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By Michael Clarke, Dr Robert Gillespie and Dr Saul Cunningham

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Foreword

This project has quantified the regional economic impact of closing the pollination deficit across crops and provided more general conclusions on the national economic impact of pollination deficits.

While considerable focus of recent research has been directed toward the total value of pollination services and what is at risk from incursion of highly destructive honey bee pests such as *Varroa destructor*, less is known about the current state of pollination and whether there is a net economic gain from addressing under-pollination.

This study examined the deficit between current and optimal pollination across crops dependent on insect pollination in the Shepparton Region of Victoria. It found that there were substantial losses in business turnover, value-added, income and employment as a result of a pollination deficit. Furthermore, the deficit can be closed through investment and improved information flow.

Results from this study are relevant to policy makers, agricultural producers and beekeepers. Policy makers will be interested in the finding that showed that investment in improving pollination efficiency, that closed the pollination gap, would deliver gains in economic outcomes for industries and regional economies from closing the pollination gap. Agricultural producers and beekeepers would also earn additional economic rent.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our Honey Bee and Pollination R&D Program, which aims to support research, development and extension that will secure a productive, sustainable and more profitable Australian beekeeping industry and secure the pollination of Australia's horticultural and agricultural crops.

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

John Harvey
Managing Director
Rural Industries Research and Development Corporation

Abbreviations

ABS	Australian Bureau of Statistics
APAL	Apple and Pear Australia Limited
DAFWA	Department of Agriculture and Food in Western Australia
DPI	Department of Primary Industries
DPIPWE	Department of Primary Industries, Parks, Water and Environment Tasmania
GRDC	Grains Research and Development Corporation
GRIT	Generation of Regional Input-Output Tables
GVP	Gross Value of Production
LGA	Local Government Areas
MAF	Ministry of Agriculture and Forestry New Zealand
NEC	Not Elsewhere Classified
RIRDC	Rural Industries Research and Development Corporation
SA4	Statistical Area 4 (a group of local government areas defined by the ABS)

Contents

Executive Summary

What the report is about

This report quantifies the current impact of a shortfall in insect pollinators on the regional economy of Shepparton Victoria. While some data has been available on the loss of yield and crop quality as a result of a pollination deficit, this study is the first attempt at quantifying both the direct and indirect impact on a regional economy.

Who is the report targeted at?

The report is targeted at policy makers including those concerned with the allocation of resources to pollination research; economic policy analysts including those focussed on regional development and natural resource management; farmers especially those engaged in growing crops identified as experiencing a pollination deficit; and beekeepers who might realise an economic opportunity by better marketing their pollination services.

Where are the relevant industries located in Australia

The relevant industries affected by a pollination deficit are located Australia wide. In Shepparton they include apple, pear, cherry, peach, nectarine, plum, apricot, canola, pasture hay and improved pasture used for dairy production. Intensive irrigated horticulture has an especially high demand for pollination services and these crops are well represented in Shepparton.

Background

Pollination is the movement of male pollen grains from the anthers of a flower to the female stigma of the same or different flowers. Once on the stigma the pollen grain must germinate and the resulting pollen tube must break through the stigmatic tissue and down through the style to reach the ovule. The genetic material in the pollen tube then combines with an ovule to create a fertilised seed. For a commercial crop this needs to happen reliably and often.

A pollination deficit occurs when a crop whose production is dependent on insect pollination receives a less than optimal amount of insect visits.

Under-visiting of a crop by native bees, flies and beetles can result from too small a population of these pollinators for the crop in question, difficulty in penetrating central areas of large crop monocultures and agricultural management techniques (such as use of insecticides) that reduce the population of pollinating insects.

Causes of a honey bee pollination deficit may include an insufficient density and strength of hives, suboptimal proximity and distribution of honey bee colonies within the crop, alternative honey bee targets for pollen and nectar gathering and paid pollination services that are understocked relative to best practice.

Objectives

The objectives of this study were to:

1. Quantify the regional economic impact of a pollination deficit across crops
2. Provide more general conclusions on the national economic impact of pollination deficits
3. Provide an evidence base for decision-makers in relation to the regional economic costs of pollination deficits.

Methods used

An input-output model was developed for the Shepparton region of Victoria and the model was used to determine both the direct and multiplier impacts of closing the pollination deficit on regional output/business turnover, value added, household income and employment.

Results from the regional analysis were used to draw more general and somewhat more speculative conclusions on the national economic impact of closing the pollination deficit.

Key findings

The study found that closing the pollination deficit would result in an increase in Shepparton region business turnover of $78 million, an increase in value-added of $35 million, additional household income of $5 million and the creation of 106 jobs – Table E1.

Table E1 Direct and Indirect Impact of Closing the Pollination Deficit in Shepparton Region ($000)

	Direct Effect	Production Induced	Consumption Induced	Total Flow-on	TOTAL EFFECT
BUSINESS TURNOVER	51,600	23,002	3,768	26,770	78,370
Type 11A Ratio	1.00	0.45	0.07	0.52	1.52
VALUE-ADDED	23,669	9,437	2,236	11,673	35,342
Type 11A Ratio	1.00	0.40	0.09	0.49	1.49
INCOME	-	4,345	828	5,173	5,173
EMPLOYMENT (No.)	-	87	19	106	106

Definitive assessment of the national economic impact of a pollinator deficit requires a separate study. However, estimates of national impact have been prepared by scaling up the impacts identified in Shepparton to the national level using relative share of Gross Value of Production and developing a new pollination sector and inserting that sector into the National Input-Output Table 2013 (inflated to 2016).

On this basis, the national economic impact of closing the pollinator deficit is a $1 billion increase in business turnover, a $476 million increase in value-added, $156 million in additional household income and 2,384 additional jobs created.

Implications for relevant stakeholders

The current pollination deficit across crops in the Shepparton Region of Victoria is economically significant, costing the community lost business turnover, value-added, income and employment. The pollination deficit can be closed through investment and improved information flow.

Recommendations

Findings from this study are worthy of communication to policy makers, agricultural producers beekeepers and natural resource managers.

1. Introduction

This project has been completed as part of the Rural Industries Research and Development Corporation (RIRDC) Honey Bee and Pollination Program. The aim of the program is to support research, development and extension (RD&E) that will secure a productive, sustainable and more profitable Australian beekeeping industry and secure the pollination of Australia's horticultural and agricultural crops.

Objective 4 of the Honey Bee and Pollination Program 5 Year RD&E Plan 2015-19 is to 'Understand the role of pollination in delivering more productive systems'. Consistent with Objective 4 Research Priorities for 2015 identify the need to 'Calculate regional economic multiplier impacts of potential pollinator deficits across crops'.

Consequently the objectives of this project were to:

- Quantify the regional economic impact of a pollination deficit across crops
- Provide more general conclusions on the national economic impact of pollination deficits
- Provide an evidence base for decision makers in relation to the broader economic costs of pollination deficits.

Study Approach

Previously the Honey Bee and Pollination Program had supported analysis of yield and crop value loss as a result of Australian pollinator deficits (e.g. Keogh *et al* 2010, Barry *et al* 2010, Goodwin 2012). This project used these data to develop a more complete picture of the economic cost of Australian pollinator deficits.

Although crop pollination is achieved by a wide range of insects the focus of the research is honey bees. The application of honey bees to crops is one of the best known management interventions for boosting pollination and beekeepers have an interest in expanding crop pollination services where this is economically viable.

Regional economic multiplier impacts of a pollination deficit were estimated for the representative region of Shepparton Victoria. An input-output model was developed for the Shepparton region and the model was used to determine both the direct and multiplier impacts of a pollinator deficit on regional business turnover; value added; income and employment.

Results from the regional analysis were used to draw more general and somewhat more speculative conclusions on the national economic impact of a pollinator deficit.

2. Shepparton Region Defined

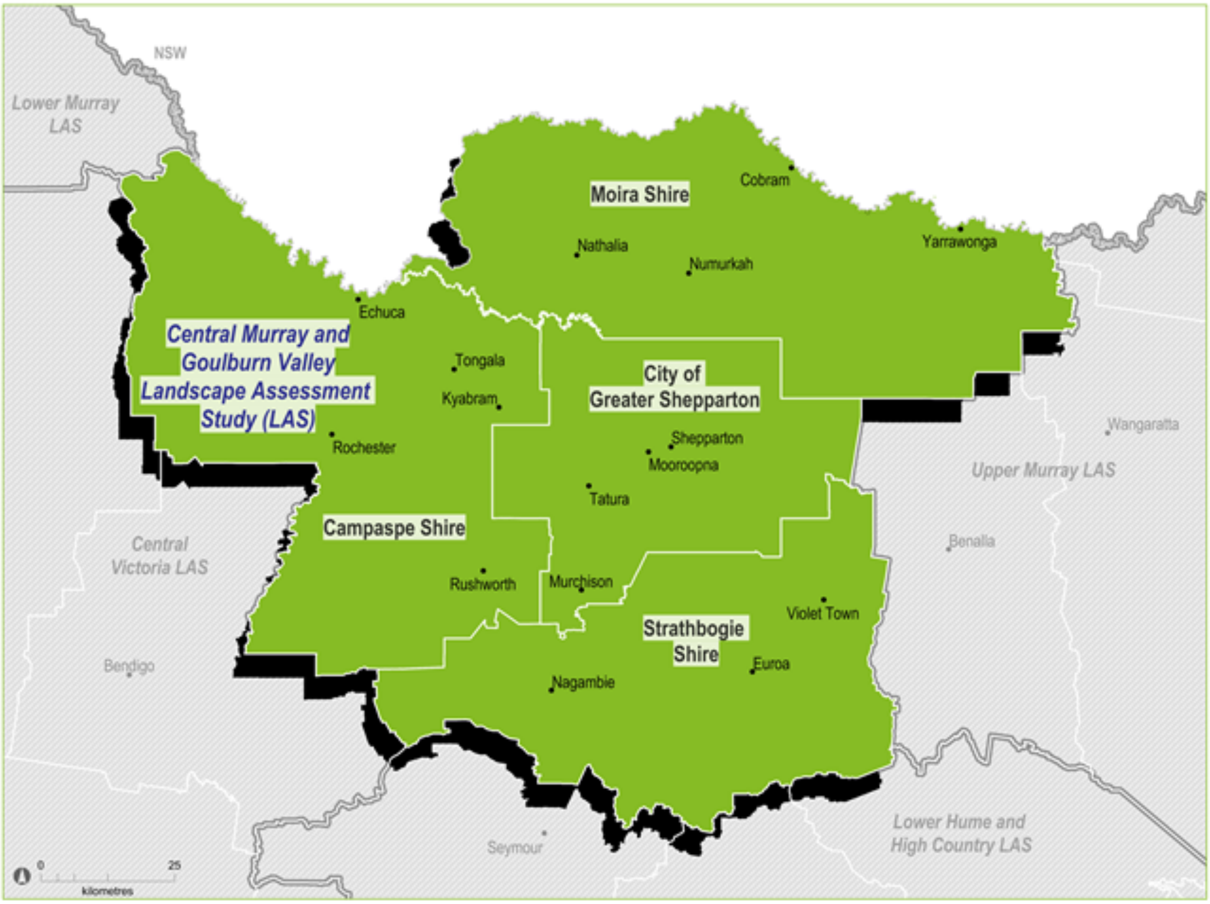
Reasons for Selecting Shepparton as the Study Region

To demonstrate the economic impact of a potential pollinator deficit across crops a region was sought with a high demand for pollinator services. Intensive irrigated horticulture has a high demand for pollinator services and the Shepparton Region of Victoria includes large areas of these crops.

