- A survey to assess the perceptions and behaviours of growers towards integrating native vegetation and pest management practices in the Lockyer Valley, QLD.

- A proof-of-concept study to determine if existing mark-capture data can be used in spatially explicit models to predict the placement of refuges for beneficial insects in a landscape.

The Key Research Findings

- **Literature review and risk assessment revealed that:**

1. Of the 110 arthropod pests of vegetable crops, less than half are ranked as important and less than 20 are perceived as difficult to control. There are no generalizations about what makes for a pest of vegetable crops, for example, exotic versus native pests, their taxonomic group (i.e. beetles vs moths), and diet breadth.

2. By cross referencing the 110 pests with 453 host feeding records on native plants, risk estimates were generated for plant families used in revegetation programs. For QLD and SA, approximately 37 native plant families are low risk for pest management in vegetable production, and good for revegetation.

•Field trials showed that:

1. Edge habitat between native remnant vegetation and crops supports many species of insect predators and there is a net immigration from remnant vegetation to crops. This is particularly true for the edge habitat between riparian remnant vegetation and crops. This trend was present in both landscapes, but significant in the landscapes with a high percentage of remnant (eg. Mulgowie), not the low percentage of remnant (eg. Gatton).

2. Some pest species also like the riparian remnant vegetation, and there is a net immigration from riparian vegetation into the crop. This is particularly true for jassids that use the exotic grass that is abundant around field and remnant edges.

•Grower survey found:

1. The majority of growers were interested in the concept of using native vegetation for pest management whether they already had native vegetation on their farm or not.

2. Most growers have an average or high regard for native vegetation for a range of benefits including erosion prevention and windbreaks. They also recognise drawbacks such as it takes water and room.

3. In order to move forward with revegetation by design, growers identified the need for demonstration and guidelines.

•Proof-of-concept paper showed we can:

1. predict the time to colonisation from a refuge to a crop of a biological control agent using existing data and spatially explicit modelling. However the type of dispersal kernel used is critical. This underscores the importance of collecting mark-capture data with modelling in mind.

Extension Highlights

- There was excellent attendance at the workshop, and survey results show that participants now think differently about native vegetation and are more likely to revegetate on their properties.

Recommendations

The Key recommendations to continue moving towards integration and adoption of revegetation by design as part of an IPM strategy include:

1. determine the response time of beneficial insects to pests in cropping systems near remnant vegetation and the scale of changes in vegetation management to delay pest colonisation. This will be achieved in the newly funded project VG07040.
2. Create decision-support tools to help growers adopt information about native plants that are low risk for their production system, plus capturing additional benefits such as drought and fire tolerant. This activity will require additional funds.
3. Provide funding for adoption and communication activities to support the findings of VG06024 and the new project VG07040.

BACKGROUND

The Lockyer/ Fassifern region in SEQ QLD is number one in the value of vegetables produced in QLD, and has seen a 72% increase in value of vegetables produced over that past 15 years. With increasing pests, planned changes to land management legislation around water courses and continuing pressure from urban encroachment, an integrated approach to vegetable production and land management is required. Furthermore, trend forecasting is showing that consumers are becoming more conscious of environmental sustainability of production. These trends combined with our previous work (VG05014), results from this study and studies from around the globe are highlighting the benefits from managing agricultural landscapes to capture Ecosystem Services of pest control.

Revegetation by Design is an environmentally sound pest management strategy. It is a component of Integrated Pest Management (IPM) and involves using native vegetation with vegetable production systems with a focus on: 1) replacing weeds that harbour pests and diseases with species of native plants that do not, and 2) providing incentive for growers to maintain existing remnant vegetation, which provides ecosystem services such as habitat for natural enemies of pests, pollinators, biodiversity and carbon sequestration.

As we previously demonstrated in VG05014 most species of pests and natural enemies are multi-habitat users, and there appears to be species-specific preference for different habitats. This tells us that pest control strategies need to be considered at the scale of the crop, the farm and the surrounding landscape. Furthermore, we've demonstrated that several pests of vegetable crops prefer weeds, eg. jassids on exotic grasses and thrips on broad-leaf weeds.

'Revegetation by Design' shows great promise as part of an IPM strategy. However, when considering integrating native vegetation with vegetable pest management and discussing this with growers, they often ask 'why should I maintain / create areas of native vegetation – (how will it benefit me), and how do I know it won't add to my pest problems?'

In VG06024, we answered these questions by: 1) conducting a desk-top review of current literature asking, "when is native vegetation a risk for pests and diseases to vegetable production in Australia?" 2) determining if beneficial and pest insects are moving into the crop from native remnants, and 3) determining the potential for the Lockyer Valley community to change perceptions and behaviours about integrating native vegetation and pest management as a potential best management practice.

I.
When is native vegetation a risk for pests and diseases to vegetable crops in Australia?

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Introduction

Before native vegetation can become part of an integrated pest management and conservation strategy, the risks need to be identified and management strategies developed. One of the top risks would be increasing pest and disease of crops – that is, potentially exacerbating pest problems. This could constitute changes in pest status − minor pests become major, and incidental pests become minor − and the incidence and severity of each outbreak.

To determine when native vegetation is a risk for pests and diseases of vegetable we conducted a literature review and risk assessment. Given that it is unclear what key factors would make ‘Revegetation by Design’ a risky strategy, we began by asking ‘who are the pests of vegetable crops’, then used a hypothesis driven approach to investigate factors such as whether vegetable pests are exotic or native, specialists (those that feed on a single plant family) or generalists (those that eat everything), difficult or easy to control. From these results we developed a risk estimate for native plants; those that pose negligible, low, moderate or high risk. This information can be used for progressing revegetation on-farm.

Materials & Methods

Literature Survey

We identified vegetable crops cultivated in Australia, along with their suite of arthropod pests, from extension/outreach material principally aimed at growers (i.e., Hely et al. 1982; Swaine et al. 1991; Hargreaves 1992). A pest constituted a species of insect or mite that could either as an immature and/or adult: (i) fed on the plant and caused damage, (ii) become a vector of a plant pathogen, or (iii) become a contaminant through presence alone.

Extension/outreach material was again used, along with scientific reviews and original research articles in referred journals, to compile an extensive list of potential host plant associations for each arthropod pest (see reference section which includes ca. 230 references). All species of plants were considered − not only vegetables. Arthropod-host plant associations were based on records of field sampling, feeding observations, and successful laboratory rearing involving the adult or (preferably) immature life stages.

Consultant Survey

To rank the 110 pests, from important and difficult to control (5) to unimportant (0), twenty professional agronomists and independent crop consultants were interviewed to record their perceptions on the important species of arthropod pests of vegetables. This level of ‘expert opinion’ fulfilled four purposes: (i) to quantitatively rate the importance of arthropods pests of vegetables, and develop a ‘difficult to control’ score, (ii) to enable the most important species of pests to be flagged for further scrutiny, (iii) to ‘ground truth' or uncover additional species of arthropod pests potentially absent from the earlier compendium, and (iv) to compare the suite of arthropod pests in two key vegetable growing states of Australia, namely Queensland (the Lockyer and Fassifern Valleys) and South Australia (the Northern Adelaide Plains and Murray Mallee district).

Each participant agreed to be separately interviewed on a voluntarily basis at a mutually convenient time by telephone. Based on their knowledge or personal experience, and without assistance, each participant was asked to: (i) nominate the species of arthropod pests of vegetables present, (ii) rate each species from 0 to 5, with 0 being not important at all and five being the most important, (iii) list the vegetable crops affected by each pest, and (iv) provided a brief rationale for each species being considered a pest. The rating for each pest species pertained to an aggregate response across all crops mentioned, rather than a separate rating for the each crop, and a 'difficult to control' (DtC) score was generated. Finally, for all pests they were asked to: (v) indicate how the pest status of each had changed in the period they had worked in that particular region (i.e., greater importance, static, or lesser), (vi) list any species of arthropod that today is no longer considered a problem, but which was previously a pest, and (vii) nominate other consultants to contact. An initial list of potential participants was provided by extension officers employed by government agencies in each state, along with one of the authors' (N.A.S.) contacts. For brevity only the results for sections (i), (ii) and (vi) are reported below.

Risk Estimate

The risk of native plants increasing vegetable pests was assessed by considering the likelihood and consequences of 'difficult to control' pests occurring on native plants. Arthropod-host plant associations were cross referenced with arrays of Australian native plants as proposed by various government and non-government agencies in 'greening' (i.e., restoration) programmes or 'bush food' production (Greening Australia, ENERGEX, Rural Industries Research and Development Corporation, South Australian Research and Development Institute). A risk estimate was generated by summing the 'difficult to control' score for all plants with a pest recorded. For example, the total DtC score for QLD is 48 and for SA is 27. The risk estimate is a percentage of the total score; < 2% = negligible, 2-20% = low, 21-50% = moderate, > 50% = high.

Statistical Analysis

A series of Chi-squared goodness of fit tests for equal proportions were used to determine if the number of pests represented by each order was equal (SAS FREQ procedure, SAS release 8.2; SAS Institute, 1999). Two-way contingency table tests with a Chi-squared distribution (SAS FREQ procedure) were used to analyse how the frequencies of Australian native and non-native pests varied between the different orders they were represented by. Categorical analysis was more appropriate than analysis of variance because the data type (counts rather than continuous variables) and because of the underlying distribution (binomial rather than normal). Lastly, a series of non-parametric tests (Wilcoxon-Mann-Whitney or Kruskal-Wallis; SAS NPAR1WAY procedure) were used to determine if: (i) the number of important pest species varied between the states of Queensland and South Australia, (ii) the overall rating assigned to these important species varied between states, (iii) the ratings assigned to these important species varied between pest species within each state; and (iv) the rating assigned to each individual important pest species varied between states at a species level. Only those pests that were rated by at least one of the 20 consultants as being greater than zero on a scale of importance were analysed above. No distinction was made between the identity of species listed of their own free will and those additional species suggested by the interviewer.

Results

Some 48 vegetable crops from 16 plant families have been commercially cultivated in Australia (Appendix 1). The vegetables included traditional vegetables, such as cabbage, lettuce and tomatoes, various Chinese vegetables and a Australian native, Warrigal greens. Herbs were not included and different varieties of rhubarb, okra, and hot chilies were treated as one crop. The vegetables were collectively host to 110 species of arthropod pests (Appendix 2), comprising 41 Australian native and 69 exotic arthropods. Overall, a total of 882 or 16.7% of the 5280 (110 arthropods × 48 vegetables) possible arthropod-vegetable associations were recorded. Thus, vegetable crops shared only some − but not all − of the 110 species of arthropod pests. Indeed, the number of arthropod pests varied significantly between crops (goodness of fit test: Pearson χ^2 = 536.12, P <0.0001, df = 47, n = 882), with a median of 19 arthropod pests per crop (range 1-59) (Table 1).

Table 1. Number of pests for each taxonomic plant family of vegetable crops.

Plant family	***Vegetable crop examples***	***Total no. pests***
Aizoaceae	Warrigal greens	1
Amaranthaceae	Chinese spinach	1
Polygonaceae	rhubarb	2
Malvaceae	okra	5
Liliaceae	asparagus	7
Zingiberaceae	ginger	9
Alliaceae	onion, garlic, leeks	13
Convolvulaceae	sweet potato	15
Poaceae	sweet corn	23
Chenopodiaceae	beetroot, English spinach, silver beet	27
Asteraceae	lettuce	30
Apiaceae	carrot, celery, parsnip	33
Cucurbitaceae	cucurbit	38
Brassicaceae	brassica	40
Fabaceae	French bean, runner bean, snake bean, pea	48
Solanaceae	capsicum, chilli, eggplant, potato, tomato	59

However, the relative numbers of Australian native and exotic arthropod pests was consistent across crops (contingency test: Pearson χ^2 = 39.84, P = 0.7612, df = 47, n = 882).

The 110 species of arthropod pests were represented by 11 orders, though the number of species in each was not equal (median of 7, range 1-29; goodness of fit test: Pearson χ^2 = 93.60, P <0.0001, df = 10, n = 110). However, the relative numbers of Australian native and exotic arthropod pests varied between orders (contingency test: Pearson χ^2 = 30.90, P = 0.0006, df = 10, n = 110) (Table 2). For instance, the Heteroptera (Hemiptera) were mostly native, while Acarina, Sternorryncha (Hemiptera), and Thysanoptera were mostly exotic, and Coleoptera, Lepidoptera, and Orthoptera were generally intermediate (Table 2).

Table 2. Identity (by taxonomic order) and origin of invertebrate pests of vegetables

Order	Common name	Total no. pests	No. native	No. exotic	Prop. native
Acarina	mites	6	0	6	0
Coleoptera	beetles	25	12	13	0.48
Dermaptera	earwigs	1	0	1	0
Diptera	flies	10	3	7	0.30
Hemiptera: Auchenorrhyncha	jassids	2	1	1	0.50
Hemiptera: Heteroptera	true bugs	9	8	1	0.89
Hemiptera: Sternorryncha	aphids, whiteflies	17	0	17	0
Hymenoptera	wasps	1	0	1	0
Lepidoptera	moths	29	14	15	0.48
Orthoptera	crickets	3	2	1	0.67
Thysanoptera	thrips	7	1	6	0.14
Total		**110**	**41**	**69**	**0.37**

The diet breadth of the 110 pests across vegetable crops indicated that 45% feed on vegetables from a single plant family (eg. only vegetables in the Brassica vegetable family) or are diet specialists *(i.e.,* fed on plants from only one family). However, 55% feed on vegetable plants from more than one plant family (Figure 1).

