The Economic Value

of Australia's

Insect Crop Pollinators

in 2014 – 2015.

John M Karasiński [1]

July, 2018

[1] Department of Mineral and Energy Economics, WA School of Mines, Curtin University. Email: John.Karasinski@gsb.curtin.edu.au This paper benefited from presentations made to various WA bee industry groups including The Bee Industry Council of WA, the WABA and WA Farmers Bee 2017 Conference, the Centre for Integrative Bee Research at the University of Western Australia and a seminar presentation made to the Agriculture and Natural Resource Economics Society (W.A. Branch).

Table of Contents

Acknowledgements.

I would like to acknowledge the helpful advice and on-going support provided by Robert Manning, Madlen Kratz, Peter Brindal, Geoff Crocker, Serena Dorf, Geoffrey Defrenne, Liz Barbour and Fiona Chambers during the development of this research paper.

Abstract

This paper reports for the first time the quantification of the economic value of Australia's two major groups of insect pollinators - honey bee pollinators and non-honey bee insect pollinators, see Chart 1. The results unambiguously confirm the significant economic importance of Australia's insect crop pollinators.

This research uncovered two surprising results one at the national level and the other at the regional level where both groups of pollination agents made almost identical economic contributions. In 2014-2015, the overall economic value of Australian insect pollinators has been estimated to be worth $A 28.4 bn, see Table 2 and Chart 2. At the regional level the total economic value of the Avon Valley strawberry industry has been estimated to be worth $A 10.5 m, see Table 4.

As excepted, the economic values vary between the states and territories. Victoria has the highest economic value of $ 8.7 bn with $A 6.0 bn the direct result of the economic activity of honey bee pollinators and $A 2.7 bn due to the role played by non-honey bee insect pollinators. New South Wales reported the next highest level with an overall economic value with $A 6.1 bn split between $A 2.5 bn from honey bee pollinators and $A 3.6 bn from non-honey bee insect pollinators. Queensland recorded the next highest economic value of $A 5.6 bn with $A 2.1 attributed to honey bee pollinators and $3.5bn to non-honey bee insect pollinators.

The states where honey bee pollinators made the greater economic contribution were Victoria, Tasmania and the Northern Territory.

1.0 Introduction

This paper presents the results of original research that quantified the economic value of the important role played by all insect pollinators in Australia. This paper is based on two previous papers which reported the economic values of managed and feral honey bee pollinators and Karasiński (2018a) and the economic value of non honey bee insect pollinators Karasiński (2018b).

It is a well-accepted and understood that insect crop pollinators play an important role in enhancing crop yields, but until now the exact economic value of that role was both unquantified and unknown.

2.0 Review of the Australian Literature.

The body of industry and economics literature on the topic of the economic value of insect pollinators has been skewed exclusively favour of research papers and industry reports reporting some form of an “economic” value of honey bee pollinators.

As outlined in Karasiński (2018a) with the exception of the Australian study by Gill (1989) the remainder of the research papers and industry reports published reported a dollar amount that was not calculated using the appropriate economic model. The only paper which correctly measured and reported the economic value of Australian managed and feral honey bee pollinators was Karasiński (2018a).

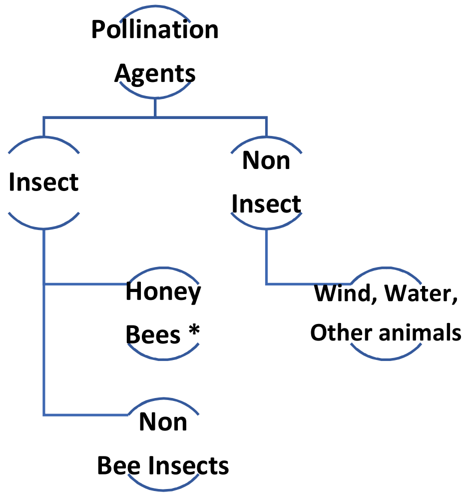
Similarly, the discrenible lack of information detailling the economic value of non-honey bee insect pollinators has been overcome with the paper by Karasiński (2018b) which reported the correct economic value of non-honey bee insect pollinators using the same economic model that was used to measure the economic value of Austrralian managed and feral honey bee pollinators.