Definition of the Study Region

The study area has been defined as the Australian Bureau of Statistics (ABS) Shepparton Statistical Area 4 (SA4) region comprising the local government areas of the City of Greater Shepparton, Moira, and Campaspe local government areas (LGAs) – Figure 1.

Figure 1: Shepparton (SA4) – City of Greater Shepparton, Moira and Campaspe LGAs



Source: Victoria Government http://www.dtpli.vic.gov.au/planning/plans-and-policies/rural-and-regional-planning/landscapestudies/central-murray-and-goulburn-valley-landscape-assessment-study

This aggregation provided ready access to ABS agricultural production area, enterprise number, value and employment data, required for the regional input-output model. This data is not available for the larger SA3 or Natural Resource Management data sets.

Agriculture in the Shepparton Region

The gross value of agricultural commodities Shepparton SA4 2014-15 is presented in Appendix 1.

Analysis of pollinator deficits focused on the larger and more valuable agricultural industries in the Shepparton SA4. Larger industries were selected to highlight differences in the 'with' and 'without' pollination deficit situations, smaller industries would not show up in the regional input-output model. A cut off of $10 million Gross Value of Production (GVP) in 2014-15 was used for selecting larger industries.

Larger agricultural industries with a GVP greater than $10 million and their share of total Shepparton GVP are summarised in Table 1.1.

Nineteen larger agricultural industries cover 95% of the total value of agricultural production.

Table 1.1 Shepparton Agricultural Industries with GVP Greater than $10 million (2014-15)

Commodity	Gross Value ('million)
Wheat	131.3
Barley	23.8
Cereal hay	61.4
Canola	56.3
Apples	179.8
Pears	101.5
Cherries	18.7
Nectarines	24.9
Peaches	34.0
Plums and apricots	16.8
Tomatoes – processing	22.5
Tomatoes – fresh	53.7
Lucerne hay	44.4
Pasture hay	26.2
Wool	23.1
Milk	754.0
Sheepmeat	46.4
Beef cattle	249.8
Pigs	42.6
Total GVP >$10 million	**1,911.2**
Total all Shepparton SA4	**2,009.1**
Large industry share of total	**95%**

Source: 75030DO001_201415 Value of Agricultural Commodities Produced, Australia, 2014-15, Table 3: Value of Agricultural Commodities Produced, State and SA4 Region–Victoria–2014-15

3. Pollination Deficits in Australian Agriculture

Pollination is the movement of male pollen grains from the anthers of a flower to the female stigma of the same or a different flower. Once on the stigma the pollen grain must germinate and the resulting pollen tube must break through the stigmatic tissue and down through the style to reach the ovule. The genetic material in the pollen tube then combines with an ovule to create a fertilised seed. For a commercial crop this needs to happen reliably and often (Goodwin 2012).

Some flowers will be pollinated by the movement of pollen in the wind, but for many crops the pollination rate is much higher when insects visit flowers and move pollen on their bodies. Honey bees are very important flower visitors, but a range of other native bees, flies and beetles can also be important. A few crops benefit from bird or bat pollination, but none of these crops are grown in the Shepparton region.

Why a Pollination Deficit Occurs

A pollination deficit can occur when a crop whose production is dependent on insect pollination receives a less than optimal amount of insect visits.

For insect pollination dependent crops a less than optimal amount of insect visits will result in crop yield and/or quality loss (Keogh *et al* 2010).

Under Pollination by Wild Pollinators

Insects other than managed honey bees contribute to crop pollination, but in many circumstances they will not provide an optimal service. Reasons for this form of under pollination include:

- Populations of wild insects are geared to the availability of suitable floral resources over the course of their life time, and may not be able to respond to short periods of intense flowering, such as occurs with agricultural crops
- Large monocultures associated with commercial cropping – wild pollinators may not penetrate to the centre of large fields because the environment does not provide the other resources that they need (e.g. nesting sites, food diversity)
- Agricultural management techniques – chemical sprays used to manage pest insects and disease agents may have unintended impacts on the population of beneficial pollinating insects

Wild insects cannot usually service a whole crop in broad scale monocultural plantings (Cunningham *et al* 2002).

Under Pollination by Honey Bees

Causes of a honey bee pollination deficit include (Keogh *et al* 2010):

- Density and strength of honey bee hives (managed)
- Proximity and distribution of honey bee colonies (feral)
- Competition with alternative floral resources
- Understocked paid pollination
- Other factors

Each of these causes of under pollination by honey bees is reviewed below.

Density and Strength of Honey Bee Hives

Factors affecting the density and strength of honey bee hives and hence the quality of pollination services include the strength of unmanaged (feral) populations and the stocking of honey bees to maximise honey production rather than pollination.

<u>Feral bees</u>: available information on feral bee populations in Australia indicates that hive densities are extremely variable. One study has shown that feral colony densities in the general landscape are less than one per hectare and often less than half that amount (Patton 1996). Furthermore populations vary with the seasons and from year to year. The number of individuals in a feral colony is likely to be in the order of 10,000 (Patton 1996). These densities contrast with the hive density recommended for optimal pollination of 2 to 8 or more hives per hectare and with hive strengths of 50-60,000 individuals (Keogh *et al* 2010). A 10,000 individual hive is at a minimum sustainable level and has relatively few bees available for foraging for pollen and nectar and thereby performing pollination services. Commercial hives are carefully managed to increase hive strength to a level that is not normal in a feral colony.

<u>Hives managed for honey production</u>: where bees are managed for honey production optimal stocking densities are likely to be about one per hectare, each with a population of 20-30,000 individuals. The pollination potential of this arrangement is also likely to be an order of magnitude less than that required for optimal pollination, meaning that producers of pollination-responsive crops who rely on this incidental source of pollination are likely to severely under-serviced (Keogh *et al* 2010).

Proximity and Distribution of Honey Bee Hives

The proximity of the population of honey bees to and their distribution amongst the target crop is an important factor in determining pollination effectiveness. Ideally honey bees should be either close to or in the crop and evenly distributed 150-300 metres apart. Unmanaged honey bee colonies cannot meet this requirement. Consequently pollination will be non-uniform with plants on the outside more likely to receive pollination (Ricketts *et al* 2004). A common trend in both horticulture and agriculture is increasingly large plantings, larger plantings further exacerbate non-uniform pollination (Keogh *et al* 2010).

Alternative Targets

Many pollination dependent crops are not highly attractive to honey bees as sources of pollen and nectar. For example honey bees placed in a cherry orchard to deliver pollination services might be drawn away from this crop to nearby flowering canola. The timing of introduction and placement of hives associated with paid pollination can be used to force bees to forage amongst the target crop (Keogh *et al* 2010). Forcing managed honey bees to forage on the target crop requires planning by the beekeeper.

Understocked Paid Pollination

Growers may augment background insect pollination with the introduction of hives managed for pollination. Supplementary paid pollination may still be less than optimal and result in a pollination deficit. For example Cunningham *et al* (2016) found that almond orchard yields could be improved with better distribution of honey bee hives introduced for paid pollination.

Other Factors

Other factors that can cause a pollination deficit include lack of honey bee access to water and the death or damage to honey bees caused by agricultural chemicals. Managed pollination can minimise these risks, incidental pollination carries these risks (Keogh *et al* 2010).

In Summary

Where the optimal pollination of a crop would normally require greater than 1 honeybee hive/ha it is likely that reliance on vectors other than honey bees managed for pollination will result in crop yield and/or quality being foregone.

Which Crops Are Vulnerable to a Pollination Deficit?

Crops vulnerable to a pollination deficit are those that are difficult to pollinate and those that do not provide a honey production or bee health benefit to the beekeeper from placing hives in the crop.

Crops that are highly responsive to pollination (i.e. there is a major gain in crop yield and/or quality as a result of efficient pollination) provide a strong economic incentive for the grower to invest in paid pollination at the correct honey bee hive stocking rate. These crops include almonds and high value specialty commodities such as vegetable and lucerne seed crops.

Crops that provide an economic return to the beekeeper from placing hives in the crop include macadamia which is capable of producing both a high value honey and a gain in hive strength early in the honey production season.

Crops that fall between these two categories, may in some instances, receive paid pollination services to 'top up' the background level of incidental pollination. These crops include apples, pears, cherries and other summerfruit (Keogh *et al* 2010). Although Leach (2014), notes a high reliance on feral bees in the apple, pear, cherry and blueberry industries.

Insect pollination dependent crops that fall outside these categories (highly responsive to pollination, economic return for beekeepers, paid top up) are likely to forego some yield and quality (size and shape) benefits unless they are fortunate enough to benefit from high levels of free pollination by wild insects. This free service is poorly understood, and varies greatly from place to place and from year to year.

Economic Impact of a Pollination Deficit

Australian agriculture is highly dependent on insect pollination, in particular pollination provided by the honey bee, and a large fraction of agricultural pollination is provided as an unpaid service by honey bees (Cunningham *et al* 2002).

The contribution of pollinators is not always measured by their effect on fruit number. For multi-seed fruits such as apples and pears growers are more concerned with maximising fruit quality rather than quantity. A well-pollinated pome fruit will contain more seeds which prompts the development of a bigger and better shaped fruit with more market value (Cunningham *et al* 2002).

For some single-seed fruits such as cherries and plums, pollination is more important for the quantity of yield (Cunningham *et al* 2002).

Ample pollination can also reduce the time between flowering and fruit set. By shortening this period the risk from exposing developing fruits to pests and diseases and bad weather is reduced and there can be savings in water, fertiliser and pesticide (Cunningham *et al* 2002).

Most nitrogen fixing pasture legumes, such as clover and lucerne, also benefit from insect pollination. Insect pollination is therefore critical to maintaining good grazing land in particular high intensity grazing land such as that used by the dairy industry (Cunningham *et al* 2002).

Farmers generally buy seed to maintain good nitrogenous fodder in their pastures, with legumes being a key ingredient. When buying seed, farmers are indirectly paying for pollination services. This is true for seeds of vegetables such as onions and carrots as well as clovers and lucerne for pasture. The pollination cost can be as much as 25% of the seed price (Westerkamp and Gottsberger 2000, Kevan and Phillips 2001 reported in Cunningham *et al* 2002).

If legumes in the farmer's own fields are well pollinated and set ample seed, less seed needs to be subsequently purchased. Ministry of Agriculture and Forestry (MAF) New Zealand modelling noted that the major cost of honey bee destroying Varroa mite was production losses associated with dairy and clover reseeding costs in the pastoral sector (MAF 2000). The production of lucerne in Australia is currently limited by pollination problems that prevent high levels of seed production (Cunningham *et al* 2002).

Broadacre crops like wheat and barley are wind pollinated and do not require insect vectors (Cunningham *et al* 2002).

Economic Impact of a Pollination Deficit in the Shepparton Region

It is important to note that definitive data on the magnitude of pollination deficits in the Shepparton region, or even Australian agriculture, is simply not available. Instead this study has relied on relevant literature and the development of informed assumptions based on that literature.