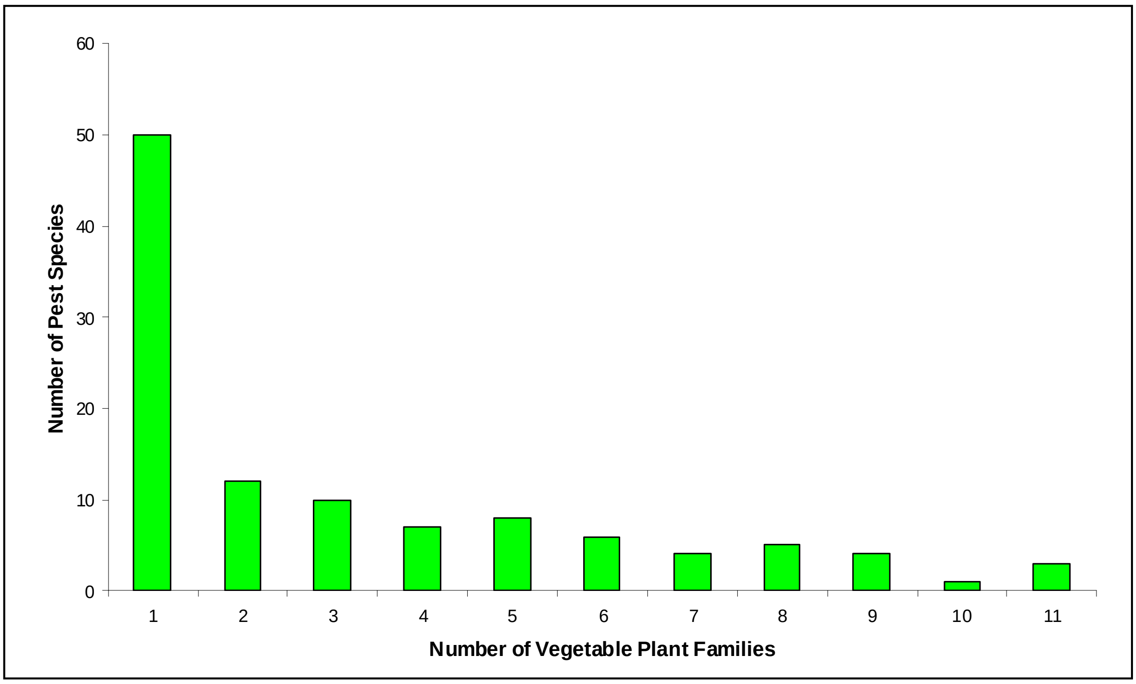

Figure 1. The number of pest species that feed on the number of plant families of vegetable crops.

However, there was no statistical variation in the distribution of diet breadths of native and exotic pests feeding only on vegetable crops (Table 3; *G* = 0.414, *P* = 0.889, df = 3, n=110).

Table 3. Number of Australian native and exotic arthropod vegetable pests with specific feeding breadths on vegetable crops.

No. host plants	No. pests			Proportion	
	Total arthropods	Native arthropods	Exotic arthropods	Native arthropods	Exotic arthropods
1 family	50	17	33	.41	.48
2-3 families	22	11	11	.27	.16
4-6 families	21	7	14	.17	.20
7+ families	17	6	11	.15	.16
Total	110	41	69	1	1

A broader search of the literature for the 110 arthropod pests of vegetables revealed a total of 1271 host plants, vegetable or otherwise (weeds, exotic ornamentals and native plants), comprised of 453 Australian native and 818 non-native species from 146 plant families. This resulted in a total of 3703 or 2.6% of the 139,810 (110 arthropods × 1271 plants) possible arthropod-host plant associations. In other words, either relatively few plants were hosts of arthropod pests of vegetables or just as likely, surveys for vegetable pests on weeds and native plants have not been conducted.

Of the 41 species of native arthropod pests, it initially appeared that relatively fewer were diet specialists (i.e., fed on plants from only one family) and conversely relatively more were broad generalists (i.e., fed on plants from seven or more families) compared with the 69 species of exotic pests (Tables 4). However, there was no statistical variation in the distribution of diet breadths of native and exotic pests, regardless of whether the counts for strictly monophagous species (i.e., fed on only one species or plants from one genus) were duplicated in the analyses as separate categories or encompassed only within the one family category (contingency tests, separate categories: Pearson χ^2 = 5.15, *P* = 0.3982, df = 5, n = 125; together: Pearson χ^2 = 3.65, *P* = 0.3020, df = 3, n = 110) (Table 4).

Table 4. Number of Australian native and exotic arthropod vegetable pests with specific feeding breadths. # denotes that the total excludes counts for arthropods that fed on a single species or genus of plant, because these counts are included in the one family tally.

No. host plants	No. pests			Proportion	
	Total arthropods	Native arthropods	Exotic arthropods	Native arthropods	Exotic arthropods
1 species#	5	3	2	0.07	0.03
1 genus#	10	5	5	0.12	0.07
1 family	29	8	21	0.20	0.30
2-3 families	13	3	10	0.07	0.14
4-6 families	16	7	9	0.17	0.13
7+ families	52	23	29	0.56	0.42
Total*	110	41	69	1	1

The 20 most ubiquitous feeders (those that can eat nearly every type of plant) of any host plant species were represented by the orders Hemiptera (9 species; 2 aleyrodids, 3 aphids, 5 Heteroptera), Thysanoptera (4), Lepidoptera (3), Acarina (2) and Diptera (1) (Table 5).

Table 5. Identity of 20 arthropod pests that are the most ubiquitous feeders of any host plant species (vegetables and non-vegetables). * denotes exotic species.

Order	Family	Species	No. host families	No. host spp.
Thysanoptera	Thripidae	*Thrips imaginis, plague thrips*	70	219
Hemiptera: Sternorryncha	Aphididae	**Aphis gossypii,* cotton aphid	53	151
Diptera	Tephritidae	*Bactrocera tryoni*, Queensland fruit fly	50	244
Lepidoptera	Noctuidae	*Helicoverpa punctigera*, native budworm	43	214
Thysanoptera	Thripidae	**Frankliniella schultzei,* tomato thrips	41	142
Thysanoptera	Thripidae	**Thrips tabaci,* onion thrips	40	142
Acarina	Tetranychidae	**Tetranychus urticae,* twospotted spider mite	35	106
Lepidoptera	Noctuidae	*Helicoverpa armigera,* cotton bollworm	34	125
Hemiptera: Sternorryncha	Aleyrodidae	**Aleurodicus dispersus,* spiralling whitefly	31	75
Hemiptera: Heteroptera	Miridae	*Creontiades dilutus*, green mirid	30	109
Lepidoptera	Tortricidae	*Epiphyas postvittana,* light brown apple moth	30	78
Hemiptera: Heteroptera	Pentatomidae	**Nezara viridula,* green vegetable bug	23	95
Hemiptera: Heteroptera	Miridae	*Campylomma liebnechti,* apple dimpling bug	23	63
Hemiptera: Heteroptera	Lygaeidae	*Nysius vinitor,* Rutherglen bug	21	85
Thysanoptera	Thripidae	**Frankliniella occidentalis,* western flower thrips	21	62
Hemiptera: Heteroptera	Pyrrhocoridae	*Dindymus versicolor,* harlequin bug	20	60
Hemiptera: Sternorryncha	Aleyrodidae	**Trialeurodes vaporariorum*, greenhouse whitefly	19	51
Hemiptera: Sternorryncha	Aphididae	**Aphis craccivora,* cowpea aphid	18	60
Acarina	Tetranychidae	**Tetranychus ludeni,* bean spider mite	17	47
Hemiptera: Sternorryncha	Aphididae	**Myzus persicae,* green peach aphid	16	70

Similarly, the 20 most ubiquitous feeders of vegetables were represented by the orders Lepidoptera (7), Hemiptera (5; 2 aphids, 3 Heteroptera), Acarina (3), Thysanoptera (3), Coleoptera (1), and Diptera (1) (Table 5). However, 11 of the 20 species appeared in both tables 5 and 6, which indicate that arthropod pests that attack a wide range of vegetable crops also generally attack a lot of other plants too.

Table 6. Identity of 20 arthropod pests that are the most ubiquitous feeders of vegetable crops. * denotes exotic species.

Order	Family	Species	No. vegetable host families	No. vegetable host species
Hemiptera: Sternorryncha	Aphididae	**Aphis gossypii*, cotton aphid	11	23
Lepidoptera	Noctuidae	*Agrotis infusa*, common cutworm	11	29
Lepidoptera	Noctuidae	**Agrotis ipsilon*, black cutworm	11	29
Lepidoptera	Noctuidae	*Agrotis munda*, brown cutworm	11	29
Lepidoptera	Noctuidae	**Helicoverpa armigera*, cotton bollworm	10	18
Thysanoptera	Thripidae	**Thrips palmi*, melon thrips	9	20
Hemiptera: Sternorryncha	Aphididae	**Myzus persicae*, green peach aphid	9	21
Lepidoptera	Noctuidae	*Helicoverpa punctigera*, native budworm	9	22
Coleoptera	Curculionidae	**Listroderes difficilis*, vegetable weevil	8	20
Hemiptera: Heteroptera	Miridae	*Creontiades dilutus*, green mirid	8	20
Hemiptera: Heteroptera	Lygaeidae	*Nysius vinitor*, Rutherglen bug	8	24
Thysanoptera	Thripidae	*Thrips imaginis*, plague thrips	7	13
Acarina	Tetranychidae	**Tetranychus ludeni*, bean spider mite	7	20
Diptera	Anthomyiidae	**Delia platura*, onion maggot	7	20
Acarina	Tetranychidae	**Tetranychus urticae*, twospotted spider mite	7	21
Hemiptera: Heteroptera	Pentatomidae	**Nezara viridula*, green vegetable bug	7	22
Thysanoptera	Thripidae	**Thrips tabaci*, onion thrips	7	22
Lepidoptera	Noctuidae	*Chrysodeixis eriosoma*, green looper	6	11
Lepidoptera	Noctuidae	**Spodoptera litura*, cluster caterpillar	6	14
Acarina	Penthaleidae	**Halotydeus destructor*, red-legged earth mite	6	19

The 10 arthropod pests ranked the most important by the authors again resembled the ordinal composition of the above: Hemiptera (4 species; 1 aleyrodid, 2 aphids, 1 cicadellid), Leidoptera (3), Thysanoptera (2), Coleoptera (1) (Table 6). Nevertheless, only four species were common to both Tables 5 and 7 (i.e., *Frankliniella occidentalis, Helicoverpa armigera, Myzus persicae, Thrips tabaci*), and three common to both Tables 6 and 7 (i.e., as above apart from the former). Thus, the most important arthropod pests of vegetables are not necessarily those that also attack a wide range of vegetable crops and other plants. In other words, pest status and diet breadth are not synonymous.

Table 7. Identity of 10 arthropod pests ranked by authors in order of importance. Also shown is the host range of these species. *exotic species

Rank	Order	Family	Species	No. host families	No. host spp.	No. veg. host families	No. veg. host spp
1	Lepidoptera	Noctuidae	*Helicoverpa armigera,* cotton bollworm	34	125	10	18
2	Hemiptera: Sternorryncha	Aphididae	**Myzus persicae,* green peach aphid	16	70	9	21
3	Thysanoptera	Thripidae	**Thrips tabaci,* onion thrips	40	142	7	22
4	Hemiptera: Sternorryncha	Aleyrodidae	**Bemisia tabaci* biotype B, silverleaf whitefly	14	52	5	12
5	Thysanoptera	Thripidae	**Frankliniella occidentalis,* western flower thrips	21	62	3	4
6	Hemiptera: Auchen.	Cicadellidae	*Cicadulina bimaculata*, maize leafhopper	8	13	2	2
7	Coleoptera	Curculionidae	**Cylas formicarius* var. *elegantulus*, sweet potato weevil	4	21	2	2
8	Hemiptera: Sternorryncha	Aphididae	**Nasonovia ribisnigri*, lettuce aphid	6	18	1	1
9	Lepidoptera	Pyralidae	**Crocidolomia pavonana*, cabbage cluster caterpillar	2	8	1	4
10	Lepidoptera	Plutellidae	**Plutella xylostella*, cabbage moth	1	16	1	7

Twenty professional agronomists and independent crop consultants provided their perceptions of important species of arthropod pests of vegetables. The consultants together listed 49 of the 110 arthropod pests as being at least partly important (i.e., ranked greater than 0 at least once); in QLD and SA, 39 and 30 species, respectively (Tables 8 and 9).

Table 8. Rank order for the top 10 important pest species in QLD.

Order	Family	Species	Average score	SE
Lepidoptera	Noctuidae	*Helicoverpa armigera*	4.32	0.3
Lepidoptera	Noctuidae	*Helicoverpa punctigera*	4.02	0.52
Thysanoptera	Thripidae	**Frankliniella occidentalis*	3.75	0.32
Thysanoptera	Thripidae	**Thrips tabaci*	3.15	0.46
Lepidoptera	Pyralidae	*Hellula hydralis*	2.9	0.67
Lepidoptera	Plutellidae	**Plutella xylostella*	2.7	0.52
Hemiptera: Sternorryncha	Aleyrodidae	**Bemisia tabaci biotype B*	2.55	0.36
Lepidoptera	Pyralidae	*Crocidolomia pavonana*	2.4	0.57
Hemiptera: Sternorryncha	Aphididae	**Myzus persicae*	2.15	0.33
Hemiptera: Auchenorrhyncha	Cicadellidae	*Cicadulina bimaculata*	1.55	0.5

Table 9. Rank order of top 10 important pest of SA.

Order	Family	Species	Average score	SE
Thysanoptera	Thripidae	**Thrips tabaci*	3	0.6
Thysanoptera	Thripidae	**Frankliniella occidentalis*	2.8	0.77
Lepidoptera	Plutellidae	**Plutella xylostella*	2.55	0.72
Hemiptera: Sternorryncha	Aphididae	**Myzus persicae*	2.5	0.38
Hemiptera: Sternorryncha	Aleyrodidae	**Trialeurodes vaporariorum*	2.35	0.66
Acarina	Tetranychidae	**Tetranychus urticae*	1.85	0.67
Hemiptera: Sternorryncha	Aphididae	**Macrosiphum euphorbiae*	1.1	0.57
Lepidoptera	Noctuidae	*Helicoverpa armigera*	1.1	0.55
Hemiptera: Heteroptera	Lygaeidae	*Nysius vinitor*	0.9	0.5
Thysanoptera	Thripidae	*Thrips imaginis*	0.9	0.6

Of the 39 identified pests of QLD, 19 are unique to QLD, and of the 30 identified pests of SA, 10 are unique to SA. The initial impressions of consultants found that Queensland was host to a significantly higher number of at least partly important pests compared with South Australia (Wilcoxon two-sample test, W statistic = 137, z = 2.41, two-sided P = 0.0161).