Until now industry and economics literature has been devoid of disucssion of the economic contribution made by all Australian insect pollinators.

3.0 Pollination Agents

Chart 1 which is reproduced from Karasiński (2018b) shows agriculure and horticulutre crop pollination agents classified into insect pollinators and non-insect pollinators. Insect pollinators are classified into either honey bee pollinators (managed and feral) or non-honey bee insect pollinators which are shown in Chart 1 as non-bee insects.

Chart 1: Schematic shows the broad relationship between pollination agents



* Honey Bees include Managed and Feral (native) honey bee pollinators.

Source: Karasiński (2018b) p.7

As reported in Karasiński (2018a and 2018b), pollination agents include: (in alphabetic order): Ants, Artificial (electronic) wands, Bats, Beetles, Blowflies, Birds, Butterflies, Flies, Hawkmoths, Hoverflies, Humans (in parts of China and the Himalayan region), Maggots, Moths, Thrips, Other animals, Water and Wind.

4.0 The Economic Model.

The economic model which is formerly known as a Partial Equilibrium Model (or P.E.M) that was used in this study is the same model used to calculate the economic value of Australian managed and feral honey bee pollinators as detailed by Karasiński (2018). The adoption of the P.E.M. for measuring the economic value of non-honey bee insect pollinators provides a uniform approach and methodology to be used to enable meaningful comparisons of economic value to be made between the two major groups of insect pollination agents.

The three components of the Economic Model

The major components of the economic model include: firstly, the Non-Honey Bee Insect Pollinator Dependency Factors, secondly, the farm gate agriculture crop values published by the Australian Bureau of Statistics which become the data for this study. Thirdly, the integration of both these components into the economic model along with the fourth component which is the relevant price elasticity of demand coefficients that categorise whether insect pollinated agriculture crops are "luxury" or "necessity" crops. Those coefficients give the mathematical value of the slope of the two demand curves.

If the crops are "luxury" crops their empirically derived price elasticity of demand coefficient approximates -1.0. "Necessity" agriculture crops on the other hand, since they lack substitutes their empirically derived own price elasticity of demand coefficient is less than -1.0. The calculated economic values are then arithmetically averaged to give an average economic value of non-honey bee insect pollinators.

The Data set used in this study

This study uses readily available data sourced from the Australian Bureau of Statistics *Value of Agriculture Commodities Produced,* for 2014 – 2015.[2] A total of 53 insect pollinated agriculture crops were identified from that publication which in turn became the data base for this study.[3]

Deriving the Non-Honey Bee Insect Dependency Factors

Using beans as an illustration entomologists credit 10% of bean crops to be insect pollination.[4] Of that ten percent, 20% is pollinated by honey bee pollinators and the remaining 80% is pollinated by non-honey bee insect pollinators.

Table 2: Deriving Insect Dependency Factors [5]

Crop	Percent Pollinated by Insects (1)	Percent of Pollinators that are Honey bees (2)	Honey Bee Dependency Factor (3) = (1) *(2)	Percent Pollinated by Non-Honey Bee Insect Pollinators (4) = 1 - (2)	Non-Honey Bee Insect Dependency Factor (5) = (1) *(4)
Beans	0.10	0.20	0.02	0.80	0.08

Note: Column 1 = (Column 3 plus Colum 5) that is, 0.10 = (0.02 + 0.08).

Source: Modified Table 2 Karasiński (2018) p. 20.

Multiplying columns 1 and 4 in Table 2 results in the all-important Non-Honey Bee Insect Dependency Factor shown in the final column in Table 2. This Non-Honey Bee Insect

[2] Australian Bureau of Statistics, 2015. "Value of Agricultural Commodities Produced, Australia, 2013-14 , Cat. No. 7503.0."
[3] I am grateful for the assistance provided by entomologist Rob Manning in the development of the dependency factors.
[4] The remaining 90% of bean crop pollination is the direct result of the activities of non-insect pollinators.
[5] I am greatly indebted to the assistance provided by entomologist Robert Manning, (2016) who assisted in identifying the honey bee pollinated crops and for updating the estimates of the Honey Bee Dependency Factors for Australian agriculture crops.