The analysis completed in Chapter 2 of this report identified 19 separate agricultural commodities in the Shepparton SA4 with a GVP greater than $10 million in 2014-15. Each commodity is now reviewed for its dependence on insect pollination, current sources of any pollination deficit and the assumed economic impact of the pollination deficit.

Wheat, Barley and Cereal Cut for Hay

Cereals are grown for grain, less successful crops may be cut for hay production. Cereals are wind pollinated and do not produce nectar, odour or colourful petals that would attract insect pollinators. Klein *et al* (2006) found no increase in production attributable to insect pollination.

Canola

Dependence on insect pollination

- Canola is grown for the production of seed which is crushed to produce edible oil
- Canola has self-fertile flowers but seed set is enhanced with cross pollination. Cross pollination can occur with wind but is improved with insect pollination (Goodwin 2012)
- In the absence of adequate pollination the number of seeds set is reduced (Klein *et al* 2016)
- While dependent on variety, canola is on average 15% dependent on insect pollination for its seed yield (Cunningham *et al* 2002). Recent studies have also shown that better cross pollination can improve oil quality and seed size (Bommarco *et al* 2012)
- A honey bee hive stocking rate of 1.28 hives/ha has been shown to be too low for some canola varieties (Goodwin 2012). Somerville (2002) suggests an optimal stocking rate for canola pollination of 6 hives/ha.

Current source of pollination deficit

- Canola flowers are attractive and rewarding for honey bees and beekeepers receive an economic return from servicing canola crops. Canola flowers produce large volumes of nectar and a valuable honey crop (Somerville pers comm 2015)
- Honey production stocking rates are less than those required for optimal pollination
- Somerville (2002) suggests the normal stocking rate for honey production is 0.5 hives/hectare

Assumed economic impact of pollination deficit

- Honey production stocking rates are less than those required for optimal pollination and some loss of yield and quality will occur. An income loss estimate of between 5% and 15% has been assumed in this study.

Apples

Dependence on insect pollination

- Apples are mostly sold as whole fruit, a small volume is processed for sauce and cider
- Most varieties are self-incompatible, flowers that are not pollinated are shed by the tree
- Apple is 90% dependent on insect pollination for its fruit yield (Cunningham *et al* 2002)
- Apple blossom is attractive to honey bees and beekeepers can use apple orchards to build hive strength and prepare them for honey production on other crops in other locations
- Over-pollination can result in the need to thin the apple crop. Under-pollination can result in uneven seed set in the fruit and misshapen apples (Cunningham pers comm 2016)
- Apple yield and quality are dependent upon the intensity of pollination (Keogh *et al* 2010)
- Optimal apple pollination has been researched since the 1970s, with recommendations of 1 to 12 hives/ha (Delaney and Tarpy 2008) with average rates in the scientific literature of 2 to 4 hives/ha. High density orchards should be stocked at 3 to 5 hives/ha (Keogh *et al* 2010).

Current source of pollination deficit

- Although use of paid pollination is a common strategy, some growers chose to rely on wild pollination (Leach 2014)
- Leach (2014) notes a high perceived reliance on feral honey bees by apple growers
- The principles of good pollination may not be given sufficient attention in the apple orchard, especially during the busy spring season (Somerville 1999; Vicens and Bosch 2000).

Assumed economic impact of pollination deficit

- Optimal pollination is not always accomplished in Shepparton apple orchards, the importance of feral bees may be overestimated and stocking rates for newer high intensity orchards may be less than recommended. An overall loss in gross margin, reflecting yield but especially quality problems associated with under-pollination has been assumed. The quantum of this loss has been estimated at between 5% and 10%.

Pears

Dependence on insect pollination

- Pears are grown for fruit which are sold fresh and canned
- Pears are not self-compatible and honey bees are their most important insect pollinators (Goodwin 2012). Wind is also important in pollinating pears (Keogh *et al* 2010)
- Pear is 50% dependent on insect pollination for its fruit yield (Cunningham *et al* 2002)
- High concentrations of foraging bees in the crop have not only been shown to ensure a good fruit set, but will also increase seed numbers in each pear. This in turn ensures better, even-shaped fruit and improved storage qualities (DPI Victoria 2008 in Keogh *et al* 2010)
- Optimal pear pollination is reported in the literature as ranging from 1 to 5 hives/ha for low density orchards and 5 hives/ha for high density orchards (Keogh *et al* 2010).

Current source of pollination deficit

- Leach (2014) notes a high perceived reliance on feral honey bees by pear growers
- Despite the fact that pear trees rely heavily on insects for pollination they are not very attractive to honey bees and bees will leave pear trees to pollinate other crops and weeds. Pear tree pollination with honey bees requires careful management and skill (Keogh *et al* 2010)

Assumed economic impact of pollination deficit

- As a consequence of a relatively low attraction of honey bees to pears and the need for high stocking rates, optimal pollination is not always accomplished in Shepparton pear orchards. An overall loss in gross margin, reflecting yield but especially quality problems associated with under-pollination has been assumed. The quantum of this loss has been estimated at 5%.

Cherries

Dependence on insect pollination

- Cherries are grown for fruit which are mostly sold fresh
- Most varieties are self-incompatible i.e. pollen must be introduced to the stigma of a flower on a different tree
- Pollination is by insects and honey bees are the most important insect pollinators
- Cherry is 90% dependent on insect pollination for its fruit yield. Fruit size and shape are not pollination dependent (Cunningham *et al* 2002)
- A high honey bee stocking rate of 10 hives/ha is recommended for optimal cherry pollination (Goodwin 2012)

Current source of pollination deficit

- High reliance of feral honey bees for pollination by cherry growers (Leach 2014)
- The supply of pollination services from feral honey bees is inconsistent (Keogh *et al* 2010)
- Understocking may occur when managed pollination is used, e.g. rate more likely to be 6 hives/ha

Assumed economic impact of pollination deficit

- Optimal pollination is not always accomplished in Shepparton cherry orchards, the role being played by feral bees may be overestimated and paid pollination stocking rates may be less than optimal. As a consequence cherry yield is reduced by an estimated 10%. Under pollination does not impact fruit quality.

Peaches and Nectarines

Dependence on insect pollination

- Peaches and nectarines are grown for fruit which are mostly sold fresh. Peaches grown in the Shepparton region are also canned
- Peaches and nectarines come in varieties that are both self-fertile and self-sterile. Regardless of the variety there is strong evidence that a commercial crop cannot be obtained in the absence of pollinating insects (Keogh *et al* 2010)
- Peaches and nectarines are 60% dependent on insect pollination for their fruit yield. Fruit size and shape are not pollination dependent (Cunningham *et al* 2002)
- Peach and nectarine nectar is highly attractive to honey bees
- The Department of Agriculture and Food West Australia (2005) recommends 2 hives/ha for young trees and 2.5 hives/ha in older orchards

Current source of pollination deficit

- Peach and nectarine growers use paid pollination to back up other 'background' pollination sources (Cunningham *et al* 2002)
- High density plantings require higher stocking rate levels than traditional orchards – 3 to 4 hives/ha have been suggested. Pollination needs to be carefully managed during a period when chemical sprays that are potentially harmful to honey bees are needed (e.g. dormancy breaking and thinning chemicals) – adverse use of chemicals may reduce pollination effectiveness. As a consequence pollination, especially in newer high density plantings may be less than optimal

Assumed economic impact of pollination deficit

- Optimal pollination is not always achieved in Shepparton peach and nectarine orchards. Under pollination affects yield and a 5% reduction is assumed. Under-pollination does not impact peach and nectarine fruit quality.

Plums and Apricots

Dependence on insect pollination

- Plums and apricots produce fruit which is sold fresh and dried. Dried plums are known as prunes
- Plums and apricots come in varieties that are both self-fertile and self-sterile. Most are self-sterile and honey bees are important crop pollinators for both summerfruit types (Keogh *et al* 2010)
- Plums and apricots are 70% dependent on insect pollination for their fruit yield (Cunningham *et al* 2002). Effective pollination also results in improved fruit weight, adequate seed formation / full kernels and a decreased incidence of deformed fruit (Keogh *et al* 2010)
- Honey bees are not especially attracted to plums and apricots. In particular apricot nectar is low in sugar and honey bees may be drawn away from both crops in the absence of careful management.
- Stocking rates recommended in the literature vary from 2 to 6 hives/ha (DAFWA 2005, Keogh *et al* 2010, Goodwin 2012)

Current source of pollination deficit

- Management required to ensure good pollination is often missing from plum and apricot orchards and pollination is dependent on informed hive placement (Keogh *et al* 2010)
- Both plums and apricots experience problems with a shortage of pollinators at flowering. In particular apricots flower early in the spring (mid-August) when conditions are cool, more likely to be wet and not suitable for pollination (Goodwin 2012)

Assumed economic impact of pollination deficit

- Optimal pollination is not always achieved in Shepparton plum and apricot orchards. An overall loss in gross margin, reflecting both yield and quality problems associated with under-pollination has been assumed. A loss of 10% has been estimated.

Tomatoes

Dependence on insect pollination

- Tomatoes are grown for their fruit which is sold fresh and for processing. The Shepparton region supports a large tomato processing industry. While most Shepparton tomatoes are field grown there is also a greenhouse based industry
- Field grown tomatoes rely on wind pollination. Greenhouse grown tomatoes require the use of handheld vibrators sometimes with the addition of honey bees. In a single trial, honey bees provided better pollination than vibrators and vibrators plus honey bees were better than vibrators alone (Goodwin 2012)
- In countries where they are available, bumblebees contribute to greenhouse pollination of tomatoes (Klein *et al* 2006). Bumblebees are not present on the Australian mainland
- Tomatoes have very low dependence on insect pollination for yield when field grown and a high dependence when greenhouse grown (Cunningham *et al* 2002)

Current source of pollination deficit

- Minor reliance on insect pollination, pollination deficit will be something less than the 1% contributed by insects.

Assumed economic impact of pollination deficit

- No significant loss in pollination and no economic impact incurred.

Lucerne Hay

Dependence on insect pollination

- Lucerne is grown and grazed as a fresh pasture and preserved as hay and silage
- Lucerne is 100% dependent on insect pollination for seed set (Cunningham *et al* 2002)
- The lucerne seed industry is dependent on effective pollination. Effective pollination is not relevant to lucerne hay production – lucerne stands are cut for hay before seed is set

Current source of pollination deficit

- Honey bees are the major source of pollination for lucerne seed production in Australia and honey bees are not attracted to lucerne flowers. Honey bees pollinating lucerne flowers receive a blow to the head when the lucerne flower is stripped and soon learn to avoid the experience (Keogh *et al* 2010).

Assumed economic impact of pollination deficit

- Lucerne is grown for production of seed, livestock pasture and conserved fodder. Lucerne cut for hay is a major economic activity in the Shepparton region.
- 80% of the lucerne seed produced in Australia and used in Shepparton to produce hay is grown in Keith, Naracoorte, Tintinara and Bordertown South Australia (Keogh *et al* 2010)
- Production of this seed is currently limited by pollination problems (Cunningham *et al* 2002) and the cost of pollination can be as much as 25% of the seed price (Westerkamp and Gottsberger 2000, Kevan and Phillips 2001 reported in Cunningham *et al* 2002)
- While lucerne seed is not produced in Shepparton it might be argued that an embedded cost is incurred by local lucerne hay growers and this cost is expressed as an increase in the cost of lucerne seed/ reduction in profit associated with the enterprise. However, a change in the status quo would require technical solutions to under pollination in South Australia, outside the Shepparton SA4 case study area, and confidence that the technical solution to lucerne seed pollination is so effective that it results in a reduction in the price of South Australian lucerne seed. This is unlikely as lucerne seed is an internationally traded commodity whose price is set by the world market.
- There is no change in lucerne hay gross margin – yield and income remain the same.