The two states also differed in the consultants' ratings of pest importance, with the 49 pests as a whole being rated an average (± SE) of 0.98 (± 0.07) in Queensland and 0.55 (± 0.06) in South Australia (Wilcoxon two-sample test, W statistic = 225,585, z = 4.53, two-sided P < 0.0001). Consultants' ratings of pest importance varied significantly between the 49 species both within Queensland (Kruskal-Wallis test, χ^2 = 238.03, P < 0.0001, df = 48) and South Australia (Kruskal-Wallis test, χ^2 = 169.61, P < 0.0001, df = 48). For instance, the pest species rated as being the most important in Queensland were: *Helicoverpa armigera* (4.32 ± 0.30), *Helicoverpa punctigera* (4.02 ± 0.52), *Frankliniella occidentalis* (3.75 ± 0.32), *Thrips tabaci* (3.15 ± 0.46), and *Hellula* *hydralis* (2.9 ± 0. 76). Similarly, the most important pests in South Australia were: *T. tabaci* (3.00 ± 0.60), *F. occidentalis* (2.80 ± 0.77), *Plutella xylostella* (2.55 ± 0.72), *Myzus persicae* (2.50 ± 0.38), and *Trialeurodes vaporariorum* (2.35 ± 0.66) (Tables 8 and 9).

Of the 110 pests, 69 were not rated as important by the 20 crop agronomists. Therefore, these were considered to pose negligible risk and were not included in the formal analysis of risk estimates. The 41 remaining pests were cross referenced with the 453 native plant host records and their DtC score was summed for each pest species occurrence recorded on a native plant species within a particular plant family (i.e. Myrtaceae plant family). A single recorded event of either the presence of an adult or juvenile was counted. This approach is very conservative an errors on the side of caution – possibly too cautious. For QLD and SA, the total DtC score was 48 and 27, respectively, and the risk estimates were a percentage of the total; < 2% = negligible, 2-20% = low, 21-50% = moderate, > 50% = high. For QLD, of the 47 plant families with native plant species only 8 families received a risk estimate of moderate, the rest were either negligible or low (Table 10). Risk estimates were also generated for plant families with exotic plant species and of the 12 families, one was low, four moderate and the remaining seven were high risk (Table 11). For SA, nine families received a risk estimate of moderate, the rest were either negligible or low (Table 10). For exotic plant species in SA, one was low, three moderate and the remaining seven were high risk (Table 11).

Table 10. Risk estimates for plant families of native plants used in ‘greening activities’ in QLD and SA. ‘Negligible (no record)’ indicates that no data exists for a DtC pest on any plants in that family. ‘Negligible’ indicates that a pest was recorded and the percent of the total score was less than 2%.

Plant family	Risk Estimate Native Plants
Agavaceae	Negligible (no record)
Aizoaceae	Negligible (no record)
Anacardiaceae	Negligible
Apiaceae	Low
Apocynaceae	Negligible
Araucariaceae	Negligible (no record)
Arecaceae	Negligible (no record)
Asteliaceae	Negligible (no record)
Asteraceae	Moderate
Casuarinaceae	Negligible
Capparaceae	Negligible
Chenopodaceae	Moderate
Combretaceae	Negligible
Davidsoniaceae (Cunoniaceae)	Negligible
Dioscoreaceae	Negligible (no record)
Dracaenaceae	Negligible
Elaeocarpaceae	Negligible (no record)
Euphorbiaceae	Low
Fabaceae – Mimosaceae	Low – QLD / Moderate - SA
Fabaceae - non mimosaceae	Moderate
Haemodoraceae	Low
Lamiaceae	Low – QLD / Moderate - SA
Lauraceae	Negligible

Luzuriagaceae	Negligible (no record)
Malvaceae	Moderate – QLD / Low - SA
Melastomataceae	Negligible
Meliaceae	Low
Moraceae	Low
Myoporaceae	Low
Myrtaceae	Moderate
Phormiaceae	Negligible (no record)
Pittosporaceae	Negligible
Poaceae	Moderate
Podocarpaceae	Negligible (no record)
Proteaceae	Moderate
Rhamnaceae	Negligible (no record)
Rosaceae	Negligible (no record)
Rubiaceae	Negligible
Rutaceae	Low
Santalaceae	Negligible
Sapindaceae	Low
Sapotaceae	Negligible
Solanaceae	Moderate
Sterculiaceae	Negligible
Winteraceae	Negligible (no record)
Xanthorrhoeaceae	Low
Zingiberaceae	Negligible (no record)

Table 11. Risk estimates for plant families of exotic plants (ornamentals, weeds, crops) of QLD and SA.

Family	**Risk Estimate Exotic Plants**
Apiaceae	Moderate – QLD / High – SA
Asteraceae	High
Chenopodaceae	High
Cucurbitaceae	High
Euphorbiaceae	Moderate
Fabaceae – non Mimosaceae	High
Lamiaceae	Moderate
Malvaceae	High
Myrtaceae	Low
Poaceae	High
Rutaceae	Moderate
Solanaceae	High

Discussion

Several hypotheses were explored to identify generalisations about the risk of integrating native vegetation with vegetable crop production. There were no trends for country of origin (eg. native or exotic), arthropod taxonomic grouping (eg. mites versus lepidoptera), or diet specialization (eg. specialists versus generalists). Of the 110 pests ca. 40% are native and 60% exotic. All of the pest mites are exotics, but nearly all of the pest hemipteran are native; lepidopteran and coleopteran are ca. 50:50, native:exotic. Nearly half of the 110 pests feeding on vegetable crops are specialists and feed primarily within a single plant family, the other half are generalists and feed on two or more families. As more host records are included for pest feeding on weeds, ornamentals and native plants, the trend is towards a broader diet breadth.

Of the 110 vegetable pests, less than 50% were ranked as a pest by 20 consultants in QLD and SA. Less than 20 of the 110 pests received an average score of one or greater on a scale of 0-5 with 5 being the most difficult to control. The most important arthropod pests of vegetables are not necessarily those that also attack a wide range of vegetable crops and other plants. In other words, pest status and diet breadth are not synonymous. Also, the top five vegetable pests of QLD were somewhat different from the top pests of SA with only *T. tabaci* (onion thrips) and *F. occidentalis* (western flower thrips) being the same.

One of the greatest difficulties in assessing whether native plants will increase the incidence of vegetable pests is the limited availability of data. Although we found 1271 host records of the 110 vegetable pests, this represented only 2.6% of the arthropod-host plant associations. Either relatively few plants were hosts of arthropod pests of vegetables or just as likely, extensive surveys for vegetable pests on weeds and native plants have not been conducted. Therefore, we must caution that absence of evidence does not necessarily conclude evidence of absence. To try and overcome the lack of evidence we error on the side of caution. A single record of a DtC pest species was counted and all records were included, even if we could not tell whether the record was for the insect stage that feeds on the plant (eg. a moth versus grub). To further substantiate our current findings, in the future an additional analysis will be done to generate a risk estimate by considering the evolutionary relatedness of plant and insect species.

Thirty-seven plant families of native plants were estimated to pose negligible or low risk. Ten families were estimated to pose moderate risk for native plants, and moderate to high risk for the exotic plants. The exception to this trend is for the family Myrtaceae. Therefore, a conservative approach to revegetating with native plants is to avoid using native plant species from the same plant family as crops. The 37 low risk families can be matched with lists from local greening groups and Catchment Management Authorities to select local species. For example, in the Lockyer Valley, several species would be suitable including species of Acacia (*A. frimbriata* and *A. leicocalyxIn*), casuarina (*Allocasuarina littoralis*), Sapindaceae *Dodonaea triangularis*, and Rubiaceae (*Pavetta australiensis*).   Although Myrtaceae received a moderate score for native plants, this was due to a single record each of *Helicoverpa armigera* (cotton bollworm) and *H. punctigera* (native bud worm) and several records of *Franklinella occidentalis* (western flower thrips -WFT) and *Thrips tabaci* (onion thrips). The two thrips examples are from South Australia and more recent evidence has shown that WFT does not perform well on foliage of Myrtaceae.

The next step will be to match our risk estimate to our lists of native plants that provide additional benefits. For example, some native plants are known to provide nectar sources that are attractive to beneficial insects, drought tolerant, and fire retardant. This will allow growers to select a range of attributes that are most suited to their production system.

II.
Are beneficial and pest insects moving into the crop from native remnants?

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Introduction

There is wider recognition that insect pest problems need to be considered beyond the crop boundary, and the crucial role of non-crop habitats in agricultural landscapes (Bianchi *et al.* 2007). Even small and isolated fragments of remnant vegetation are thought to play important roles in maintaining the ecosystem services (products of nature that yield human well-being) of pest control and pollination. Remnant patches may provide perennial habitat for natural enemies (Bianchi *et al*. 2006, Renchen 2006), feral and native pollinators (Blanch *et al*. 2006, Heard 2001), species of conservation interest and, in some instances, a source of pests (Schellhorn et al 2008).

VG05014 showed that several species of beneficial insects were using the edge habitat between native remnant vegetation and the crop. This study focuses on whether insects are moving into the crop from the remnant vegetation, riparian (riparian = creeks, streams and rivers) and non-riparian, and whether the landscape context (percent of remnant remaining in a 4 km radius) influences beneficial and pest insect species and numbers.

Materials & Methods

Bi-directional malaise traps (Figure 1) were used to assess the habitat preference and the movement of insects to and from different habitat types, agricultural crops (crop), native remnant vegetation (Rem), the edge habitat between remnant vegetation and crops (ERem), and riparian remnant and crops (ERip). However, to minimize variation, all Malaise traps were placed on grass that was kept short (< 10 cm) throughout the year. Immigration from native vegetation to crops was considered for the two edge habitats (ERem and ERip). The traps were set on 23 May 2007 and insects were trapped for a week at a time, every other week for an entire year until 15 May 2008. For this report we focus on 15 species of known predators of pests, and 6 species of pests.

The traps were set up in two landscapes in the Lockyer Valley, QLD. The landscapes differed in the amount of native remnant vegetation remaining; Gatton with ca. 1% and Mulgowie with more than 60% (Figure 2). Gatton Research Station (GRS) (152°34′10”E 27°53′05”S) is a 50 ha site that sits in the middle of highly intensive vegetable production region. The majority of native remnant vegetation has been cleared except along riparian zones (i.e. vegetation immediately adjacent to and supporting creeks, streams and rivers). Mulgowie Farm (152°22′00”E 27°45′30”S) is 20 km south of GRS and enclosed between the Mistake Mountains and the Little Liverpool Range in the Great Dividing Range, Australia, at an altitude of ± 150-160m above sea level. Mulgowie Farm is more than 3200ha (8000 acre) in size and produces several vegetables (sweet corn, green beans, broccoli etc.) throughout the seasons. The experimental sites were chosen because of the simple landscape around

Gatton and the complex landscape (different habitats located near each other) around Mulgowie. Sampling occurred in all four habitats listed above at Mulgowie, but only two at Gatton, crop and ERip, because there is no Rem or ERem.

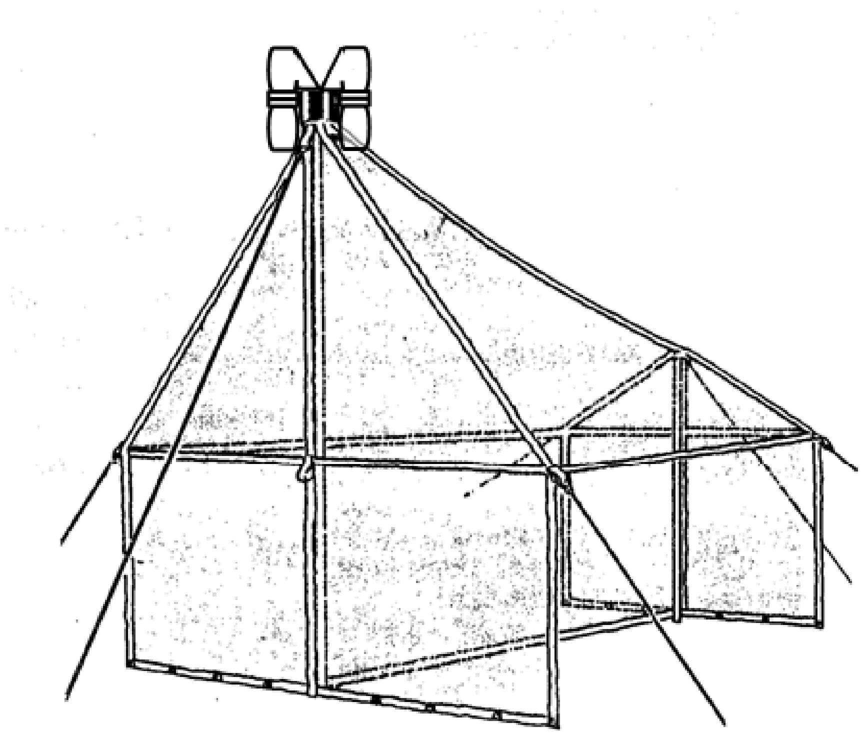

Figure 1. The bi-directional Malaise Trap is designed as a passive trap intended to survey insects flying in a given area at a given time. It consists of an open-fronted tent with a roof that slopes upward to the innermost corner at which there is an aperture leading to a collecting bottle. It halts the insects in flight and directs them to collecting bottles, utilizing the natural behaviour of most insects to crawl upward and to move towards the light penetrating the trapping bottles.

Figure 2. Google maps showing Gatton (at top) and Mulgowie (at bottom). Red circle shows study area.