Dependency Factor is then incorporated into the economic model to calculate the economic value of non-honey bee insect pollinators.

The Price Elasticity of Demand Coefficient

The fourth and final component of the economic model is the price elasticity of demand coefficients for those insect pollinated agriculture crops.

This study used the Australian results published by Ulubasoglu et al (2010 and 2016) [6] who note: "Fresh fruit is estimated to have … an elasticity … of -1.049 … the demand for fresh vegetables is (price) inelastic … -0.053." [7] Fruits are considered "luxury" crops and have a higher price elasticity coefficient due to the existence of substitutes (i.e. apples substituted for pears etc). As vegetables typically lack substitutes their price elasticity coefficient is lower. The two coefficients are incorporated into the model results to calculate an upper and a lower economic value as shown in columns 2 and 3 in Table 4 below. An arithmetic average of the two ranges is presented as a mid-point estimate of the economic value.

---

[6] While Gill did not state the source of the price elasticity of demand coefficients he used, it can be assumed he used American data publisehd by Houthakker, Hendrik S, and Lester D Taylor (1970) "Consumer Demand in the United States."

[7] Ulubasoglu, Mehmet, Debdulal Mallick, Mokhtarul Wadud, Phillip Hone, and Henry Haszler. 2010. "Food Demand Elasticities for Australia."p.8.

5.0 Results and Discussion

The contents of column 2 and column 3 in Table 2 below are based on the results contained in two previous papers by Karasiński (2018a)[8] and Karasiński (2018b)[9]with the exception that both sets of results have been arithmetically averaged.

When the results in Table 2 are rounded the economic value of honey bee pollinators and non-honey bee insect pollinators are strikingly similar with each recording an economic value of $A 14.2 bn.

Table 2: The Average Economic Value of All Insect Pollinators 2014 -2015.

	Honey Bee Pollinators	Non-Honey Bee Insect Pollinators	Total Insect Pollinators
State and Territory	**Average $**	**Average $**	**Average $**
New South Wales	2,480,580,442	3,643,114,453	6,123,694,895
Victoria	6,084,180,105	2,631,777,553	8,715,957,658
Queensland	2,120,321,611	3,500,352,453	5,620,674,064
South Australia	1,705,444,604	1,744,477,416	3,449,922,020
Western Australia	1,111,690,580	2,592,965,589	3,704,656,168
Tasmania	267,755,281	87,019,027	354,774,308
Northern Territory	388,399,643	39,239,890	427,639,532
A.C.T.	1,098,925	1,513,581	2,612,505
Australia	**14,159,471,189**	**14,240,459,960**	**28,399,931,149**

Combining the two sets of economic values they present for the first time a clear indication of the overall economic value of Australia's insect pollinators which in 2014 -2015 was $A 28.4 bn, see Chart 2 below.

[8] See Karasiński (2018a) Table 4 p.25.
[9] See Karasiński (2018b) Table 3 p.11.

Chart 2: The Economic Dollar Value of Australian Insect Pollinators in 2014 – 2015