Pastures Incorporating Clover – for Pasture Hay, Milk, Lamb, Beef and Wool Production

Dependence on insect pollination

- Clover species are 90% dependent on insect pollination for seed set (Cunningham *et al* 2002)
- Honey bees are the most important pollinators of clover (Goodwin 2012)
- Honey bees are attracted to clover which produces significant nectar and reasonable quality pollen (Somerville 2001)
- Optimal clover pollination occurs at 2 to 3 hives/ha (Somerville 2001).

Current source of pollination deficit

- Honey bees placed on clover are stocked for honey production rather than pollination, rates are more likely to be 1 hive /ha

Assumed economic impact of pollination deficit

- Pollination of clover is relevant to pasture hay production, milk, sheepmeat (including lamb), beef and wool production on improved pastures
- Optimal pollination lowers the cost of pasture maintenance. A well pollinated pasture is more likely to set seed and the stand will remain vigorous and productive for a longer period of time
- A pollination deficit increases pasture hay production costs/decreases net income. A pollination deficit also increases the cost of improved pasture maintenance /decreases net income for milk, sheepmeat, beef and wool production. An estimated increase in costs/decrease in net income of between 5% and 10% has been assumed for each of these enterprises. Of all estimates used in this study least is known about the impact of a pollination deficit on pastures incorporating clover

Pig Production

Most pigs within the Shepparton region are intensively produced relying on a cereal grain based diet. Cereal is not pollinated by insects. Pigs produced free range would have access to pasture which may contain some pollinated legumes (e.g. lucerne and clover). The contribution of pollinated legumes to economic values associated with the pig industry in the Shepparton region is insignificant.

4. Input-Output Modelling

Input-Output analysis is concerned with the effect of an impacting agent such as closing the pollination deficit on an economy in terms of a number of specific economic activity indicators, such as gross regional output, value-added, income and employment.

These indicators can be defined as follows:

- **Gross regional output** – the gross value of business turnover;
- **Value-added** (gross regional product) – the difference between the gross value of business turnover and the costs of the inputs of raw materials, components and services bought in to produce the gross regional output;
- **Income** – the wages paid to employees including imputed wages for self-employed and business owners; and
- **Employment** – the number of people employed (including full-time and part-time).

The economy on which the impact is measured can range from a township to the entire nation (Powell *et al*., 1985). This study is concerned with examining the impacts of a pollination deficit on the

Shepparton SA4 which comprises the local government areas of Greater Shepparton, Moira and Campaspe.
Input-output analysis essentially involves two steps:

- Construction of an appropriate input-output table (regional transaction table) that can be used to identify the economic structure of a defined region and multipliers for each sector of the economy; and
- Identification of the initial impact or stimulus of an industry in a form that is compatible with the input-output equations so that the input-output multipliers and flow-on effects can then be estimated (Jensen and West, 1986).

For this study, a 2012-13 input-output table of the regional economy was developed using the Generation of Input-Output Tables (GRIT) procedure (Appendix 2) and the latest National Input-Output Table produced by the Australian Bureau of Statistics for 2012-13 as the parent table. Values were then adjusted to 2016 values.

Identification of the initial impact of overcoming a pollinator deficit across crops in a form compatible with the input-output table required the development of a specific incremental aggregate employment, revenue and expenditure profile for crops affected by a deficit, based on available industry information. A specific intermediate input-output sector was developed for the increased production from closing the pollination deficit. For this sector:

- The estimated additional gross annual revenue was allocated to the output row;
- The estimated additional wage bill of employees (including imputed wages for the self-employed) was allocated to the household wages row;
- Additional non-wage local expenditure was initially allocated between regional expenditure and imports. Regional expenditure was then allocated across the relevant 114 intermediate sectors in the regional economy;
- Purchaser prices for expenditure in each sector in the economies were adjusted to basic values and margins and taxes and allocated to appropriate sectors using relationships in the National Input-Output Tables;
- For expenditure on manufactured items, allocation was made between intermediate sectors and imports based on regional location quotients;
- The difference between additional total revenue and additional total costs was allocated to the other value-added row; and
- Additional direct employment was allocated to the employment row.

This sector was inserted into the input-output table and the computer program IO7 (Input-Output Analysis Version 7.1) was used to estimate the average annual direct and indirect output, value-added, income and employment[1] impacts associated with closing the pollination deficit.

Indirect impacts are disaggregated into:

- Production-induced effects - economic activity from the purchase of goods and services that are used as an input into production; and
- Consumption-induced effects - economic activity from the spending of employees in pollination deficit industries.

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[1] It is important to understand that the focus of input-output analysis is on the economic stimulus provided by closing the pollinator deficit and not on the economic costs and benefits of the activity. Consideration of the economic costs and benefits of closing the pollinator deficit would require the undertaking of a benefit cost analysis.

In both cases, in addition to first-round purchases, there will be a series of indirect purchases as waves of second, third and subsequent-round effects make their way throughout the economy.

Ratio multipliers are reported in Section 5. These provide summary measures used for predicting the total impact on all industries in an economy from changes in the demand for the output of any one industry. They express direct impacts and flow-ons in terms of the initial own sector effects e.g. total value-added impacts in relation to direct value-added effects, total output effects in relation to direct output etc. Refer to Appendix 3 for a discussion of multipliers and the assumptions underpinning input-output analysis.

5. Revenue, Expenditure and Employment Profiles for Shepparton Agriculture

Section 5 develops revenue, expenditure and employment profiles for each pollination dependent agricultural industry in the Shepparton Region in order to estimate subsequent direct and multiplier impacts associated with closing the pollination deficit.

Section 3 analysis has shown that there are eleven agricultural industries which are likely to be experiencing a pollination deficit, these industries are:

- Canola – 5 to 15% income loss
- Apple – 5 to 10% income loss
- Pear – 5% income loss
- Cherry – 10% yield loss
- Peach/nectarine – 5% yield loss
- Plum/apricot – 10% income loss
- Pasture hay – 5% cost increase/loss of income
- Milk production on improved pasture – 10% pasture cost increase
- Lamb production on improved pasture – 10% pasture cost increase
- Beef production on improved pasture – 10% pasture cost increase
- Wool production on improved pasture – 10% pasture cost increase

The economic profile of each of these industries is developed below.

Canola

A representative canola industry gross margin was sourced from the NSW DPI and reproduced in the table below. Canola industry current regional value was estimated using ABS Shepparton SA4 data for 2014-15. Canola industry employment was taken from the same source which provides an aggregate for 'grain and sheep', 'grain and beef' and 'other grain growing'. The aggregate was allocated to each grain and livestock industry using GVP as a proxy. On this basis there are approximately 64 jobs in canola growing in Shepparton SA4.

Closing the pollination deficit will:

- Increase revenue due to improved yield and a potential lift in seed quality, 10% gain assumed
- Require an increase in honey bee hive numbers from an assumed average of 0.5 hives/ha for honey production to 1.5 hives/ha for pollination. The additional hive per hectare placed in canola does not generate an economic return for the beekeeper and must be hired by the grower. Hives are hired as a cost of $60 each for this pollination service

- A 10% increase in contract labour costs associated with additional canola harvest and haulage is also incurred. The increase in contract labour, measured in the input-output table as a production-induced flow-on effect, does not result in an increase in canola industry direct employment which remains at 64 jobs.

All other expenditure items remain unchanged.

The table below shows enterprise gross margin (column 2), current regional value – enterprise gross margin aggregated up to a regional total (column 3) and the improved pollination regional value with additional income earned from improved pollination and additional costs incurred e.g. pollination expenses (column 4).

Table 4.1 Canola Growing Revenue and Expenditure Profile

	Average Gross Margin ($/ha)	**Current Regional Value ($'million)**	**Improved Pollination Regional Value ($'million)**
Revenue (A)	**1,150**	**56.3**	**61.9**
Expenditure			
Contract labour	135	6.6	7.3
Levies	15	0.8	0.8
Chemicals	86	4.2	4.2
Nutrition/fertiliser	228	11.2	11.2
Cultivation	21	1.0	1.0
Sowing	56	2.7	2.7
Pollination	0	0	2.9
Insurance	41	2.0	2.0
Total expenditure (B)	**582**	**28.5**	**32.1**
Net Revenue (A) less (B)	**568**	**27.8**	**29.9**
Employment		**64**	**64**

Closure of the pollinator deficit increases Shepparton SA4 canola net revenue i.e. the increase in revenue is greater than the increase in total expenditure and makes sense from an economic perspective. Closing the canola pollinator deficit is included in the input-output model.

Apple

A representative apple industry gross margin was supplied by APAL and is reproduced in the table below. Apple industry current regional value was estimated using ABS Shepparton SA4 data for 2014-15. Apple industry employment was taken from the same source which provides an aggregate for apple and pear growing. The aggregate was allocated to each industry using GVP as a proxy – approximately two thirds apple and one third pear.

Closing the pollination deficit will:

- Increase revenue due to improved yield and quality by 10%
- Require an increase in honey bee hive numbers from an assumed average of 3 hives/ha to 4 hives/ha. Hives are hired at a cost of $60 each for the pollination of apples

- Add to contract labour expenditure as additional yield requires harvesting, 10% increase. The increase in contract labour, measured in the input-output table as a production-induced flow-on effect, does not result in increase in apple industry direct employment which remains at 106 jobs
- Add to fruit marketing and freight costs including cartons for packing, 10% increase
- Add to machinery expenses and fuel costs to recover additional yield, 1% increase

All other expenditure items remain unchanged.

The table below shows enterprise gross margin (column 2), current regional value – enterprise gross margin aggregated up to a regional total (column 3) and the improved pollination regional value with additional income earned from improved pollination and additional costs incurred e.g. pollination expenses (column 4).

Table 4.2 Apple Growing Revenue and Expenditure Profile

	Average Gross Margin ($/ha)	Current Regional Value ($'million)	Improved Pollination Regional Value ($'million)
Revenue (A)	**69,579**	**179.8**	**197.8**
Expenditure			
Farm labour	4,438	11.5	11.5
Contract labour	5,230	13.5	14.9
Fruit marketing, freight, etc	22,413	57.9	63.7
Levies	650	1.7	1.8
Chemicals	3,600	9.3	9.3
Nutrition/fertiliser	939	2.4	2.4
Orchard management	9,074	23.4	23.4
Pollination	180	0.5	0.6
Sundry	1,071	2.8	3.7
Machinery expenses	562	1.5	1.5
Machinery fuel	1,032	2.7	2.7
Machinery hire	181	0.5	0.5
Water and drainage costs	91	0.2	0.2
Repairs and maintenance	1,913	4.9	4.9
Overheads	1,754	4.5	4.5
Total expenditure (B)	**53,128**	**137.3**	**145.7**
Net Revenue (A) less (B)	**16,451**	**42.5**	**52.0**
Employment		**106**	**106**

Closure of the pollinator deficit increases Shepparton SA4 apple net revenue i.e. the increase in revenue is greater than the increase in total expenditure and makes sense from an economic perspective. Closing the apple pollinator deficit is included in the input-output model.