At Gatton, the experiment was set up on (and parallel to) the south sides of a 14 ha field with either barley or soy bean –depending on the time of year, and the north side of a 8 ha field with either barley or forage sorghum (Figure 3). At Mulgowie, the experiment was set up on (and parallel to) the north and south sides of an 18.2ha broccoli field (Figure 4).

Adjacent to the field in the north was a 2m wide grassy strip, a dirt road and power lines and an 9.7ha field with broccoli or sweet corn – depending on the time of year. The remnants at Gatton and Mulgowie have similar native species, a few different ones, but also weeds (list available on request). The broccoli and sweet corn fields were sprayed with oil and soft insecticide (Chess®) to control aphids.

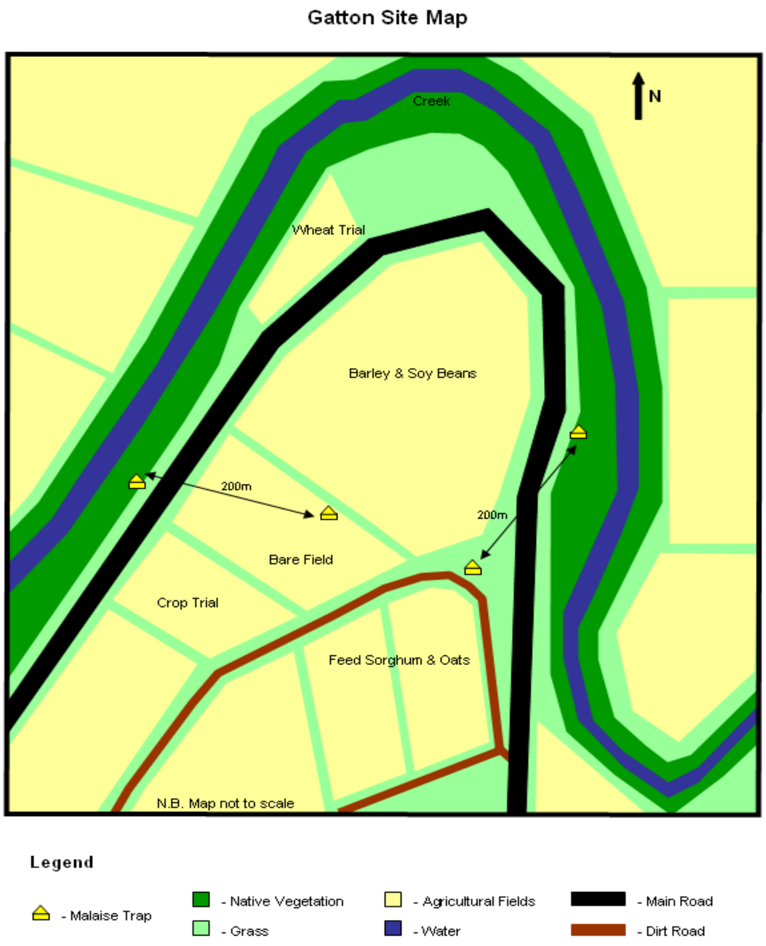

Figure 3. Schematic for Gatton showing the sampling area and design.

Mulgowie Site Map

Figure 4. Schematic for Mulgowie showing the sampling area and design.

On both sides of the fields, two transects were laid out parallel to the field edge (Fig. 4). On each transect, four Malaise traps were situated. The first trap was located in the remnant vegetation forest 200m from the remnant-crop edge, the second trap at the edge, the third in the crop 200m from the edge, and the fourth 200m away on the riparian remnant-crop edge.

Eight and four Malaise traps in total were used to trap the insects at Mulgowie and Gatton, respectively. The Malaise traps used in this study have been purchased at BioQuip and consist of dark green or black polyester with two vertically attached wet catch collecting bottles. In order to kill the insects, 400 mls of ethanol was used and replaced for each week of trapping. The caught insects were taken back to the lab and stored in vials with 70% ethanol. In the lab, the beneficial insects were selected and sorted into morphospecies. One-way ANOVAs were used to determine whether the average number of predators or pests was: moving out of remnants into crops or visa versa and preferred particular habitats.

Results

Immigration from remnant to crop

Forty-eight species of beneficial insects were considered, however for this the focus is on 15 species of predators; those species with at least 25 individuals captured throughout the year (Table 1).

Table 1. The species of predators and pests considered in the analysis.

Status	**Order**	**Family**	**Scientific Name**	**Common Name**
Predators	Coleoptera	Coccinellidae	*Diomus notescens*	Minute two-spotted ladybeetle
	Coleoptera	Coccinellidae	*Coelophora inaequalis*	Variable ladybeetle
	Coleoptera	Coccinellidae	*Hippodamia variegata*	White collared ladybeetle
	Coleoptera	Coccinellidae	*Coccinella transversalis*	Transverse ladybeetle
	Coleoptera	Coccinellidae	*Micraspis frenata*	Striped ladybeetle
	Coleoptera	Coccinellidae	*Harmonia conformis*	Common spotted ladybeetle
	Coleoptera	Melyridae	*Dicranolaius bellulus*	Red & blue beetle
	Diptera	Asilidae	*Morpho spp78*	Robber fly
	Diptera	Asilidae	*Morpho spp79*	Robber fly
	Diptera	Syrphidae	*Melangyna (Austrosyrphus) sp.*	Hoverfly
	Diptera	Syrphidae	*Sphaerophoria macrogaster*	Hoverfly
	Diptera	Syrphidae	*Simosyrphus grandicornis*	Hoverfly
	Diptera	Syrphidae	*Episyrphus viridaureus*	Hoverfly
	Neuroptera	Chrysopidae	*Mallada spp.*	Green lacewing
	Neuroptera	Hemerobiidae	*Micromus spp.*	Brown lacewing
Pests	Hemiptera	Ciccadellidae	*Cicadulina bimaculata*	Maize leafhopper
	Hemiptera	Miridae	*Campylomma liebknechti*	Apple dimpling bug
	Hemiptera	Miridae	*Campylomma liebknechti*	Apple dimpling bug
	Hemiptera	Pentatomidae	*Nezar viridula*	Green vegetable bug
	Lepidoptera	Pieridae	*Pieris rapae*	Cabbage white butterfly

The net immigration of beneficial insects into crops from ERem and ERip habitat depended on the landscape and insect species. There was either a net immigration of predators from native vegetation into crops or no difference in movement from or to the crop, but there was never greater immigration from crops to native vegetation. When all 15 species of predators were grouped together there was a net immigration from ERip to crops of 3.4 and 3.7 individuals per day for Gatton and Mulgowie, respectively. However, only at Mulgowie was the immigration of predators from ERip to crop significant (Mulgowie F=4.24, df=1, P=0.043; Gatton F=2.98, df=1, P=0.087). When each predator species was consider separately there was significantly higher immigration from ERip to crops regardless of landscape (Table 2). The only species listed are those that are statistically significant.

Table 2. Average daily immigration of predators from native vegetation to crops.

Landscape	**Direction of movement**	**Species name**	**Common name**	***F***	***P***
Gatton	Riparian edge to crop	*Coelophora inaequalis*	Variable ladybeetle	8.45	0.0023
		Micraspis frenata	Striped ladybeetle	9.83	0.0027
		Mallada spp.	Green lacewing	6.47	0.0014
Mulgowie	Riparian edge to crop	*Coelophora inaequalis*	Variable ladybeetle	15.32	0.0003

		Micraspis frenata	Striped ladybeetle	25.7	0.0001
		Mallada spp.	Green lacewing	5.14	0.0186
		Dicranolaius bellulus	Red & blue beetle	3.57	0.06
	Remnant edge to crop	*Coelophora inaequalis*	Variable ladybeetle	8.13	0.0078
		Dicranolaius bellulus	Red & blue beetle	3.57	0.06
		Sphaerophoria macrogaster	Hoverfly	6.28	0.0175
		Mallada spp.	Green lacewing	4.46	0.039

A total of five species of pest were considered, and the criteria for analyses were similar to above (Table 2). In Gatton, three of the five pest species had significantly higher immigration from riparian remnant, whereas in Mulgowie, two of the five were higher (Table 3). In both landscapes the maize leafhopper moved from remnants into crops.

Table 3. Net daily immigration of pests from native vegetation to crop.

Landscape	**Direction of movement**	**Species name**	**Common name**	***F***	***P***
Gatton	Riparian edge to crop	*Cicadulina bimaculata*	Maize leafhopper	20	0.0001
		Campylomma liebknechti	Apple dimpling bug	5.25	0.0269
		Nezara viridula	Green vegetable bug	4.81	0.0344
Mulgowie	Riparian edge to crop	*Cicadulina bimaculata*	Maize leafhopper	13.92	0.0006
		Pieris rapae	Cabbage white butterfly	7.32	0.0102
	Remnant edge to crop	*Cicadulina bimaculata*	Maize leafhopper	9.35	0.0036

Habitat Preference

The five species of predators that were present in both landscapes and all habitats include two ladybird beetles (*Diomus notescens* and *Coccinella transversalis),* brown lacewing (*Micromus* spp.) and two species of hover flies (*Simosyrphus grandicornis Melangyna (Austrosyrphus)* spp.). In Gatton, when all 15 species of predators were grouped together there were significantly more captured per day in the crop habitat, 7.3 (2) (mean ± SE), than the ERip habitat, 3.36 (0.95) (*F*=4.76, df=3, *P*=0.0312). There was no difference in the number captured for robberflies, ladybird beetles, lacewings (brown or green) or red & blue beetles. In Mulgowie, when all predators were grouped together the same number were captured per day in the crop, 4.68 (1.46) and riparian vegetation 3.7 (1.11), but significantly more were captured in the crop compared to the Rem, 0.7 (0.19) (*F*=11.42, df=3, *P*< 0.0001). Significantly more red & blue beetles were captured per day in the ERip, 0.05 (0.01) than in all other habitats (*F*=6.38, df=3, *P*=0.005). Significantly more brown lacewings were captured per day in the crop and ERip, 0.27 (0.06) compared to the ERem and Rem 0.05 (0.01) (*F*=7.79, df=3, *P*<0.0001). Significantly more robber flies were captured per day at the ERem, 0.38 (0.04) compared to all other habitats (*F*=29.63, df=3, *P*<0.0001).

When all five pests were grouped together there was no difference in the number captured per day between the crop and ERip at Mulgowie or Gatton, 4.8 (0.72) and 4.7 (0.94), respectively. However, at Mulgowie there were significantly fewer pests captured in the Rem compared to the crop (F=12.44, df=3, P<0.0001). For all predators, the main seasonal peak happened in October regardless of landscape. However, some predators are present earlier in the season in some habitats than others. The example for robber flies (Figure 5) and hover flies (Figure 6) at Mulgowie is provided. The maize leafhopper was the most abundant pest, and the seasonal peak happened in autumn.

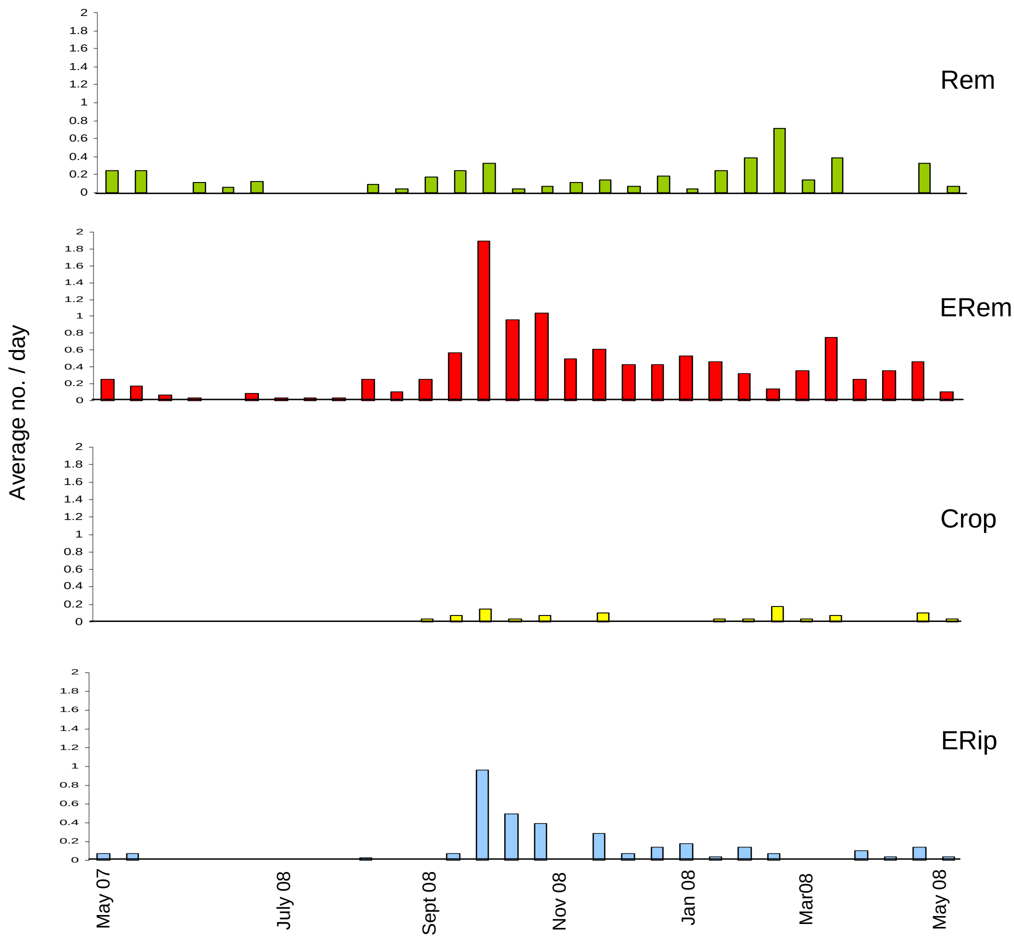

Figure 5. Seasonal abundance of robber fly (morpho spp 78) in each habitat at Mulgowie, QLD.