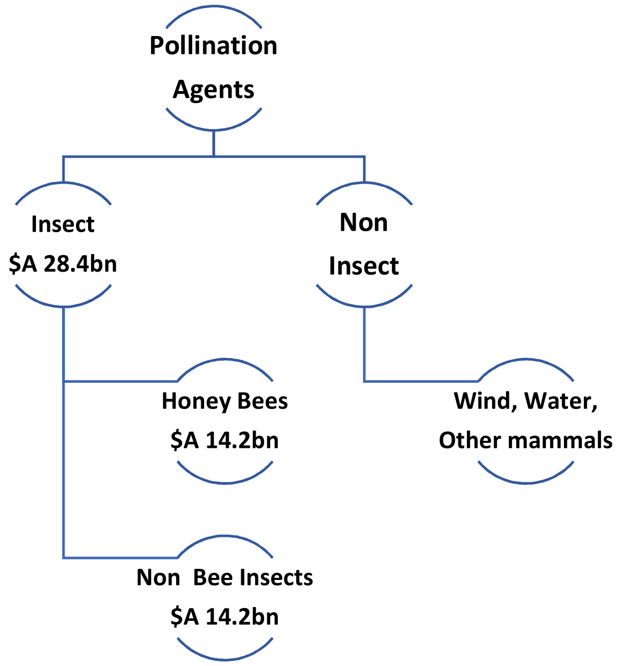
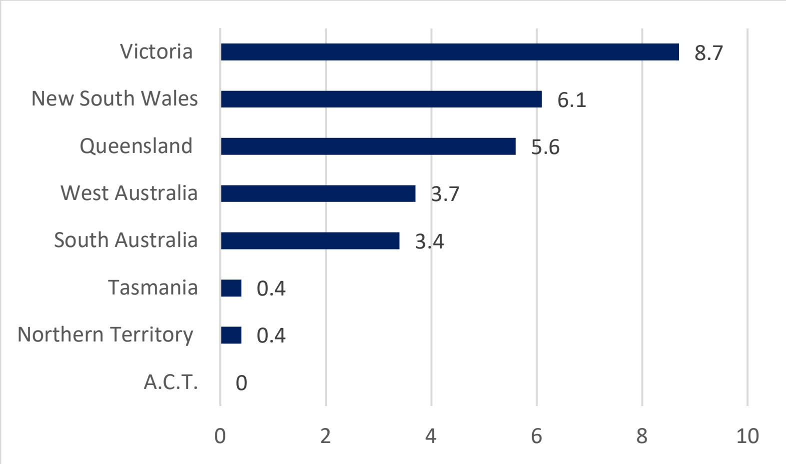


Table 2 also details the economic value of all insect pollinators on a state by state basis. The relative contribution made by honey bee pollinators and non-honey bee insect pollinators as excepted vary considerably between the states due to the crop type, volume of the crops grown along with their specific pollination requirements.

In 2014 – 2015, Victoria had the largest overall economic value recording $A 8.7 bn (with $A 6.1 bn from honey bee pollinators and $A 2.6 bn from non-honey bee pollinators). New South Wales recorded the next highest overall economic value with $A 6.1 bn ($A 2.5bn from honey bee pollinators and $A 3.6 bn) followed by Queensland with $A 6.5 bn ($A 2.1 bn from honey bee pollinators and $A 3.5 bn).

Chart 3 displays the economic values of all insect pollinators on a state by state and territory basis.

Chart 3: Economic Value of All Insect Pollinators by State and Territory 2014-2015 - $A bn



The relatively small economic value for the A.C.T. is not unexpected given the relatively minor role agriculture plays in the nation's capital. Although, the calculated economic value for the Northern Territory necessitates further research.

Economic Value Ratio Analysis – Another Insight

Another way to view the content of Table 2 is to use ratio analysis which measures the percentage contribution made by both major pollination groups to the total economic value for Australia, the states and territories.

The economic value ratio (EVR) for honey bee pollinators is given by equation (1) below:

$$\text{Economic Value Ratio} = \frac{Honey\ Bee\ Pollinators\ Economic\ Value}{Total\ Insect\ Pollinators\ Economic\ Value} \quad Equation\ 1$$

And the economic value ratio (EVR) for non-honey bee insect pollinators is given by equation (2) below:

$$\text{Economic Value Ratio} = \frac{Non - Honey\ Bee\ Insect\ Pollinators\ Economic\ Value}{Total\ Insect\ Pollinators\ Economic\ Value} \quad Equation\ 2$$

The calculated EVR's are detailed in Table 3 below. For Australia the EVR shows an identical contribution made by both pollinator groups with a 50% - 50% (rounded) EVR contribution.

The EVR also highlights differences in the role played by both pollinator groups across Australia where Victoria (69.8%), Tasmania (75.5%) and the Northern Territory (90.8%) report a higher EVR attributed to honey bee pollinators. The opposite is the case for the other four states and the A.C.T.