Pear

A representative pear industry gross margin was supplied by APAL and is reproduced in the table below. Pear industry current regional value was estimated using ABS Shepparton SA4 data for 2014-15. Pear industry employment was taken from the same source which provides an aggregate for apple and pear growing. The aggregate was allocated to each industry using GVP as a proxy – approximately two thirds apple and one third pear.

Closing the pollination deficit will:

- Increase revenue due to improved yield and quality by 5%
- Require an increase in honey bee hive numbers from an assumed average of 3 hives/ha to 4 hives/ha. Hives are hired at a cost of $60 each for the pollination of pears
- Add to contract labour expenditure as additional yield requires harvesting, 5% increase. The increase in contract labour, measured in the input-output table as a production-induced flow-on effect, does not result in increase in apple industry direct employment which remains at 59 jobs
- Add to fruit marketing and freight costs including cartons for packing, 5% increase
- Add to machinery expenses and fuel costs to recover additional yield, 1% increase

All other expenditure items remain unchanged.

The table below shows enterprise gross margin (column 2), current regional value – enterprise gross margin aggregated up to a regional total (column 3) and the improved pollination regional value with additional income earned from improved pollination and additional costs incurred e.g. pollination expenses (column 4).

Table 4.3 Pear Growing Revenue and Expenditure Profile

	Average Gross Margin ($/ha)	**Current Regional Value ($'million)**	**Improved Pollination Regional Value ($'million)**
Revenue (A)	**55,964**	**101.5**	**106.6**
Expenditure			
Contract grading, packing, cartons	13,448	24.4	25.6
Cool storage, freight, fruit marketing, etc	8,965	16.3	17.1
Farm labour	4,438	8.0	8.0
Contract labour (hand harvesting)	5,230	9.5	10.0
Orchard management (pruning & thinning)	9,074	16.5	16.5
Levies	650	1.2	1.2
Chemicals	3,600	6.5	6.5
Nutrition / fertiliser	939	1.7	1.7
Pollination	180	0.3	0.4
Sundry materials / supplies / other	1,071	1.9	1.9
Machinery expenses	562	1.0	1.0
Machinery fuel	1,032	1.9	1.9
Machinery hire	181	0.3	0.3
Water and drainage costs (Irrigation)	91	0.2	0.2
Repairs and maintenance	1,913	3.5	3.5
Overheads	1,754	3.2	3.2
Total expenditure (B)	**53,128**	**96.4**	**99.0**
Net Revenue (A) less (B)	**2,836**	**5.1**	**7.6**
Employment		**59**	**59**

Closure of the pollinator deficit increases Shepparton SA4 pear net revenue i.e. the increase in revenue is greater than the increase in total expenditure and makes sense from an economic perspective. Closing the pear pollinator deficit is included in the input-output model.

Cherry

A representative cherry industry gross margin was sourced from DPIPWE Tasmania and reproduced in the table below. Cherry industry current regional value was estimated using ABS Shepparton SA4 data for 2014-15. Cherry industry employment was taken from the same source which provides an aggregate for 'stone fruit' growing. The aggregate was allocated to each stone fruit industry using GVP as a proxy. On this basis there are approximately 19 jobs in cherry growing in Shepparton SA4.

Closing the pollination deficit will:

- Increase revenue due to improved yield by an estimated 10%
- Require an increase in honey bee hive numbers from an assumed average of 6 hives/ha to 10 hives/ha. Hives are hired at a cost of $92 each for the pollination of cherries (total current gross margin cost of $550 spread over 6 hives)
- Add to contract labour expenditure as additional yield requires harvesting, 10% increase. The increase in contract labour, measured in the input-output table as a production-induced flow-on effect, does not result in an increase in cherry industry direct employment which remains at 19 jobs
- Add to fruit marketing and freight costs including cartons for packing, 10% increase
- Add 10% to levy costs which are separately itemised in this gross margin
- Add to machinery expenses and fuel costs to recover additional yield, 1% increase

All other expenditure items remain unchanged.

The table below shows enterprise gross margin (column 2), current regional value – enterprise gross margin aggregated up to a regional total (column 3) and the improved pollination regional value with additional income earned from improved pollination and additional costs incurred e.g. pollination expenses (column 4).

Table 4.4 Cherry Growing Revenue and Expenditure Profile

	Average Gross Margin ($/ha)	Current Regional Value ($'million)	Improved Pollination Regional Value ($'million)
Revenue (A)	**101,125**	**18.7**	**20.6**
Expenditure			
Contract labour	15,625	2.9	3.2
Contract grading, packing, cartons, etc.	36,094	6.7	7.3
Fruit marketing, freight, etc	17,448	3.2	3.2
Levies	744	0.1	0.2
Chemicals	2,420	0.4	0.4
Nutrition / fertiliser	1,649	0.3	0.3
Orchard management	3,750	0.7	0.7
Pollination	550	0.1	0.2
Sundry materials / supplies / other	1,000	0.2	0.2
Machinery expenses / fuel / hire	4,480	0.8	0.8
Water and drainage costs (Irrigation)	1,200	0.2	0.2
Overheads	2,500	0.5	0.5
Total expenditure (B)	**87,460**	**16.2**	**17.2**
Net Revenue (A) less (B)	**13,665**	**2.5**	**3.4**
Employment		**19**	**19**

Closure of the pollinator deficit increases Shepparton SA4 cherry net revenue i.e. the increase in revenue is greater than the increase in total expenditure and makes sense from an economic perspective. Closing the cherry pollinator deficit is included in the input-output model.

Peach/nectarine

A representative peach/nectarine industry gross margin was supplied by a private source and reproduced in the table below. Peach/nectarine industry current regional value was estimated using ABS Shepparton SA4 data for 2014-15. Peach/nectarine industry employment was taken from the same source which provides an aggregate for 'stone fruit' growing. The aggregate was allocated to each stone fruit industry using GVP as a proxy. On this basis there are approximately 59 jobs in peach/nectarine growing in Shepparton SA4.

Closing the pollination deficit will:

- Increase yield by 5% which will also increase revenue by the same amount
- Require an increase in honey bee hive numbers from an assumed average of 2.5 hives/ha to 3.5 hives/ha. Hives are hired at a cost of $92 each for the pollination of peaches and nectarines (total gross margin cost of $230 spread over 2.5 hives/ha)
- Add to contract labour expenditure as additional yield requires harvesting, 5% increase. The increase in contract labour, measured in the input-output table as a production-induced flow-on effect, does not result in an increase in peach/nectarine industry direct employment which remains at 59 jobs
- Add to fruit marketing and freight costs including cartons for packing, 5% increase
- Add to machinery expenses and fuel costs to recover additional yield, 1% increase

All other expenditure items remain unchanged.

The table below shows enterprise gross margin (column 2), current regional value – enterprise gross margin aggregated up to a regional total (column 3) and the improved pollination regional value with additional income earned from improved pollination and additional costs incurred e.g. pollination expenses (column 4).

Table 4.5 Peach/Nectarine Growing Revenue and Expenditure Profile

	Average Gross Margin ($/ha)	Current Regional Value ($'million)	Improved Pollination Regional Value ($'million)
Revenue (A)	**37,188**	**58.9**	**61.8**
Expenditure			
Contract labour	10,055	15.9	16.7
Contract grading, packing, cartons, etc.	12,311	19.5	20.5
Fruit marketing, freight, etc	2,667	4.2	4.4
Chemicals / fertiliser	1,122	1.8	1.8
Pollination	230	0.4	0.4
Machinery expenses	497	0.8	0.8
Machinery fuel / hire	1,823	2.9	2.9
Water and drainage costs (Irrigation)	148	0.2	0.2
Electricity	118	0.2	0.2
Overheads	3,357	5.3	5.3
Total expenditure (B)	**32,328**	**51.2**	**53.2**
Net Revenue (A) less (B)	**4,860**	**7.7**	**8.7**
Employment		**59**	**59**

Closure of the pollinator deficit increases Shepparton SA4 peach/nectarine net revenue i.e. the increase in revenue is greater than the increase in total expenditure and makes sense from an economic perspective. Closing the peach/nectarine pollinator deficit is included in the input-output model.

Plum/apricot

A representative plum/apricot gross margin was developed from data assembled by Tasmanian Irrigation for that state's apricot industry. The gross margin was cross checked with the peach/nectarine and cherry analyses. Gross margin estimates have been reproduced in the table below. Plum/apricot industry current regional value was estimated using ABS Shepparton SA4 data for 2014-15. Plum/ apricot industry employment was taken from the same source which provides an aggregate for 'stone fruit' growing. The aggregate was allocated to each stone fruit industry using GVP as a proxy. On this basis there are approximately 17 jobs in plum/apricot growing in Shepparton SA4.

Closing the pollination deficit will:

- Increase revenue due to improved yield and fruit quality, 10% gain assumed
- Require an increase in honey bee hive numbers from an assumed average of 4 hives/ha to 5 hives/ha. Hives are hired at a cost of $92 each for the pollination of plum/apricot (total current gross margin cost of $368 spread over 4 hives)
- Add to contract labour expenditure as additional yield requires harvesting, 10% increase. The increase in contract labour, measured in the input-output table as a production-induced flow-on effect, does not result in an increase in plum/apricot industry direct employment which remains at 17 jobs
- Add to fruit marketing and freight costs including cartons for packing, 10% increase
- Add to machinery expenses and fuel costs to recover additional yield, 2% increase

All other expenditure items remain unchanged.

The table below shows enterprise gross margin (column 2), current regional value – enterprise gross margin aggregated up to a regional total (column 3) and the improved pollination regional value with additional income earned from improved pollination and additional costs incurred e.g. pollination expenses (column 4).

Table 4.6 Plum/Apricot Growing Revenue and Expenditure Profile

	Average Gross Margin ($/ha)	Current Regional Value ($'million)	Improved Pollination Regional Value ($'million)
Revenue (A)	**42,907**	**16.8**	**18.5**
Expenditure			
Contract labour	11,840	4.6	5.1
Contract grading, packing, cartons, etc.	12,560	4.9	5.4
Fruit marketing, freight, etc.	2,950	1.2	1.3
Chemicals	1,771	0.7	0.7
Nutrition / fertiliser	1,254	0.5	0.5
Pollination	368	0.14	0.18
Sundry materials / supplies / other	500	0.2	0.2
Machinery expenses	510	0.2	0.2
Machinery fuel / hire	1,587	0.6	0.6
Water and drainage costs (Irrigation)	164	0.1	0.1
Electricity	240	0.1	0.1
Overheads	2,500	1.0	1.0
Total expenditure (B)	**36,244**	**14.2**	**15.3**
Net Revenue (A) less (B)	**6,663**	**2.6**	**3.2**
Expenditure		**17**	**17**

Closure of the pollinator deficit increases Shepparton SA4 plum/apricot net revenue i.e. the increase in revenue is greater than the increase in total expenditure and makes sense from an economic perspective. Closing the plum/apricot pollinator deficit is included in the input-output model.

Pasture hay

A representative pasture hay gross margin was developed from information supplied by the NSW DPI and reproduced in the table below. Pasture hay current regional value was estimated using ABS Shepparton SA4 data for 2014-15. Pasture hay industry employment was estimated from the same source. There are approximately 30 jobs in pasture hay growing in Shepparton SA4.