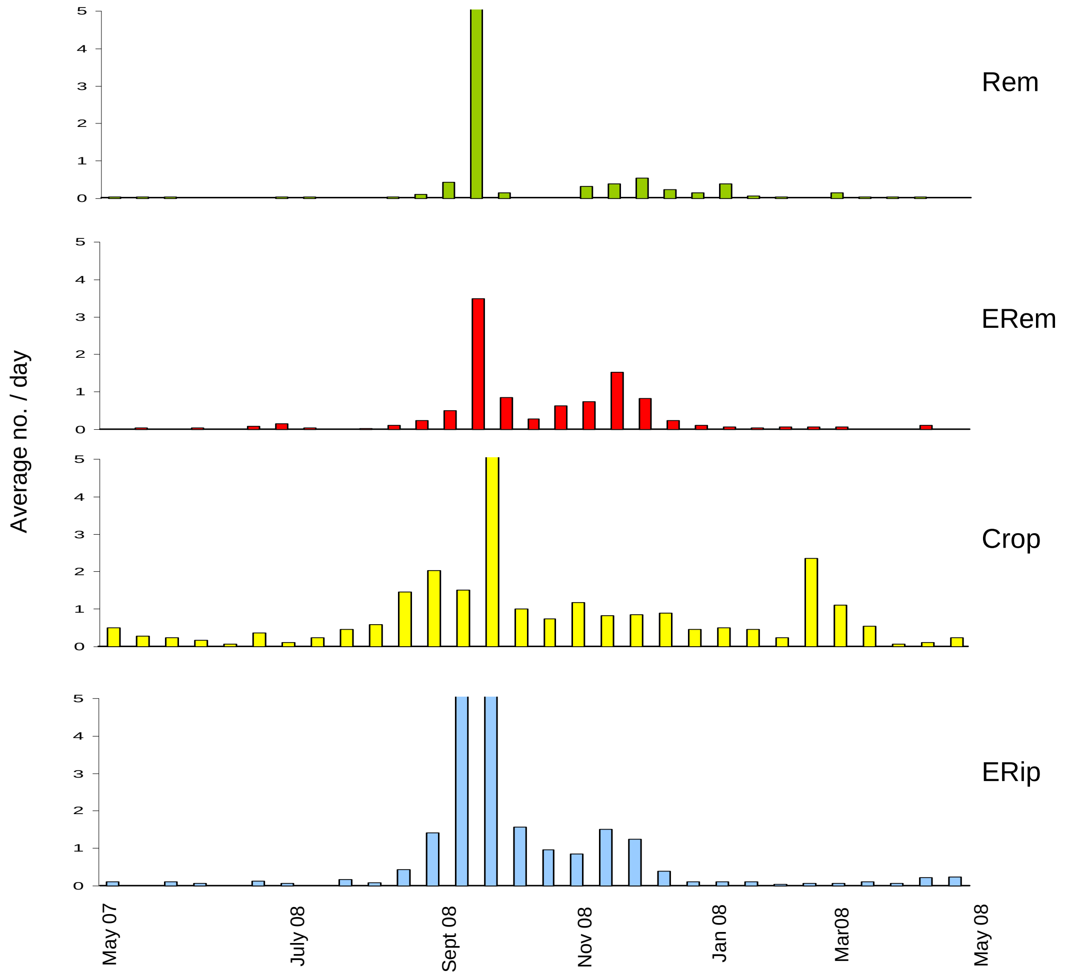

Figure 6. Seasonal abundance of hover fly (*Sphaerophoria macrogaster*) in each habitat at Mulgowie, QLD. Note that the y axis has been truncated at the maximum value for the 'Rem' habitat, an that the maximum values in Crop and ERip are 27 and 24 per day, respectively.

Discussion

Edge habitat between native remnant vegetation and crops supports many species of insect predators and there is a net immigration from remnant vegetation to crops. This is particularly true for the edge habitat between riparian remnant vegetation (ERip) and crops. Although this trend was present in both landscapes, it was statistically significant in the landscapes with a high percentage of remnant vegetation (eg. Mulgowie), not the one with little remnant remaining, eg. Gatton.

Some pest species also like the riparian remnant vegetation, and there is a net immigration from these habitats into the crop. This is particularly true for jassids that use the exotic grass that is abundant around field and remnant edges. Work from VG 05014 showed that jassids are abundant on the exotic grass, but not the native plants. At Gatton, there is a trend for two bugs (green vegetable bug and apple dimpling bug – the second is an omnivore) to immigrate from the remnant vegetation to the crops. The ERip habitat at Mulgowie and Gatton had more broad-leaf weeds than the ERem or Rem habitats. Both pests and natural enemies can be associated with weeds (see result from VG05014).

Some species are ubiquitous and occur in all habitats, while others prefer different habitats. Robber flies prefer the ERem habitat compared to the ERip, whereas hover flies prefer the ERip habitat. Although there was no difference in the number of green lacewings in the different habitats, there was significantly more immigrating from all types of remnant vegetation to crops. Therefore, landscapes with different types of habitats may support more types and numbers of natural enemies. Several of the insect predators feed on aphids, which would be present in the crops (barley, maize and broccoli), weeds and some native plants. Although Malaise traps are not appropriate for surveying aphid populations, we did see a peak in winged aphids on 12 and 28 Sept 2007, around the same time as the peak in aphid predator numbers.

The ‘transition zone’ between crops and remnant vegetation often has weeds and grasses. This is particularly true for riparian zones which are a perfect corridor for dispersing weeds. Therefore, the condition of the remnant vegetation is quite critical to the role is plays for maintaining ecosystem services. In the next project, VG07040, using a combination of experimentation and spatial modelling we will investigate whether on-farm changes in vegetation management can change pest and natural enemy dynamics or whether the surrounding landscape has the greatest influence. Answers to this question will determine whether it pays to manage weeds in the edge habitat between crops and remnant vegetation, and if so, how much needs to be managed in order to reduce pests.

As to be expected the results of this project have positive and negative implications for vegetable pest management. Beneficial insects use native remnant vegetation and there is a net immigration into crop habitat, however it is also used by pests. The key will be in the balance. The presence of remnant habitat (with and without weeds) near vegetable crops may allow for faster arrival to crops, earlier suppression of pests and fewer pest outbreaks.

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III.
Perceptions and behaviours towards integrating native vegetation and pest management practices in the Lockyer Valley, QLD

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Introduction

Vegetable production in the Lockyer Valley, Queensland is concentrated along the alluvial flats of several creeks that constitute the Lockyer Valley. A smaller proportion of area includes higher country of non-agricultural land. Native vegetation is found in the creek areas and road sides and where the alluvial flats border adjacent upland grazing areas. Equally these areas may have weeds such as lantana or castor oil plant.

Natural resource management practices of using native vegetation for managing riparian zones, run-off, reducing flows and salinity mitigation are reasonably commonly known. In addition research in QLD (Schellhorn 2006) and South Australia (Taverner and Wood 2006),has shown some promise for the use of native vegetation in pest management in a horticultural system.

Pest management is an on-going issue for Lockyer Valley vegetable farmers with serious pests such as heliothis, diamondback moth and more recently silverleaf whitefly causing losses across vegetable crops. Any pest management system used in these crops relying solely on pesticides is destined for failure and the crops to decimation by the pests. In the last 20 years significant resources have been dedicated to managing these pests using an integrated pest management (IPM) approach. This emphasises using biological and cultural control practices as well as judicious use of pesticides to successfully manage the pests. This trend away from sole reliance on pesticides has meant some that pests have been managed to a level below that which causes economic losses in yield and quality.

Natural resource management is a topical issue in the Lockyer Valley as the extensive creek network is part of the western catchment zone that feeds into Moreton Bay. Recent modelling studies suggest that the sediment found in Moreton Bay can be traced back to the Lockyer Valley. Secondly with close to 10 years of drought, water is a precious resource of farmers for ensuring their on-going profitability.

We also know that there are at least 30 reasons why growers may not decide to use natural resource management techniques being promoted (Vanclay, 2004; Hockings *et al*, 2005) and equally there are barriers to adoption of IPM. Further in the process of changing farm management practice, such as using some of the natural resource management techniques, generally speaking growers, as with any other person, will move through a simplified model of a practice change continuum, that shows as people increase their knowledge (K), modify their attitudes (A), improve their skills (S), and raise their aspirations (A), and they can then apply these KASAs to change their practice in their own living and working situations (Rockwell and Bennett, 2007). This gives some insight into the potentially long timeframe in which the process of achieving practice change can occur and some of the hurdles that may be encountered.

Therefore in a project investigating the role native vegetation can play in pest management in field vegetable cropping system and the wider implications and links to natural resource management incentives and wider public benefits, it was also worth investigating the current grower perspective on using native vegetation for pest management. In understanding their perceptions researchers can capture the best aspects and produce targeted research development and extension.

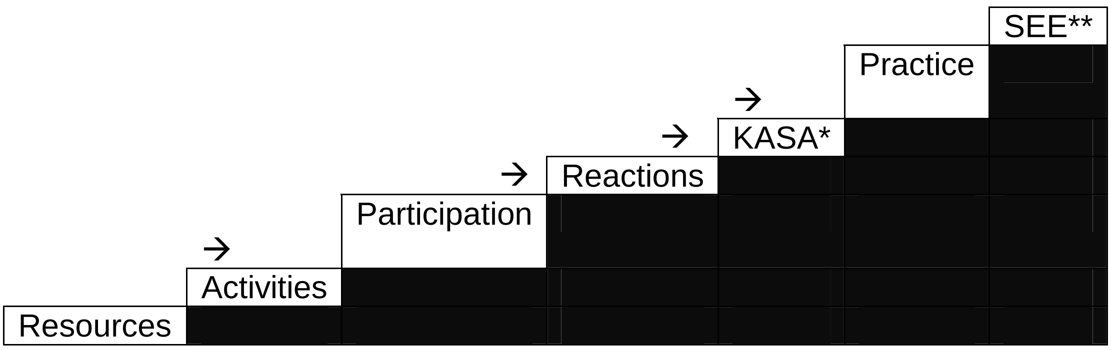
The survey results reported represent one part of a two part project, where the other part is the entomological investigation of the pests and natural enemies in a crop and native vegetation environment. This report covers the ‘social’ aspect. The objective of which was to determine the potential for the Lockyer Valley community to change perceptions and behaviours about integrating native vegetation and vegetable pest management as a potential best management practice. The information and recommendations will be used in developing a new project that will further the concept of using native vegetation for pest management.

Methodology

Questionnaire design

A questionnaire was used to establish the perceptions and behaviours of growers towards integrating native vegetation and pest management practices on vegetable farms in the Lockyer Valley from August 2007.

The questions were based on the project objectives and Bennett’s Hierarchy. The questions targeted collecting information for assessing participation, reactions, knowledge, attitude, skills and aspirations (KASA) and practice change with regard to native vegetation use and pest management (Figure 1) as well as assessing the needs and opportunities for native vegetation use in pest management. In addition to encourage participation and gauge interest in future project activities, a separate fax back sheet was distributed with the questionnaire. Growers were asked if they would like to participate in further project activities, trials or to be kept up to date with information. To ensure or improve future communication a question identifying the information source of native vegetation was also included and mixture of qualitative and quantitative data was collected in the form of multiple choice and open ended questions.



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* KASA – knowledge, skills, attitudes and aspirations
** SEE - social, economic and environmental outcomes
→ arrow indicates the level where the questionnaire is targeting information

Figure 1. Bennett's Hierarchy (modified from Rockwell and Bennett, 2007)

A small test group of 5 farmers was used to test the questionnaire and provide feedback, which was incorporated where necessary.

The questionnaire was mailed to 150 vegetable growers in the Lockyer Valley. Response was encouraged by also offering on-line and telephone interview as alternative methods. Twenty growers were contacted by telephone prior to the questionnaire being sent out and after they received it. Five growers requested to complete the questionnaire on-line (an internet link was sent to them via email). Other than telephone interviews the questionnaire was anonymous. The Zoomerang software was used for the on-line survey design, and respondents had 2-3 weeks to complete the task.

Analysis

Responses from 20 growers were grouped into common themes for the qualitative and quantitative analysis of multiple choice answers. The implications of the questionnaire results for the new project being proposed are discussed.

Results and Discussion

The responses have been presented according to the different levels of Bennett's Hierarchy, starting from participation through to practice. They represent the current status of the participants in their perception and behaviour with regard to native vegetation. This is then followed by a discussion on the needs, opportunities, motivators and drivers.

Participation in survey

Twenty growers responded to the questionnaire, which was 13% of the target audience. Of the 20 returned questionnaires, 17 were returned by mail, 2 were telephone interviews and 1 was completed over the internet. Responses were from growers with and without native vegetation on their property (55:45). This means that a picture of the current role, perceptions of native vegetation on vegetable farm could be described.

The response rate overall however seems relatively low for the number of growers in the Lockyer Valley, however other researchers consider anywhere between 10-60% to be an acceptable response rate for questionnaires and depends on the sector (ABARE). Further contact and enquiry could further enhance understanding of the 'potential' for native vegetation use in pest management. The responses themselves have provided important insight into the issue of native vegetation and pest management in a vegetable production system in the Lockyer Valley from properties with and without native vegetation (55:45) and from a range of vegetable crops production systems. It is also important to consider the 'environment' effect which the survey was conducted. For example relative to water availability, in current on-going drought conditions, native vegetation may be relatively low priority as well. The participation level in the native vegetation survey may also indicate the relative level of interest in the topic.

Reaction
What is your reaction to the concept of using native vegetation for pest management?(Q1.5)

The reactions to the concept of using native vegetation for pest management were varied from "*not possible*" and "*haven't thought about it"* to "*already doing it on farm*" (Table 1). Four growers from each group (the 'have' and 'have not' got native vegetation) thought that it was possible on their farm (Table 1 &2). Two growers who already have native vegetation stated that they were already using it for pest management.

Growers comments included: '*I need further information, it provides pests with a place to go* and *I don't know how it would work*'. These are consistent with the setting of the current project proposal where it states: '*two of the most frequently asked questions are: why should I maintain/create areas of native vegetation – how will it benefit me, and how do I know it won't add to my pest problems?*'.