Closing the pollination deficit will:

- Decrease pasture hay production costs/increase revenue by an assumed 5% (maintenance costs are saved when pollination increases seed set and the stand remains vigorous for a longer period of time)
- Require an increase in honey bee hive numbers from an average of 1 hive/ha (for honey production) to 2 hives/ha (for pollination). Hives are hired at a cost of $60 each for the pollination of pasture (clover honey sourced from pasture is well regarded by beekeepers and 1 hive/ha will generate a honey crop but two needed for optimal pollination. The second hive does not generate an economic return for the beekeeper and consequently must be paid for by the pasture hay producer)
- Result in the same yield – the benefit is saved maintenance cost rather than an increase in enterprise output.

All other expenditure items remain unchanged.

The table below shows enterprise gross margin (column 2), current regional value – enterprise gross margin aggregated up to a regional total (column 3) and the improved pollination regional value with additional income earned from improved pollination and additional costs incurred e.g. pollination expenses (column 4).

Table 4.7 Pasture Hay Growing Revenue and Expenditure Profile

	Average Gross Margin ($/ha)	Current Regional Value ($'million)	Improved Pollination Regional Value ($'million)
Revenue (A)	**1,700**	**26.2**	**27.5**
Expenditure			
Contract labour (mow, rake, bale)	1,064	16.4	16.4
Cart and stack	71	1.1	1.1
Chemicals (herbicide & insecticide)	19	0.3	0.3
Nutrition / fertiliser	55	0.8	0.8
Pollination	0	0	0.9
Sundry materials/supplies	36	0.6	0.6
Total expenditure (B)	**1,245**	**19.2**	**20.1**
Net Revenue (A) less (B)	**455**	**7.0**	**7.4**
Employment		**30**	**30**

Closure of the pollinator deficit increases Shepparton SA4 pasture hay net revenue i.e. the increase in revenue is greater than the increase in total expenditure and makes sense from an economic perspective. Closing the pasture hay pollinator deficit is included in the input-output model.

Dairy

A representative dairy gross margin was sourced from Dairy Australia and reproduced in the table below. Dairy current regional value was estimated using ABS Shepparton SA4 data for 2014-15. Dairy industry employment was estimated from the same source. There are approximately 2,197 jobs in dairy cattle farming in Shepparton SA4.

Closing the pollination deficit will:

- Decrease dairy pasture production costs / increases revenue by an assumed 10% (maintenance costs are saved when pollination increases seed set and the stand remains vigorous for a longer period of time)
- Require an increase in honey bee hive numbers from an average of 1 hive/ha (for honey production) to 2 hives/ha (for pollination). Hives are hired at a cost of $60 each for the pollination of dairy pasture (clover honey sourced from pasture is well regarded by beekeepers and 1 hive/ha will generate a honey crop but two needed for optimal pollination. The second hive does not generate an economic return for the beekeeper and consequently must be paid for by the dairy farmer)
- Result in the same milk yield – the benefit is saved maintenance cost rather than an increase in enterprise output.

All other expenditure items remain unchanged.

The table below shows enterprise gross margin (column 2), current regional value – enterprise gross margin aggregated up to a regional total (column 3) and the improved pollination regional value with additional income earned from improved pollination and additional costs incurred e.g. pollination expenses (column 4).

Table 4.8 Dairy Production Revenue and Expenditure Profile

	Average Gross Margin ($/ha)	Current Regional Value ($'million)	Improved Pollination Regional Value ($'million)
Revenue (A)	**5,420**	**754.0**	**769.1**
Expenditure			
Farm labour	635	88.3	88.3
Shed cost	171	23.8	23.8
Contract labour	372	51.8	51.8
Chemicals (Animal Health)	245	34.1	34.1
Feed	1,634	227.3	227.3
Pasture maintenance (home grown feed)	1,083	150.7	150.7
Pollination	0	0	8.3
Depreciation	157	21.8	21.8
Repairs and maintenance	270	37.6	37.6
Overheads	199	27.7	27.7
Total expenditure (B)	**4,766**	**663.0**	**671.3**
Net Revenue (A) less (B)	**654**	**91.0**	**97.8**
Employment		**2,197**	**2,197**

Closure of the pollinator deficit increases Shepparton SA4 dairy net revenue i.e. the increase in revenue is greater than the increase in total expenditure and makes sense from an economic perspective. Closing the dairy pollinator deficit is included in the input-output model.

Lamb

A representative prime lamb gross margin was sourced from the GRDC Farm Gross Margin Guide and reproduced in the table below. Prime lamb current regional value was estimated using ABS Shepparton SA4 data for 2014-15. Prime lamb employment was estimated from the same source. There are approximately 170 jobs in prime lamb production in Shepparton SA4.

Closing the pollination deficit will:

- Decrease prime lamb pasture production costs / increases revenue by an assumed 10% (maintenance costs are saved when pollination increases seed set and the stand remains vigorous for a longer period of time)
- Require an increase in honey bee hive numbers from an average of 1 hive/ha (for honey production) to 2 hives/ha (for pollination). Hives are hired at a cost of $60 each for the pollination of pasture (clover honey sourced from pasture is well regarded by beekeepers and 1 hive/ha will generate a honey crop but two needed for optimal pollination. The second hive does not generate an economic return for the beekeeper and consequently must be paid for by the dairy farmer)
- Result in the same meat yield – the benefit is saved maintenance cost rather than an increase in enterprise output.

All other expenditure items remain unchanged.

The table below shows enterprise gross margin (column 2), current regional value – enterprise gross margin aggregated up to a regional total (column 3) and the improved pollination regional value with additional income earned from improved pollination and additional costs incurred e.g. pollination expenses (column 4).

Table 4.9 Lamb Production Revenue and Expenditure Profile

	Average Gross Margin ($/ha)	Current Regional Value ($'million)	Improved Pollination Regional Value ($'million)
Revenue (A)	**548.41**	**46.4**	**46.9**
Expenditure			
Contract labour (shearing)	17.13	1.4	1.4
Shearing supplies	4.59	0.4	0.4
Marking	4.16	0.4	0.4
Chemicals (Animal Health)	12.11	1.0	1.0
Stock purchases	155.09	13.1	13.1
Water and drainage costs	15	1.3	1.3
Feed	53.37	4.5	4.5
Pollination	0	0.0	5.1
Stock selling charges (excl levies)	28.63	2.4	2.4
Levies	9.32	0.8	0.8
Freight	20.05	1.7	1.7
Sundry materials / supplies	3.00	0.3	0.3
Machinery fuel, R&M	7.20	0.6	0.6
Insurance	1.01	0.1	0.1
Total expenditure (B)	**330.66**	**28.0**	**33.1**
Net Revenue (A) less (B)	**217.75**	**18.4**	**13.8**
Employment		**170**	**170**

Closure of the pollinator deficit decreases Shepparton SA4 lamb net revenue i.e. the increase in revenue is less than the increase in total expenditure consequently it does not make sense from an economic perspective. Closing the lamb pollinator deficit is not included in the input-output model.

Beef

A representative beef cattle gross margin was sourced from the GRDC Farm Gross Margin Guide and reproduced in the table below. Beef cattle current regional value was estimated using ABS Shepparton SA4 data for 2014-15. Beef cattle employment was estimated from the same source. There are approximately 585 jobs in beef cattle production in Shepparton SA4.

Closing the pollination deficit will:

- Decrease beef cattle pasture production costs / increases revenue by an assumed 10% (maintenance costs are saved when pollination increases seed set and the stand remains vigorous for a longer period of time)
- Require an increase in honey bee hive numbers from an average of 1 hive/ha (for honey production) to 2 hives/ha (for pollination). Hives are hired at a cost of $60 each for the pollination of pasture (clover honey sourced from pasture is well regarded by beekeepers and 1 hive/ha will generate a honey crop but two needed for optimal pollination. The second hive does not generate an economic return for the beekeeper and consequently must be paid for by the dairy farmer)
- Result in the same meat yield – the benefit is saved maintenance cost rather than an increase in enterprise output.

All other expenditure items remain unchanged.

The table below shows enterprise gross margin (column 2), current regional value – enterprise gross margin aggregated up to a regional total (column 3) and the improved pollination regional value with additional income earned from improved pollination and additional costs incurred e.g. pollination expenses (column 4).

Table 4.9 Beef Production Revenue and Expenditure Profile

	Average Gross Margin ($/ha)	Current Regional Value ($'million)	Improved Pollination Regional Value ($'million)
Revenue (A)	**216**	**249.8**	**256.28**
Expenditure			
Chemicals (Animal Health)	5	5.8	5.8
Stock purchases	10	11.6	11.6
Water and drainage costs	12	13.9	13.9
Feed	56	64.8	64.8
Pollination	0	0.0	69.4
Stock selling charges (excl. levies)	12	13.9	13.9
Levies	1	1.2	1.2
Freight / Transport	4	4.6	4.6
Sundry materials / supplies	2	2.3	2.3
Machinery fuel, R&M	5	5.8	5.8
Insurance	1	1.2	1.2
Total expenditure (B)	**108**	**124.90**	**194.30**
Net Revenue (A) less (B)	**108**	**124.90**	**61.98**
Employment		**523**	**523**

Closure of the pollinator deficit decreases Shepparton SA4 beef net revenue i.e. the increase in revenue is less than the increase in total expenditure consequently it does not make sense from an economic perspective. Closing the beef pollinator deficit is not included in the input-output model.

Wool

A representative self-replacing merino wool gross margin was sourced from the GRDC Farm Gross Margin Guide and reproduced in the table below. Wool industry current regional value was estimated using ABS Shepparton SA4 data for 2014-15. Wool industry employment was estimated from the same source. There are approximately 70 jobs in wool production in Shepparton SA4.

Closing the pollination deficit will:

- Decrease wool pasture production costs / increases revenue by an assumed 10% (maintenance costs are saved when pollination increases seed set and the stand remains vigorous for a longer period of time)
- Require an increase in honey bee hive numbers from an average of 1 hive/ha (for honey production) to 2 hives/ha (for pollination). Hives are hired at a cost of $60 each for the pollination of pasture (clover honey sourced from pasture is well regarded by beekeepers and 1 hive/ha will generate a honey crop but two needed for optimal pollination. The second hive does not generate an economic return for the beekeeper and consequently must be paid for by the dairy farmer)

- Result in the same wool yield – the benefit is saved maintenance cost rather than an increase in enterprise output.

All other expenditure items remain unchanged.

The table below shows enterprise gross margin (column 2), current regional value – enterprise gross margin aggregated up to a regional total (column 3) and the improved pollination regional value with additional income earned from improved pollination and additional costs incurred e.g. pollination expenses (column 4).

Table 4.9 Wool Production Revenue and Expenditure Profile

	Average Gross Margin ($/ha)	**Current Regional Value ($'million)**	**Improved Pollination Regional Value ($'million)**
Total Revenue (A)	**409**	**23.1**	**23.4**
Expenditure			
Contract labour (shearing)	27	1.5	1.5
Shearing supplies	3	0.1	0.1
Marking (castration, tail docking)	4	0.2	0.2
Chemicals (Animal Health)	20	1.1	1.1
Stock purchases	25	1.4	1.4
Water and drainage costs	15	0.8	0.8
Feed	50	2.8	2.8
Pollination	0	0	3.4
Stock selling charges (excl. levies)	18	1.0	1.0
Levies	7	0.4	0.4
Freight	10	0.6	0.6
Sundry materials / supplies	3	0.2	0.2
Machinery fuel, R&M	7	0.4	0.4
Insurance	1	0.1	0.1
Total expenditure (B)	**189**	**10.7**	**14.1**
Net Revenue (A) less (B)	**220**	**12.4**	**9.3**
Employment		**76**	**76**

Closure of the pollinator deficit decreases Shepparton SA4 wool net revenue i.e. the increase in revenue is less than the increase in total expenditure consequently it does not make sense from an economic perspective. Closing the wool pollinator deficit is not included in the input-output model.