Table 1 Response from growers who **have native vegetation** on their farm:

No. responses	**Ranking**	**Comments**
4	**4 -** Interesting and possible on my farm	I need further and more information
1	**1 -** Interesting but not possible on my farm	provides pests with a place to grow
1	**1 -** Not interesting or possible on my farm	not possible to have native vegetation where we are growing vegetables.
2	**2** – Already using native vegetation for pest management	
3	**3** – No box ticked	interesting but don't know how it would work, had not thought of the possibility in our situation

Table 2 Response from growers who **do not have native vegetation** on their farm:

No. responses	Ranking	Comments
4	Interesting and possible on my farm	But around the outside or as a hedge wind break beside the nursery. But I don't have enough room to plant NV on my property in place of vegetables; farms are too close to each other as insects fly over fences.
5	Interesting but not possible on my farm	All land currently under use; my personal belief is that native vegetation attracts as many pests and crops do; I need all the land for cultivation; could help control some pests but also could breed others.

Other activities within this project, such as the literature review of native vegetation to determine its benefits and risks in vegetable farming, will help to alleviate (or confirm) many beliefs that growers currently have, such as native vegetation is a source of pests, disease and weeds and is not useful on farms.

Perception (Knowledge) of native vegetation roles on own property

Question: What do you consider to be, or could be the ***benefits*** *of having native vegetation on your property? Tick 5 boxes.*

Not all respondents ticked 5 boxes each. Regardless of whether the participants had native vegetation on their farm or not, most identified more than two benefits that native vegetation could or does have on their property, indicating some current knowledge of the benefits of native vegetation.

The benefits identified were ranked according to the number of responses (ticks) (Table 3a). The top 3 benefits of native vegetation were: prevents erosion, refuge for animals and a windbreak. These were chosen by more than 50% of the growers. '*Reduces, weeds, insect pests and/or diseases*' was ranked in the last third of benefits listed. Other responses that ranked higher include : *it looks good*, *it doesn't cost anything*, *improves biodiversity*, and *prevents runoff of nutrients* (Table 3a).

Table 3a. Benefits of having native vegetation on vegetable farms.

Ranking*	Benefit
1	prevents erosion [16]
2	refuge for animals [13]
3	windbreak [11]
4	improves biodiversity [9]
5	prevents runoff of nutrients [7]
6	looks good [6]
6	doesn't cost anything [6]
7	makes use of land that is not in crop [4]
7	reduces weeds [4]
7	reduces insect pests [4]
8	reduces diseases [2]
9	Other: A shield for close neighbours and it breeds beneficial insects [1]

*1 having the most ticks and 9 having the least.
The benefits that are ranked the same had the same number of ticks

Two growers did not list any benefits for having native vegetation on their property, but provided the following comments:

- I grow vegetables not native vegetation
- There is not enough ground and it is far too expensive to put in native vegetation. You need to pick the right spots for it.

What are, or could be the ***drawbacks*** *of having native vegetation on your property? Please tick 5 boxes.*

Most growers could identify at least two drawbacks (only one grower did not tick any drawbacks), not all respondents ticked 5 boxes.

The drawbacks are ranked according to the number of responses (ticks) (Table 3b). The top 3 drawbacks were: *takes time to maintain*, *takes water away from the crops*, and *takes up too much room*, which were about 50% of the response (Table 3b).

Table 3b. Drawbacks of having native vegetation on vegetable farms.

Ranking	Drawback
1	takes time to maintain [10]
2	takes water away from the crops [9]
2	takes up too much room [9]
3	costs too much money to maintain [8]
3	source of pests [8]
3	gets in the way of farm machinery [8]
4	has to be fenced off [7]
5	it's not useful on my farm [6]
6	source of weeds [5]
7	it dies [4]
8	source of diseases [1]
8	Other: establishment cost can be high [1]
8	Other: it is of no use to me as it does not produce income [1]

*1 having the most ticks and 8 having the least. The drawbacks that are ranked the same had the same number of ticks.

This data shows that with respect to insect pests, native vegetation is considered to be more of a drawback (source of pests) than a benefit (source of beneficials that reduce insect pests) and therefore will impact on the potential for vegetable growers to change perception and behaviour with regard to native vegetation. This data could be compared to 'the facts' as they are available in order to determine the true potential for change, integrating native vegetation. A complementary activity of the current project is a literature review to assess the beneficial insects and pests that are harboured in native vegetation. This will provide some of the 'facts' that can be used to support or not support grower perceptions.

There was little difference in the number of responses where growers identified the benefits and drawbacks of native vegetation on their property with regard to weeds and diseases.

Extra comments provided at the end of the questionnaire:

- Great to have it along creek beds and perhaps as a hedge along the side of the nursery (this grower does not have NV on their farm).

The benefits and drawbacks identified (Table 3a & 3b) will be used as indicators of perceptions and knowledge that vegetable growers in the Lockyer Valley have of native vegetation on their farms. They also show where future project activities could target research and extension addressing drawbacks and promoting benefits

Attitude
How do you generally regard native vegetation? Rank on a scale of 1 to 8, please provide comments

Most growers regarded native vegetation highly, which reflects mostly positive attitudes (Table 4). Some growers who did not have native vegetation on their property and did not think it was possible to use native vegetation as part of their pest management strategy still recorded a high ranking (Table 4). This is consistent with Vanclay (2004) which states that farmers attitudes are not the problem when it comes to natural resource management, that is they are generally positive about environmental management but that the discrepancies in view comes about whether native vegetation on-farm is considered good 'farm management'.

Growers who currently have native vegetation on their property and are using integrated pest management practices, had the highest regard for native vegetation and commented that it harbours beneficial insects. These growers may be industry leaders/ innovators in this area of technology/farm practice and would be ideal sites for future project activities and engagement such as trial work, case studies, data collection, visits, testimonials.

One grower did not respond to this question – this grower had native vegetation on their property.

Table 4. Growers regard for native vegetation using a ranking scale.

Ranking	Number of growers with NV * on farm		Comments
	Yes	No	
Low regard 1	1	-	-
2	1	1	▪ had no knowledge of how it can work for me, not me work for it ▪ there are more drawbacks than advantages
3	-	-	-

4	2	1	▪ I only have native vegetation in my grazing paddock so does not impact on my farming ▪ we should have native vegetation to a certain degree, we need to be able to thin it out so machinery and vehicles can have access to areas in the paddock
5	1	3	▪ every new person on the planet takes water - room the native vegetation
6	1	3	▪ it is a pain but you need it
7	1	-	
8 **High regard**	4	-	▪ native vegetation has advantages over other vegetation ▪ excellent for habitation of predatory insects ▪ highly regarded for around creek banks and on the edge of our property, but also harbours weeds ▪ I am in favour of native vegetation, it has a place but not on our expensive country in the Lockyer Valley

NV = native vegetation
- = no information provided

Skills and Aspirations

Do you have any environmental or conservation goals for your farm? (comment)

Environmental aspirations were only provided by growers with native vegetation already on their property. No response to this question was provided from growers who did not have native vegetation on their farm. Of the 11 growers (55%) who did have native vegetation, 7 of these provided conservation or environmental goals (Table 5). Growers in general have positive attitudes towards environmental management (Vanclay, 2004).

Not all growers with native vegetation on their property or who ranked their regard for native vegetation as high (above 5, Table 3), provided environmental goals or comments. These growers may not wish to share them or perhaps interpreted the question differently.

Table 5. Environmental goals provided by growers.

Environmental goals
▪ Do it yourself because books have to be written before you can learn what farmers know
▪ Silt dams to catch silt and nutrient trap from farm
▪ I would like to be able to get rid of all non native weeds in the water ways (creeks, rivers, water courses, gullys) and revegetate with native trees, shrubs and grasses to hold back water flows naturally. Mainly in the higher country in the gullys. Also to be able to use the native vegetation planted to support insect predators, parasitoids and pests.
▪ Erosion control, weed control
▪ Broadly, yes. By growing out crops without disturbing the natural environment any more than necessary (co habitat)
▪ I'm using fertilisers with 50% mineral rock based instead of 100% chemical based.
▪ I use a unique IPM system for my cropping of vegetables

Practice…the role of native vegetation on their property
Does the native vegetation on your property play a role in pest management in your crops?

Three growers commented that the native vegetation plays a role in pest management in their crops. Additional comments from these growers included that '*it is a natural haven for predatory insects*' and '*breeds beneficials*'. One grower stated that *they were unsure* and then went on to answer '*yes*' to pest management being the primary reason for keeping native vegetation on their property (but also commented: maybe to make a bit of money out of native flowers, oils etc). These growers may be ideal to have as project team members to record what they are already doing and to help to set benchmarks for best practice.

One grower with native vegetation on their property did not respond to this question.

Seven growers stated that the native vegetation on their property did not play a role in pest management in their crops. However, one of these growers also commented that they didn't really know, and another stated that the native vegetation was too far from the crop.

It is likely that there are growers with native vegetation on their property that have not thought about using it as part of their pest management program. Participating in this survey may have started some growers thinking about the possibility. Training to build growers capacity relating to pest management and native vegetation on their farm could be included in a new project.

Is pest management the primary reason for keeping native vegetation on your property?

Four growers indicated that pest management is the primary reason for keeping native vegetation on their property. Three of these growers ticked that native vegetation is beneficial because it reduces insect pests. The grower that did not tick this specific reason for native vegetation being beneficial added an additional comment that said that it '*breeds beneficial insects*'. These growers each ranked their regard for native vegetation as 5,6 8 and 8.

Growers that were not keeping native vegetation primarily for pest management still recorded positive comments about having it on their property, for example, '*I have a desire to leave the country in a better state than it was when I started cropping*' and another commented that there are '*Bee hives present that are too big to remove and they are not doing any harm*'. It is also likely that even though many growers did not maintain native vegetation on their farm for the primary reason of pest management, it may still be on their list of reasons. Further information can be sought on characteristics of the native vegetation on these properties.

Practice: pest management

Please complete the table with information on your major pests and the management strategies that you use?

Information was collected on pest management practices and major pests (can be provided on request). The major pests listed include heliothis, diamondback moth, aphids, beetroot webworm, marshmallow weed and sclerotinia.

The information was provided by only 13% of growers and may not represent a realistic picture of pest problems in the Lockyer Valley. Additional information is available from other pest management practice surveys conducted in the region by DPI&F staff.

The majority of growers indicated that their current pest management practices were effective. This may impact on the potential or likelihood for growers to change pest management practice, as current practice failure would provide a stronger driver to try something else.

Influence/Motivator/driver

What currently influences your choice of pest management strategy?

There did not appear to be a difference in the influences on choice of pest management strategy between growers who did and did not have native vegetation on their property (Table 6). However, the growers with native vegetation generally recorded more influencing factors than those that did not have native vegetation on their property.

The most common influences were: integrated pest management related reasons, money and economic reasons, environmental, health and safety reasons and effectiveness of the strategy (Table 6).

Table 6 Current influences on choice of pest management strategy for growers who do and do not have native vegetation on their property. [figures indicate multiple responses]

Native vegetation on property	No native vegetation on property
▪ **IPM reasons [10]** (Selective to favour natural predators, beneficial insects, Holistic approach, Pest management breeding, Less heavy chemicals, Native birds and animals, Less use of hard chemicals, Eventually it will look after itself – hopefully, IPM, harshness to beneficial's) ▪ **Money, cost effective (6)** ▪ **Effectiveness [4]** (Must do the required job, Chemical effectiveness, Control, WHP) ▪ **Weather/climate [4]** (Time, Seasons, Drought, Heat) ▪ **Health, safety to users and surrounds [4]** (Food safety) ▪ **Economic (3)** ▪ **Social [2]** (taking care to choose a strategy that does not affect the neighbours) ▪ **Environmental (2)** ▪ We use what we are advised to. Landmark 'free advisory service' is excellent. We use a monthly cycle.	▪ **Cost (5)** ▪ **IPM reasons [3]** (least chemicals needed/used, I am very limited to what I can use e.g. fungicides and herbicides: cost, availability, effectiveness, effect on environment, It needs to fit into my IPM strategy) ▪ **Consulting (2)** ▪ **Pest numbers or conditions (2)** ▪ Environment ▪ past experience ▪ quick and easy ▪ what works ▪ Climate change

The key influences from Table 6 need to be incorporated into designing trials and recommendations for using native vegetation for pest management. For some growers the adoption of native vegetation for pest management may depend on the cost of incorporating it compared to the benefits it returns to the farm, for example how much does it cost to maintain and manage compared to how much it saves in sprays for pests. However, for other growers environmental reasons may rate higher and cost may not be an issue. It will be individual for each farm business and individual priorities and values.

Cost was one of the top influences on choice of pest management strategy. A cost benefit study for long-term pest and weed control using the cultural control. In addition, could also include set up and maintenance costs in any native vegetation guidelines that are developed.

It is encouraging that there are so many IPM related reasons for choice of pest management strategy as this is a good indicator for the potential of integrating native vegetation to complement strategies that are already being used.

Needs

Change of attitude

What do you need in order to consider using native vegetation as part of your pest management strategy? (this can include any area of economic, social or environmental influences)

In order to capture any incentives or motivations, growers who did not have native vegetation on their property were asked what they would need in order to consider using native vegetation as part of their pest management strategy. Four of the growers did not respond to this question. Comments included: knowledge, more land, more water, more time, financial costs and one grower stated that the land is too expensive to plant native vegetation (Table 7).

Further investigation to find more details about the needs would be beneficial, such as what are the financial costs, what sort of knowledge is required, how much land, water time are required. Incorporating these comments, information and incentives will improve targeting growers who do not have native vegetation on their farm. A field day and cost benefit research would help to meet some of the needs identified in Table 7.

Table 7. Needs of growers who do not have native vegetation

List of needs in order to consider using native vegetation
• financial costs • knowledge • much more land [2] (cheap) • more water • more time • I don’t need native vegetation on my farm, the land is too expensive • Soil with less income potential

Needs for 'change of practice'
In order to plant native vegetation, what resources would you require and what resources do you already have?