6. Regional Economic Impact of Closing the Pollination Deficit Across Crops

Direct Impact of Closing the Pollinator Deficit

Aggregating the increases in revenue and expenditures from Section 4 for agricultural production where closing the pollination deficit makes economic sense i.e. additional revenues exceed additional costs, results in additional direct revenue of $51.6 million per annum and additional annual net revenue of $23.7 million.

$16.9 million of the additional annual expenditure is estimated to initially occur in the regional economy.

Table 5.1 Direct Effects of Closing the Pollination Deficit ($000)

Financial Items	Total	In region	Outside Region
Revenue	**$51,600**	**$51,600**	
Expenditure			
Contract Labour	$3,700	$1,480	$2,220
Levies	$200	0	$200
Marketing, freight etc.	$6,900	$6,900	0
Contract grading, packing, cartons	$3,300	$3,300	0
Contract labour (hand harvesting)	$500	$200	$300
Sundry	$900	$900	0
Pollination	$12,440	$4,147	$8,293
Total Expenditure	**$27,940**	**$16,927**	**$11,013**
Net Revenue	**$23,660**	**$23,660**	
Direct Employment	**0**	**0**	

Multiplier Impact Pollinator Deficit

Economic Activity

The total and disaggregated impact on the Shepparton economy (in 2016 dollars) of closing the pollination deficit is shown in Table 5.2.

Table 5.2 Direct and Indirect Impact of Closing the Pollination Deficit in Shepparton Region ($000)

	Direct Effect	Production Induced	Consumption Induced	Total Flow-on	TOTAL EFFECT
OUTPUT	51,600	23,002	3,768	26,770	78,370
Type 11A Ratio	1.00	0.45	0.07	0.52	1.52
VALUE-ADDED	23,669	9,437	2,236	11,673	35,342
Type 11A Ratio	1.00	0.40	0.09	0.49	1.49
INCOME	-	4,345	828	5,173	5,173
EMPLOYMENT (No.)	-	87	19	106	106

Closing the pollination deficit in Shepparton SA4 region is estimated to make up to the following total annual contribution to the regional economy:

- $78 million in annual direct and indirect regional output or business turnover;

- $35 million in annual direct and indirect regional value added;
- $5 million in annual direct and indirect household income; and
- 106 direct and indirect jobs.

Multipliers

Ratio multipliers provide a summary measure of the direct and indirect economic activity relative to the direct economic activity for a particular indicator. The Type 11A ratio multipliers for closing the pollination deficit in the Shepparton economy range from 1.49 for value-added to 1.52 for output. There is no ratio multiplier for employment and income as there are no direct employment or income effects. All employment and income effects are associated with production and consumption induced flow-on effects.

Main Sectors Affected

Flow-on impacts from closing the pollination deficit impact a number of different sectors of the regional economy. The sectors most impacted by output, income, employment and value-added flow-ons are:

- Road Transport;
- Agriculture, Forestry and Fishing Support Services;
- Other Agriculture;
- Wholesale Trade; and
- Retail Trade

Examination of the estimated flow-on employment impacts gives an indication of the aggregated sectors with employment linkages to closing the pollination deficit (Figure 5.1).

Figure 5.1 Sectoral Distribution of Employment Impacts on the Shepparton Economy

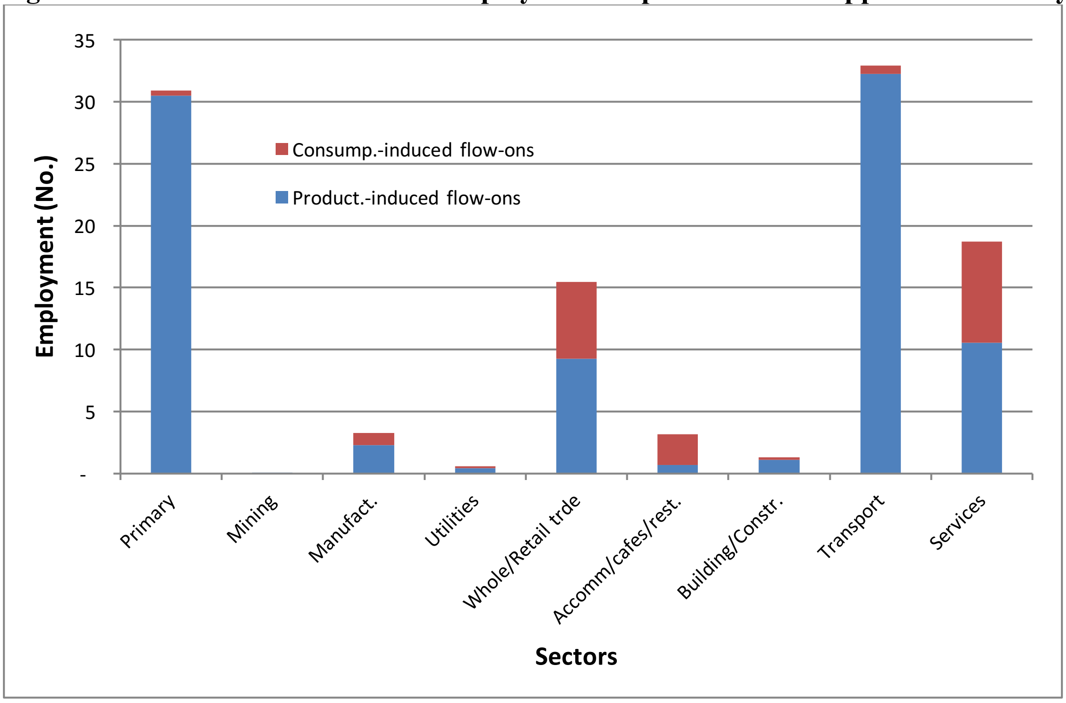

Figure 5.1 indicates that production-induced and consumption-induced employment linkages of closing the pollination deficit on the regional economy are likely to have different distributions across sectors. Production-induced flow-on employment occurs mainly in the transport and agricultural sectors while consumption induced flow-on employment is mainly in the services and trade sectors.

Uncertainty

The estimates produced by the input-output model rely on Chapter 4 assumptions about the extent and cost of closing the pollinator deficit. Estimates are 'best available' relying on the body of literature and expert advice. However, we simply do not have enough field knowledge to be confident of all of these effect sizes. Filling gaps in field knowledge is an important issue for the future.

7. General Conclusions National Economic Impact of Pollinator Deficits

Broader Economic Impacts

The results of this analysis are for the Shepparton SA4. They demonstrate the potential gains in regional economic activity from closing the pollination deficit in that region. However, conditions in the Shepparton region and gross margin budgets are likely to be very different to other regions of Australia and hence it is difficult to extrapolate the results. In some regions, farm budgets may be such that the additional costs of pollination are greater than the gains from pollination (as demonstrated in the Shepparton SA4 for Lamb, Beef and Wool) and hence farm enterprises would be unlikely to purchase increased pollination. The benefits and regional economic activity from closing the pollination deficit may therefore vary on a region by region basis.

However, an indication of the potential magnitude of the economic impacts to Australia can be gained from:

- Scaling up the impacts identified for the Shepparton Region to Australia based on the Gross Value of Production for each of the enterprises identified in Section 4;
- Development of a new sector and insertion of this sector in a 2016 National IO table.

On this basis, the potential economic activity impacts of overcoming the pollination deficit Australia wide are given in Table 5.3.

Table 5.3 Direct and Indirect Impact of the Closing the Pollination Deficit Across Australia ($000)

	Direct Effect	Production Induced	Consumption Induced	Total Flow-on	TOTAL EFFECT
OUTPUT	383,040	430,460	217,110	647,570	1,030,610
Type 11A Ratio	1.00	1.12	0.57	1.69	2.69
VALUE-ADDED	156,460	199,260	120,100	319,370	475,820
Type 11A Ratio	1.00	1.27	0.77	2.04	3.04
INCOME	0	98,520	57,910	156,430	156,430
EMPLOYMENT (No.)	-	1,506	878	2,384	2,384

Closing the pollination deficit across Australia is estimated to make up to the following total annual contribution to the economy:

- $1 billion in annual direct and indirect regional output or business turnover;
- $476 million in annual direct and indirect regional value added;
- $156 million in annual direct and indirect household income; and
- 2,384 direct and indirect jobs.

The increase in the scale of impacts relative to those estimated for the Shepparton Region is a function of:

- Increased direct effects from scaling up the impacts identified for the Shepparton Region to Australia based on the Gross Value of Production;
- Increased expenditure captured by the Australian economy relative to the Shepparton economy;
- Larger multipliers for the Australian economy relative to the Shepparton economy.

Study Conclusions

The purpose of this study was to quantify the regional economic impact of a pollination deficit and provide more general conclusions on the national economic impact of pollination deficits.

The regional economy chosen for analysis was Shepparton SA4 comprising the local government areas of Greater Shepparton, Moira and Campaspe. Crops affected by a pollination deficit and with an economic return from closing that deficit were apple, pear, cherry, peach, nectarine, plum, apricot, canola, pasture hay and dairy.

Closing the pollination deficit for these crops results in an increase in business turnover of $78 million, an increase in value-added of $35 million, additional household income of $5 million and the creation of 106 jobs.

Definitive assessment of the national economic impact of a pollination deficit requires a separate and larger study. However, estimates of national impact have been prepared by scaling up the impacts identified in Shepparton SA4 to Australia based on GVP and developing a new pollination sector within the National Input-Output table for 2013 (inflated to 2016).

On this indicative basis, the national economic impact of a pollinator deficit is significant: $1 billion in foregone turnover, $476 million in lost value add, $156 million in lost household income and 2,384 jobs foregone.

The analysis completed in this study provides an evidence base for decision-makers in relation to both the direct and broader economic costs of pollination deficits.