The resources that growers believe they require the most in order to plant native vegetation on their property are: guidelines of what to do, see a field demonstration, water and money (Table 8a and 8b), regardless of whether there is native vegetation on their property or not.

Table 8a. Resources that are required by growers who already have native vegetation
(numbers indicate the number of growers who selected the resource).

Resource	Required	Already have
Guidelines of what to do	**6**	1
See a field demonstration	**6**	-
Nursery supplier	4	2
Water	**9**	4
Land	3	8
Money	**9**	1
Staff	5	3
Cost benefit information	4	1
Other	▪ I require information on varieties to best plant to be a better haven for predators in the off season in my particular crops ▪ it regenerates by itself	▪ it becomes semi-native vegetation, not the same

Table 8b. Resources that are required by growers who do not have native vegetation
(numbers indicate the number of growers who selected the resource).

Resource	Required	Already have
Guidelines of what to do	**<u>5</u>**	-
See a field demonstration	2	-
Nursery supplier	2	-
Water	**<u>6</u>**	1
Land	3	2

Money	**<u>6</u>**	-
Staff	2	3
Cost benefit information	2	-
Other	-	-

This provides very useful information that can be used to plan activities that will need to focus on these needs and attempt to make use of what knowledge and resources are already available and how growers may be using them.

The list of what was needed did not vary greatly between growers that did and did not have native vegetation on their property. However, those that already have native vegetation on their property have more of the the resources listed than those that did not have native vegetation.

This information also shows where growers think there are gaps (needs) in information and resources. These could be used in a new project to assist in meeting these needs, such as conducting field days, on-farm trials, and build capacity by developing and conducting training on pest and beneficial identification, weed identification and native vegetation identification. Water requirements of the native vegetation should also be included in the information.

Please list the top 5 things you need in order to maintain or improve native remnant or vegetation plantings on your farm?

This question was only asked of growers who have native vegetation on their farm. The most common needs for maintaining or improving existing native vegetation on farms are related to: maintenance needs (fencing/tidying), native vegetation knowledge (what species to plant), water (we are in a drought), and management (planning and advice) (Table 9).

Table 9. Needs for maintaining or improving native vegetation that is already on-farm

Needs for maintaining or improving native vegetation
• **Maintenance needs [7]** (Fencing, needs to be tidied up - clear vegetation from a set diameter trunk, Clean around, spray for weeds, pick up broken and dead branches, trim) • **Native plant knowledge [6]** (what to plant for particular pests, which natives to plant in my area, a plan to know where to plant natives in particular places, how many would be needed to be feasible and to do that job, if wildlife brought in by the natives would

cause problems in the future, replant, plant more)

- **Water [4]**
  (Vegetation has suffered because of drought so water is on the top of the list)
- **Management needs [3]**
  (advice, Cost recovery, Planning)
- Do not burn all the remnant
- Carbon credits
- Time
- Money
- Labour in the field
- Suitable country

This is consistent with the resources that growers said they need in order to plant native vegetation. Guidelines of what to do and a field demonstration are extension activities where growers would be able to acquire information about native vegetation, maintenance, management needs and water requirements.

Other

Would you like to be a collaborative project team member?

Six growers indicated that they would like further involvement in project activities. Some wanted information and others were interested in trial work on their properties.

There is great opportunity here to gather input and facilitate a pilot group or focus group of growers and other industry representatives for planning future project trials and extension activities. Important for expanding on information gathered in this first industry engagement activity.

Where do you currently get your information on native vegetation and pest management?

The most popular native vegetation information sources were industry publications, newspapers and other growers. The most popular pest management information sources were their own experience, other growers, industry publications and consultants (Table 10).

Table 10. Information sources for native vegetation and pest management.

Information source	Native vegetation	Pest Management
Industry publications (newsletters, magazines)	**9**	**16**

Newspapers	**<u>8</u>**	5
Consultant	-	**<u>14</u>**
Web pages	3	6
Other growers	**<u>4</u>**	**<u>14</u>**
I use my own experience	5	**<u>15</u>**
I don't search for information	4	2
Other	Ipswich and Bremer catchment committee	▪ I search for info. in organic certified crops ▪ DPI&F ▪ Chemical resellers
No response	1	

This question captured current practices in information searching. It is not surprising that the most popular information sources for growers on pest management is from consultants, other growers, their own experience and industry publications. These information sources are reasonably well known in the Lockyer Valley already. Other sources such as NRM publications were not cited specifically, however they could be classified as 'industry publications, so warrants more investigation.

These information sources should be used to help distribute project information to the Lockyer Valley vegetable growers.

Four out of the 9 growers who did not have native vegetation on their property still searched for information on native vegetation. This indicates a positive attitude, interest and aspirations for having native vegetation on their farm.

Recommendations

- Extension activities need to confirm or alleviate grower's beliefs about the benefits and drawbacks of having native vegetation on their property; including basing on literature review outcome.
- Utilise the growers that are already using native vegetation for pest management to develop case studies and set examples for other growers.
- Utilise information sources that growers are already using to distribute project information
- Conduct a field day that addresses the needs of growers: native vegetation knowledge, water, cost, management and maintenance needs.

- Guidelines of what to do need to be developed to provide information about species, water, financial costs and assistance schemes (if available).

- Guidelines need to be flexible so growers can adapt them to their individual properties and management plans.

- Provide information or training that can assist growers to determine what is happening in the native vegetation on their farm.

- When developing guidelines and recommendations for growers on how to use native vegetation, take into consideration what influences their choice of pest management strategy: IPM reasons, money, effectiveness, climate, health and safety.

- Extension activities need to focus on grower needs to create an incentive to participate.

- If another questionnaire is used to collect information, more resources need to be allocated to ensure a higher response rate.

- To improve understanding could also use complementary information gathering exercises such as personal visit, group discussions, recognising that they in themselves have drawbacks and require resources.

- Engage the growers who want to participate in project activities in planning and feedback to encourage a sense of ownership.

- Visit sites

Conclusion

There is potential in the Lockyer Valley for further project activities in the concept described in Revegetation by Design projects. Some growers are already starting to adopt the use of native vegetation on their farms to complement their integrated pest management practices.

The survey identified how vegetable growers in the Lockyer Valley perceive native vegetation and pest management. It has captured current knowledge, skills, attitudes, aspirations and practices of these growers.

This data could be used to measure change over time of growers' perceptions of native vegetation and any change in pest management practices that use native vegetation in the Lockyer Valley.

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IV.

Colonization of a biological control agent (*Diadegma semiclausum)* from refuges to crops: the importance of kernel shape for predicting refuge placement

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Introduction

A request was made in January 2007 to use $5000 of VG 06024 to support an international visitor, Prof Wopke van der Werf. The purpose of the visit was for Prof van der Werf and Drs. Bianchi and Schellhorn to explore a question related to the landscape placement of habitats that are sources of beneficial insects, which will allow for beneficial insect colonisation and subsequent pest control.

From the collaboration we have completed a manuscript that is submitted to *Biological Control*. Although the problem is complicated, we hope that our approach will take us a step closer to designing pest suppressive landscapes. The abstract of the manuscript follows.

Abstract

Early colonization of natural enemies is considered an important requisite for the effective suppression of pest populations. A timely removal of pests by natural enemies when pest populations are still low can prevent a potentially large number of offspring produced in future generations. We predict the time to colonization from mark-recapture data of *Diadegma semiclausum* in Brocolli. The data originated from experiments conducted at two locations and dispersal was quantified by suction sampling before and after a major disturbance. This allows the evaluation of normal and forced dispersal patterns. Three dispersal kernels were fitted to the dispersal data: a normal, a negative exponential, and a square root negative exponential function. These functions have a thin, intermediate and a fat tail, respectively. The dispersal kernels were used to generate estimates of time to colonization of *D. semiclausum* in sink habitats at distances ranging from 100 to 2000 m from the source using a simulation model. We show that the three dispersal kernels, which provide generally a similar goodness of fit to data, can produce a wide range of outcomes. The estimated arrival time of 1% of the *D. semiclausum* population at a distance 2000 m from the source ranges from 12 to more than 35000 days. The square root negative exponential function with the thickest tail generally resulted in the fastest spread and earliest colonization. This study underscores the relevance of the selection of a proper dispersal kernel for modelling spread and colonization time of organisms and of the collection of pertinent data that can discriminate between different kernels.

Keywords: mark-recapture, parasitoid, spatial scale, earliness, biological control

Technology Transfer

Grower and Community Group Engagement

There were a few different type of activities throughout the year to engage and communicate the concept of 'Revegetation by Design' and integrating native vegetation with pest control. In addition we also liaised with key resource people and stakeholders.

First, Dr. Schellhorn gave two invited talks, one at the 2nd annual Australian Vegetable Industry Conference 2007 held in Sydney, the other to the Queensland Entomological Society in Brisbane in June 2007.

Second, a workshop lead by David Carey DPI&F and in collaboration with CSIRO was held at Gatton on 24 June 2008 and included presentations from Nancy Schellhorn CSIRO on 'Revegetation by Design for pest control: Is it risky?' Following the talk, there was discussion, a bus tour to a salt pan and a talk lead by Dr. Ken Jackson, then a visit to Mulgowie farms to view the field sites were the research was conducted. Many different stakeholders were present including growers, and representation from Department of Natural Resources, SEQ Catchment, native vegetation nurseries, Greening Australia, GrowCom and additional DPI&F and CSIRO staff. A total of 36 people attended. The flyer and results from survey are attached in appendices.

Finally, Dr. Schellhorn gave a presentation to SEQ Catchment. The results of VG 06024 and the future project VG 07040 have links with riparian restoration and NRM targets. As a result of these talks, SEQ Catchment is an official partner for the future work and their restoration sites will be used as demonstration for growers wanting to revegetate degraded areas.

Recommendations

Our outcomes from VG06024 clearly show that there is rational for integrating native vegetation and vegetable pest management. There is support from the majority of growers; there is increasing trend that consumers are becoming more conscious of environmental sustainability of production. The Key recommendations to continue moving towards integration and adoption of Revegetation by Design as part of an IPM strategy include:

1. Progressing the science in the newly funded project VG07040, which include determining: a) whether crops near remnant vegetation result in faster response by beneficial insects, hence greater pest suppression, compared to crops far from remnants; and b) the scale of changes in vegetation management to delay pest colonisation.

2. Create decision-support tools to help growers adopt information about native plants. This activity will require additional funds.

3. Develop a program for adoption and communication activities to support the findings of VG06024 and the new project VG07040. Specific details on recommendations for adoption can be found in section III. This activity will require additional funds.

There are plans to progress activities 2 and 3 with DPI&F QLD Bronwyn Walsh and David Carey.

Appendices

Appendix A. Major vegetable crops grown in Australia. All crops are exotic except for Warrigal greens.

Plant family	Scientific name	Common name
Aizoaceae	*Tetragonia tetragonoides*	Warrigal greens
Alliaceae	*Allium cepa*	onion
Alliaceae	*Allium porrum*	leek
Alliaceae	*Allium sativum*	garlic
Amaranthaceae	*Amaranthus gangeticus*	Chinese spinach (Amaranth spinach)
Apiaceae	*Apium graveolens*	celery
Apiaceae	*Daucus carota*	carrot
Apiaceae	*Pastinaca sativa*	parsnip
Asteraceae	*Lactuca sativa*	lettuce
Brassicaceae	*Brassica oleracea var. alboglabra*	Chinese broccoli
Brassicaceae	*Brassica oleracea var. botrytis*	cauliflower
Brassicaceae	*Brassica oleracea var. capitata*	cabbage
Brassicaceae	*Brassica oleracea var. gemmifera*	brussel sprouts
Brassicaceae	*Brassica oleracea var. gongylodes*	kohlrabi
Brassicaceae	*Brassica oleracea var. italica*	broccoli
Brassicaceae	*Brassica rapa*	turnip
Brassicaceae	*Brassica rapa var. pekinensis*	Chinese cabbage (wombok)
Brassicaceae	*Brassica rapa var. parachinensis*	choy sum, bak choy
Chenopodiaceae	*Beta vulgaris*	beetroot
Chenopodiaceae	*Beta vulgaris var. cicla*	silverbeet, chard
Chenopodiaceae	*Spinacia oleracea*	English spinach
Convolvulaceae	*Ipomoea batatas*	sweet potato
Cucurbitaceae	*Benincasa hispida*	winter melon
Cucurbitaceae	*Citrullus vulgaris*	water melon
Cucurbitaceae	*Cucumis melo cantaluensis*	rock melon
Cucurbitaceae	*Cucumis pepo*	pumpkin
Cucurbitaceae	*Cucumis sativus*	cucumber
Cucurbitaceae	*Cucurbita maxima*	winter squash
Cucurbitaceae	*Cucurbita moschata*	squash
Cucurbitaceae	*Cucurbita pepo*	zucchini
Cucurbitaceae	*Cucurbita pepo medullosa*	marrow
Cucurbitaceae	*Lagenaria siceraria*	bottle gourd
Cucurbitaceae	*Momardica charantia*	bitter gourd
Cucurbitaceae	*Sechium edule*	choko
Fabaceae	*Phaseolus coccineus*	runner bean
Fabaceae	*Phaseolus vulgaris*	French bean
Fabaceae	*Pisum sativum*	garden pea
Fabaceae	*Vigna sesquipedales*	snake bean
Liliaceae	*Asparagus officinalis*	asparagus
Malvaceae	*Hibiscus esculentus*	okra
Poaceae	*Zea mays var. rugosa*	sweet corn
Polygonaceae	*Rheum rhabarbarum*	rhubarb
Solanaceae	*Capsicum annuum*	capsicum
Solanaceae	*Capsicum annuum*	chilli
Solanaceae	*Solanum lycopersicum*	tomato
Solanaceae	*Solanum melongena*	eggplant
Solanaceae	*Solanum tuberosum*	potato
Zingiberaceae	*Zingiber officinale*	ginger

Appendix B. Invertebrate pests of vegetable crops of Australia.