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Appendix 1: Gross value of agricultural commodities Shepparton SA4 2014-15

Shepparton SA4 Agricultural Gross Values 2014-15

Commodity (Values>$10 million sown in bold)	Gross Value ($)
Broadacre crops - Cereal crops - Wheat for grain	**131,299,716**
Broadacre crops - Cereal crops - Oats for grain	5,766,233
Broadacre crops - Cereal crops - Barley for grain	**23,846,062**
Broadacre crops - Cereal crops - Sorghum for grain	7,923
Broadacre crops - Cereal crops - Maize for grain	6,866,241
Broadacre crops - Cereal crops - Rice for grain	920,087
Broadacre crops - Cereal crops - Triticale for grain	322,593
Broadacre crops - Cereal crops - All other cereals for grain or seed	804,846
Broadacre crops - Non-cereal crops - Other pulses	9,364,680
Broadacre crops - Non-cereal crops - Oilseeds - Canola	**56,322,508**
Broadacre crops - Non-cereal crops - Oilseeds - Other oilseeds	639,170
Broadacre crops - All other crops n.e.c.	1,157,246
Hay and Silage - Lucerne cut for hay	**44,390,021**
Hay and Silage - Pasture cut for hay	**26,153,369**
Hay and Silage - Cereal cut for hay	**61,425,195**
Hay and Silage - Other crops cut for hay	8,945,392
Nurseries, cut flowers or cultivated turf - Nurseries - Undercover	360,380
Nurseries, cut flowers or cultivated turf - Nurseries - Outdoor	1,770,781
Nurseries, cut flowers or cultivated turf - Cut flowers - Undercover	6,544,959
Nurseries, cut flowers or cultivated turf - Cut flowers - Outdoor	1,437,400
Nurseries, cut flowers or cultivated turf - Cultivated turf	116,654
Fruit and nuts - Citrus fruit - Mandarins	3,356
Fruit and nuts - Citrus fruit - Oranges	1,013,689
Fruit and nuts - Citrus fruit - All other citrus fruit n.e.c.	669,466
Fruit and nuts - Pome fruit - Apples	**179,756,833**
Fruit and nuts - Pome fruit - Pears (including Nashi)	**101,495,603**
Fruit and nuts - Pome fruit - All other pome fruit n.e.c.	1,078,264
Fruit and nuts - Stone fruit - Cherries	**18,709,108**
Fruit and nuts - Stone fruit - Nectarines	**24,916,146**
Fruit and nuts - Stone fruit - Peaches	**34,023,942**
Fruit and nuts - Stone fruit - All other stone fruit n.e.c.	**16,760,135**

Fruit and nuts - Orchard fruit - Avocados	59,997
Fruit and nuts - Orchard fruit - All other orchard fruit n.e.c.	6,344,237
Fruit and nuts - Other fruit - Strawberries	3,972
Fruit and nuts - Other fruit - All other fruit n.e.c.	**12,005,156**
Fruit and nuts - Nuts - All other nuts n.e.c.	332,210
Fruit and nuts - Grapes - Wine production	2,522,067
Fruit and nuts - Grapes - All other uses	637,672
Vegetables for human consumption - Beans (including french and runner)	196,690
Vegetables for human consumption - Capsicum - (excluding chillies)	1,212,829
Vegetables for human consumption - Carrots	1,888
Vegetables for human consumption - Lettuces - Total	2,143,277
Vegetables for human consumption - Melons	4,633
Vegetables for human consumption - Onions	2,759,512
Vegetables for human consumption - Tomatoes - Processing	**22,495,368**
Vegetables for human consumption - Tomatoes - Fresh Market	**53,668,020**
Vegetables for human consumption - All other vegetables n.e.c. (a)	17,391,004
Livestock Products - Wool	**23,117,635**
Livestock products - Milk	**754,039,756**
Livestock products - Eggs	547,669
Livestock slaughtered and other disposals - Sheep and lambs	**46,385,338**
Livestock slaughtered and other disposals - Cattle and calves	**249,800,244**
Livestock slaughtered and other disposals - Pigs	**42,594,517**
Livestock slaughtered and other disposals - Poultry	2,465,609
Livestock slaughtered and other disposals - Other n.e.c.	1,519,549
Total Agriculture – Shepparton	**2,009,136,847**

Source: 75030DO001_201415 Value of Agricultural Commodities Produced, Australia, 2014-15, Table 3: Value of Agricultural Commodities Produced, State and SA4 Region–Victoria–2014-15

Appendix 2 – The GRIT System for Generating Input-Output Tables

The Generation of Regional Input-Output Tables (GRIT) system was designed to:

- combine the benefits of survey based tables (accuracy and understanding of the economic structure) with those of non-survey tables (speed and low cost);
- enable the tables to be compiled from other recently compiled tables;
- allow tables to be constructed for any region for which certain minimum amounts of data were available;
- develop regional tables from national tables using available region-specific data;
- produce tables consistent with the national tables in terms of sector classification and accounting conventions;
- proceed in a number of clearly defined stages; and
- provide for the possibility of ready updates of the tables.

The resultant GRIT procedure has a number of well-defined steps. Of particular significance are those that involve the analyst incorporating region-specific data and information specific to the objectives of the study. The analyst has to be satisfied about the accuracy of the information used for the important sectors; in this case the coal mining sector. The method allows the analyst to allocate available research resources to improving the data for those sectors of the economy that are most important for the study.

An important characteristic of GRIT-produced tables relates to their accuracy. In the past, survey-based tables involved gathering data for every cell in the table, thereby building up a table with considerable accuracy. A fundamental principle of the GRIT method is that not all cells in the table are equally important. Some are not important because they are of very small value and, therefore, have no possibility of having a significant effect on the estimates of multipliers and economic impacts. Others are not important because of the lack of linkages that relate to the particular sectors that are being studied. Therefore, the GRIT procedure involves determining those sectors and, in some cases, cells that are of particular significance for the analysis. These represent the main targets for the allocation of research resources in data gathering. For the remainder of the table, the aim is for it to be 'holistically' accurate (Jensen, 1980). This means a generally accurate representation of the economy is provided by the table, but does not guarantee the accuracy of any particular cell. A summary of the steps involved in the GRIT process is shown in Table A2-1 (Powell and Chalmers, 1995). For this study, the National IO table was used to generate a Victorian IO table. The Victorian IO table was then used as the parent table for the Shepparton IO table.

Table A2-1 The GRIT Method

Phase	Step	Action
PHASE I		ADJUSTMENTS TO NATIONAL TABLE
	1	Selection of national input-output table (114-sector table with direct allocation of all imports, in basic values).
	2	Adjustment of national table for updating.
	3	Adjustment for international trade.
PHASE II		ADJUSTMENTS FOR REGIONAL IMPORTS (*Steps 4-14 apply to each region for which input-output tables are required*)
	4	Calculation of 'non-existent' sectors.
	5	Calculation of remaining imports.
PHASE III		DEFINITION OF REGIONAL SECTORS
	6	Insertion of disaggregated superior data.
	7	Aggregation of sectors.
	8	Insertion of aggregated superior data.
PHASE IV		DERIVATION OF PROTOTYPE TRANSACTIONS TABLES
	9	Derivation of transactions values.
	10	Adjustments to complete the prototype tables.
	11	Derivation of inverses and multipliers for prototype tables.
PHASE V		DERIVATION OF FINAL TRANSACTIONS TABLES
	12	Final superior data insertions and other adjustments.
	13	Derivation of final transactions tables.
	14	Derivation of inverses and multipliers for final tables.

Source: Bayne and West (1988).

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Appendix 3: Assumptions and interpretations, input-output analysis and multipliers

1. "The *basic assumptions* in IO analysis include the following:

- there is a fixed input structure in each industry, described by fixed technological coefficients (evidence from comparisons between IO tables for the same country over time have indicated that material input requirements tend to be stable and change but slowly; however, requirements for primary factors of production, that is labour and capital, are probably less constant);
- all products of an industry are identical or are made in fixed proportions to each other;
- each industry exhibits constant returns to scale in production;
- unlimited labour and capital are available at fixed prices; that is, any change in the demand for productive factors will not induce any change in their cost (in reality, constraints such as limited skilled labour or investment funds lead to competition for resources among industries, which in turn raises the prices of these scarce factors of production and of industry output generally in the face of strong demand); and
- there are no other constraints, such as the balance of payments or the actions of government, on the response of each industry to a stimulus.

2.The multipliers therefore describe *average effects, not marginal effects*, and thus do not take account of economies of scale, unused capacity or technological change. Generally, average effects are expected to be higher than the marginal effects.

3. The IO tables underlying multiplier analysis only take account of one form of *interdependence*, namely the sales and purchase links between industries. Other interdependence such as collective competition for factors of production, changes in commodity prices which induce producers and consumers to alter the mix of their purchases and other constraints which operate on the economy as a whole are not generally taken into account.

4. The combination of the assumptions used and the excluded interdependence means that IO multipliers are higher than would realistically be the case. In other words, they tend to *overstate* the potential impact of final demand stimulus. The overstatement is potentially more serious when large changes in demand and production are considered.

5. The multipliers also do not account for some important pre-existing conditions. This is especially true of Type II multipliers, in which employment generated and income earned induce further increases in demand. The implicit assumption is that those taken into employment were previously unemployed and were previously consuming nothing. In reality, however, not all 'new' employment would be drawn from the ranks of the unemployed; and to the extent that it was, those previously unemployed would presumably have consumed out of income support measures and personal savings. Employment, output and income responses are therefore overstated by the multipliers for these additional reasons.

6. The most *appropriate interpretation* of multipliers is that they provide a relative measure (to be compared with other industries) of the interdependence between one industry and the rest of the economy which arises solely from purchases and sales of industry output based on estimates of transactions occurring over a (recent) historical period. Progressive departure from these conditions would progressively reduce the precision of multipliers as predictive device" (ABS 1995, p.24).

Multipliers indicate the total impact of changes in demand for the output of any one industry on all industries in an economy (ABS, 1995). Conventional output, employment, value-added and income multipliers show the output, employment, value-added and income responses to an initial output stimulus (Jensen and West, 1986).

Components of the conventional output multiplier are as follows:

Initial effect - which is the initial output stimulus, usually a $1 change in output from a particular industry (Powell and Chalmers, 1995; ABS, 1995).

First round effects - the amount of output from all intermediate sectors of the economy required to produce the initial $1 change in output from the particular industry (Powell and Chalmers, 1995; ABS, 1995).

Industrial support effects - the subsequent or induced extra output from intermediate sectors arising from the first round effects (Powell and Chalmers, 1995; ABS, 1995).

Production induced effects - the sum of the first round effects and industrial support effects (i.e. the total amount of output from all industries in the economy required to produce the initial $1 change in output) (Powell and Chalmers, 1995; ABS, 1995).

Consumption induced effects - the spending by households of the extra income they derive from the production of the extra $1 of output and production induced effects. This spending in turn generates further production by industries (Powell and Chalmers, 1995; ABS, 1995).

The *simple multiplier* is the initial effect plus the production induced effects.

The *total multiplier* is the sum of the initial effect plus the production-induced effect and consumption-induced effect.

Conventional employment, value-added and income multipliers have similar components to the output multiplier, however, through conversion using the respective coefficients show the employment, value-added and income responses to an initial output stimulus (Jensen and West, 1986).

For employment, value-added and income, it is also possible to derive relationships between the initial or own sector effect and flow-on effects. For example, the flow-on income effects from an initial income effect or the flow-on employment effects from an initial employment effect, etc. These own sector relationships are referred to as ratio multipliers, although they are not technically multipliers because there is no direct line of causation between the elements of the multiplier. For instance, it is not the initial change in income that leads to income flow-on effects, both are the result of an output stimulus (Jensen and West, 1986).

A description of the different ratio multipliers is given below.

Type 1A Ratio Multiplier = $\frac{\text{Initial + First Round Effects}}{\text{Initial Effects}}$

Type 1B Ratio Multiplier = $\frac{\text{Initial + Production Induced Effects}}{\text{Initial Effects}}$

Type 11A Ratio Multiplier = $\frac{\text{Initial + Production Induced + Consumption Induced Effects}}{\text{Initial Effects}}$

Type 11B Ratio Multiplier = $\frac{\text{Flow-on Effects}}{\text{Initial Effects}}$

Source: Centre for Farm Planning and Land Management (1989).

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