Order	**Family**	**Species, Common name**
Acarina	Eriophyidae	*Aculops lycopersici*, tomato russet mite
Acarina	Penthaleidae	*Halotydeus destructor,* red-legged earth mite
Acarina	Penthaleidae	*Penthaleus major,* blue oat mite
Acarina	Tarsonemidae	*Polyphagotarsonemus latus*, broad mite
Acarina	Tetranychidae	*Tetranychus ludeni,* bean spider mite
Acarina	Tetranychidae	*Tetranychus urticae,* twospotted spider mite
Coleoptera	Cerambycidae	*Apomecyna histrio*, cucurbit stemborer
Coleoptera	Chrysomelidae	*Acanthoscelides obtectus,* bean weevil
Coleoptera	Chrysomelidae	*Aulacophora abdominalis*, plain pumpkin beetle
Coleoptera	Chrysomelidae	*Aulacophora hilaris*, pumpkin beetle
Coleoptera	Chrysomelidae	*Monolepta australis,* monolepta beetle
Coleoptera	Chrysomelidae	*Phyllotreta undulata (=P. nemorum),* striped flea beetle
Coleoptera	Chrysomelidae	*Xenidia picticornis,* potato flea beetle
Coleoptera	Coccinellidae	*Henosepilachna (=Epilachna) cucurbitae*, cucurbit ladybird
Coleoptera	Coccinellidae	*Henosepilachna (=Epilachna) vigintioctopunctata pardalis,* 28-spotted potato ladybird
Coleoptera	Coccinellidae	*Henosepilachna (=Epilachna) vigintisexpunctata vigintisexpunctata,* 26-spotted potato ladybird
Coleoptera	Curculionidae	*Asynonychus cervinus*, Fuller's rose weevil
Coleoptera	Curculionidae	*Cylas formicarius elegantulus*, sweet potato weevil
Coleoptera	Curculionidae	*Desiantha caudata*, spinetailed weevil
Coleoptera	Curculionidae	*Listroderes difficilis (=L. obliquus)*, vegetable weevil
Coleoptera	Curculionidae	*Naupactus (=Graphognathus) leucoloma,* white fringed weevil
Coleoptera	Curculionidae	*Phlyctinus callosus*, garden weevil
Coleoptera	Curculionidae	*Prosayleus dispar,* ground weevil
Coleoptera	Elateridae	*Agrypnus variabilis,* sugarcane wireworm
Coleoptera	Elateridae	*Hapatesus hirtus,* potato wireworm
Coleoptera	Nitidulidae	*Carpophilus* spp., dried fruit beetles
Coleoptera	Scarabaeidae	*Heteronychus arator,* African black beetle
Coleoptera	Scarabaeidae	*Lepidiota* spp., white (cane) grub
Coleoptera	Scarabaeidae	*Rhopaea magnicornis,* large pasture scarab
Coleoptera	Tenebrionidae	*Gonocephalum spp., small false wireworm*
Coleoptera	Tenebrionidae	*Pterohelaeus spp., large false wireworm*
Dermaptera	Forficulidae	*Forficula auricularia,* European earwig
Diptera	Agromyzidae	*Liriomyza brassicae*, cabbage leafminer
Diptera	Agromyzidae	*Liriomyza chenopodii,* beet leafminer
Diptera	Agromyzidae	*Melanagromyza apii,* celery fly
Diptera	Agromyzidae	*Ophiomyia phaseoli (Melanagromyza phaseoli)*, bean fly
Diptera	Agromyzidae	*Phytomyza syngenesiae (=P. atricornis),* cineraria leafminer
Diptera	Anthomyiidae	*Delia platura*, onion maggot
Diptera	Chironomidae	*Smittia aterrima (=S. macleayi),* seedling bean midge
Diptera	Drosophilidae	*Drosophila melanogaster*, vinegar fly
Diptera	Tephritidae	*Bactrocera (=Dacus) cucumis*, cucumber fly
Diptera	Tephritidae	*Bactrocera (=Dacus) tryoni*, Queensland fruit fly
Hemiptera: Auchenorrhyncha	Cicadellidae	*Austroasca viridigrisea*, vegetable jassid
Hemiptera:	Cicadellidae	*Cicadulina bimaculata*, maize leafhopper

Auchenorrhyncha		
Hemiptera: Heteroptera	Alydidae	*Riptortus serripes*, pod sucking bug
Hemiptera: Heteroptera	Dinidoridae	*Megymenum affine (=M. insulare)*, cucurbit shield bug
Hemiptera: Heteroptera	Lygaeidae	*Nysius vinitor,* Rutherglen bug
Hemiptera: Heteroptera	Miridae	*Campylomma liebnechti,* apple dimpling bug
Hemiptera: Heteroptera	Miridae	*Creontiades dilutus*, green mirid
Hemiptera: Heteroptera	Pentatomidae	*Nezara viridula,* green vegetable bug
Hemiptera: Heteroptera	Pentatomidae	*Plautia affinis,* green stink bug
Hemiptera: Heteroptera	Pyrrhocoridae	*Dindymus versicolor,* harlequin bug
Hemiptera: Heteroptera	Rhopalidae	*Leptocoris mitellata,* leptocoris bug
Hemiptera: Sternorryncha	Aleyrodidae	*Aleurodicus dispersus,* spiralling whitefly
Hemiptera: Sternorryncha	Aleyrodidae	*Bemisia tabaci* biotype B, silverleaf whitefly
Hemiptera: Sternorryncha	Aleyrodidae	*Trialeurodes vaporariorum*, greenhouse whitefly
Hemiptera: Sternorryncha	Aphididae	*Acyrthosiphon pisum,* pea aphid
Hemiptera: Sternorryncha	Aphididae	*Aphis craccivora,* cowpea aphid
Hemiptera: Sternorryncha	Aphididae	*Aphis gossypii,* cotton aphid
Hemiptera: Sternorryncha	Aphididae	*Brevicoryne brassicae*, cabbage aphid
Hemiptera: Sternorryncha	Aphididae	*Cavariella aegopodii,* carrot aphid
Hemiptera: Sternorryncha	Aphididae	*Dysaphis foeniculus,* fennel aphid
Hemiptera: Sternorryncha	Aphididae	*Hyperomyzus lactucae*, sowthistle aphid
Hemiptera: Sternorryncha	Aphididae	*Lipaphis pseudobrassicae (=L. erysimi)*, turnip aphid
Hemiptera: Sternorryncha	Aphididae	*Macrosiphum euphorbiae*, potato aphid
Hemiptera: Sternorryncha	Aphididae	*Myzus persicae,* green peach aphid
Hemiptera: Sternorryncha	Aphididae	*Nasonovia ribisnigri*, currant-lettuce aphid
Hemiptera: Sternorryncha	Aphididae	*Rhopalosiphum maidis*, corn aphid
Hemiptera: Sternorryncha	Aphididae	*Smynthurodes betae,* bean root aphid
Hemiptera: Sternorryncha	Pseudococcidae	*Rhizoecus falcifer,* root mealybug
Hymenoptera	Eurytomidae	*Systole albipennis,* parsnip seed wasp
Lepidoptera	Gelechiidae	*Phthorimaea operculella*, potato moth

Lepidoptera	Gelechiidae	*Symmetrischema tangolias (=S. plaesiosema),* tomato stemborer
Lepidoptera	Lycaenidae	*Zizina labradus ssp. labradus,* grass blue butterfly
Lepidoptera	Noctuidae	*Agrotis infusa*, common cutworm
Lepidoptera	Noctuidae	*Agrotis ipsilon*, black cutworm
Lepidoptera	Noctuidae	*Agrotis munda,* brown cutworm
Lepidoptera	Noctuidae	*Chrysodeixis argentifera, tobacco looper*
Lepidoptera	Noctuidae	*Chrysodeixis eriosoma*, green looper
Lepidoptera	Noctuidae	*Helicoverpa armigera,* cotton bollworm
Lepidoptera	Noctuidae	*Helicoverpa punctigera*, native budworm
Lepidoptera	Noctuidae	*Mythimna convecta (=Pseudaletia convecta)*, common armyworm
Lepidoptera	Noctuidae	*Spodoptera exempta*, day-feeding armyworm
Lepidoptera	Noctuidae	*Spodoptera litura*, cluster caterpillar
Lepidoptera	Pieridae	*Pieris rapae*, cabbage white butterfly
Lepidoptera	Plutellidae	*Plutella xylostella*, cabbage moth
Lepidoptera	Pyralidae	*Conogethes punctiferalis (=Dichocrocis punctiferalis)*, yellow peach moth
Lepidoptera	Pyralidae	*Crocidolomia pavonana (=C. binotalis)*, cabbage cluster caterpillar
Lepidoptera	Pyralidae	*Cryptoblabes adoceta*, sorghum head caterpillar
Lepidoptera	Pyralidae	*Diaphania indica (=Phakellura indica)*, cucumber moth
Lepidoptera	Pyralidae	*Hellula hydralis*, cabbage-centre grub
Lepidoptera	Pyralidae	*Hymenia recurvalis*, beet webworm
Lepidoptera	Pyralidae	*Maruca vitrata (=M. testulalis)*, bean podborer
Lepidoptera	Pyralidae	*Sceliodes cordalis*, eggfruit caterpillar
Lepidoptera	Sphingidae	*Agrius convolvuli,* concolvulus hawk moth
Lepidoptera	Sphingidae	*Hippotion celerio,* grapevine hawk moth
Lepidoptera	Sphingidae	*Hippotion scrofa,* scrofa hawk moth
Lepidoptera	Sphingidae	*Theretra oldenlandiae,* vine hawk moth
Lepidoptera	Tortricidae	*Epiphyas postvittana,* light brown apple moth
Lepidoptera	Tortricidae	*Merophyas divulsana,* lucerne leaf-roller
Orthoptera	Acrididae	*Phaulacridium vittatum, wingless grasshopper*
Orthoptera	Gryllidae	*Teleogryllus commodus,* black field cricket
Orthoptera	Gryllotalpidae	*Gryllotalpa africana*, African mole cricket
Thysanoptera	Thripidae	*Frankliniella occidentalis,* western flower thrips
Thysanoptera	Thripidae	*Frankliniella schultzei,* tomato thrips
Thysanoptera	Thripidae	*Frankliniella williamsi,* maize thrips
Thysanoptera	Thripidae	*Megalurothrips usitatus (=Taeniothrips nigricornis)*, bean blossum thrips
Thysanoptera	Thripidae	*Thrips imaginis, plague thrips*
Thysanoptera	Thripidae	*Thrips palmi, melon thrips*
Thysanoptera	Thripidae	*Thrips tabaci,* onion thrips

Appendix C. Flyer announcing workshop organised and conducted by David Carey DPI&F

Queensland **the Smart State**

Integrating native vegetation with intensive farming

INFORMATION SESSION

Is your creek bank, gully or nearby bushland working for you or against you?

Come and hear about the latest local research results

Is native vegetation a source of beneficial insects – if so which ones, how are they helping and can you get more from them?

Can your farming operation benefit more from your surroundings?

See the facts: the latest local research results from Dr Nancy Schellhorn, CSIRO Entomology.

The session will include a bus trip to look at:

NATIVE VEGETATION

- What insects we've found and what they do for you
- What you should and should not plant near crops

CREEK BANKS

- Are they an undervalued, under-utilised resource?
- An opportunity to breed your own beneficial insects
- Remove weed seed sources and replant beneficial native plants

SALT SCAR RECLAMATION

- See what can be done

CREEKS

- Bed and bank stability
- Reduction of erosion and soil loss

Listen to other relevant information and ask questions of people from SEQ Catchments, Department of Natural Resources and Water, Greening Australia, Landcare, Envirofund and others.

When: Tuesday 24 June 2008
Where: Department of Primary Industries and Fisheries (DPI&F) Gatton Research Station
When: 2.30–5.30 pm (includes afternoon tea)

Numbers are limited—please RSVP by calling 5466 2222 by 4.30 pm 19 June 2008

Appendix D. Responses from workshop participants. Tabulated by Mr. David Carey.

Presentation Feed-back Sheet Responses

After hearing the results of the beneficial insects and native vegetation survey. What are your thoughts?

Did the information surprise you ? Y / N

7 yes / 9 no

Yes – 1 surprised pleasantly

What did you find unusual or learn? Responses

Predator numbers on natives versus crops / surprised how many pests are native. Relative dist'n of pests & non pests between different species ?Great info on useful native vege families / Can plant natives that won't create pests / Ratio of native to non native pests/How many types of insects travel into crops / Liked holistic approach to crop pest control /Scale of insect pest &/ predation relation

Did the information make you think differently about native vegetation and it's role in pest control around crops and vegetables ? Y / N

12 yes / 4 no

If so - how? Like to replace exotic weeds around paddock with native vege / Had little idea about pest predators in native vege / Firmed up the idea it is useful / Investigate what types of vege and what distance from crop and area needed to make a difference / Made me realize native plants important ecologically and crop wise / Actively plant more natives along creek bank/

Did the presentation demonstrate and explain the potential benefits of native vegetation areas near intensively cropped areas? Y / N

16 yes / 0 no

Do you think native vegetation could reduce pest pressure by providing a safe sheltered breeding area for beneficial insects? Y / N

15 yes / 0 no

Has todays' information made you more or less likely to plant native vegetation in a currently underutilized area of your property? Y / N

16 yes / 0 no

Do you think there are more benefits from having native vegetation areas or do you consider it may add to pest problems ? Benefit / Problem

16 respondants all said benefit

Would you now consider maintaining or creating native veg areas. Y / N

16 yes / 0 no

Have you met people who could assist you today at this info session? Y / N

15 yes / 0 no

PLEASE HAND IN THIS SHEET AS ***YOU LEAVE THE CONFERENCE ROOM***
– YOU MAY BE REWARDED FOR YOUR EFFORTS-
Name or initials are optional. Thankyou for your feedback

Appendix E. References from the literature review

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