Table 3: Ratio of Economic Value of Honey Bee Pollinators to Non-Honey Bee Insect Pollinators

	EVR* of Honey Bee Pollinators Equation 1 %	**EVR* of Non-Honey Bee Insect Pollinators Equation 2 %**
State and Territory		
New South Wales	40.5	59.5
Victoria	69.8	30.2
Queensland	37.7	62.3
South Australia	49.4	50.6
Western Australia	30.0	70.1
Tasmania	75.5	24.5
Northern Territory	90.8	9.2
A.C.T.	42.1	57.9
Australia	49.9	50.1
EVR * = Economic Value Ratio		

Economic Value of the Strawberry industry in the Avon region.

The economic value of the contribution made by all insect crop pollinators to the Avon Valley strawberry industry is shown in Table 4 below.

In both the Avon Valley and in Western Australia, the economic value of honey bee pollinators is 6.0% less than the economic value of non-honey bee insect pollinators.

Table 4: The Average Economic Value of All Insect Pollinators - Avon Valley Strawberries 2014 -2015.

	Honey Bee Pollinators Average $	Non-Honey Bee Insect Pollinators Average $	Total Insect Pollinators Average $
Avon Valley, WA.	5,110,868	5,441,772	10,552,640
Western Australia	20,346,655	21,664,004	42,010,659
Australia	136,659,852	226,661,603	363,321,455

The EVR tool developed earlier has been applied to gain an insight into the role played by insect pollinators in the Avon Valley strawberry industry. Table 5 shows the EVR contribution made by honey bee pollinators to total economic value is identical in both the Avon Valley and in Western Australia.

Table 5: Ratio of Economic Value of Honey Bee Pollinators to Non-Honey Bee Insect Pollinators

	EVR of Honey Bee Pollinators Equation 1 %	EVR of Non-Honey Bee Insect Pollinators Equation 2 %
Avon Valley	48.4	51.6
Western Australia	48.4	51.6
Australia	37.6	62.4

There is a noticeable difference between EVR's at a national level which shows non-honey bee insect pollinators making a far greater contribution to the total economic value with an EVR of 62% compared with an EVR of 38% for honey bee pollinators.

As this is the first time EVR's for this industry at this level of detail has been reported, it is not known whether these results are anomalous. The difference may reflect different methods of strawberry farming across Australia including the industry's willingness to adopt glass-house, greenhouse or hot-house strawberry farming methods in preference to broadacre farming.

6.0 Conclusion

This paper presents the results of an economic study which quantified the total economic value of Australian insect pollinators spanning 53 insect pollinated agriculture crops. The results confirm widely held industry and stakeholder belief of the economic importance of both groups of insect pollinators in Australia.

In 2014 – 2015, both major groups of pollination agents made an identical contribution to the total economic value. To gain further insight into the contribution made by both pollinator groups an economic value ratio (EVR) was calculated. The EVR confirms the contribution made to the overall economic value in Australian in 2014-2015 were identical.

On a state by state basis the results vary with Victoria reporting the highest overall economic value of $A 8.7 bn followed by New South Wales with $A 6.1 bn and Queensland with $A 5.6 bn.

This study also quantified the total economic value of the Avon Valley strawberry industry. The contribution made by both major pollinators while similar was not identical. On an EVR basis honey bee insect pollinators contributed 38% of the overall economic value and non-honey bee insect pollinators contributed 62%.

The results contained in this paper confirm the need to regularly measure the total economic value of Australia’s insect pollinators.

7.0 References.

Abrol, Dharam P. 2012a. "Value of Bee Pollination." *Pollination Biology: Biodiversity Conservation and Agricultural Production*, 185-222. Dordrecht: Springer Netherlands.

———. 2012b. "Wild Bees and Crop Pollination." *Pollination Biology: Biodiversity Conservation and Agricultural Production*, 111-184. Dordrecht: Springer Netherlands.

Aizen, Marcelo A, Lucas A Garibaldi, Saul A Cunningham, and Alexandra M Klein. 2009. "How Much Does Agriculture Depend on Pollinators? Lessons from Long-Term Trends in Crop Production." *Annals of botany*: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2701761/

Allsopp, Mike H, Willem J De Lange, and Ruan Veldtman. 2008. "Valuing Insect Pollination Services with Cost of Replacement." *PLoS One* 3 (9): e3128.

Australian Bureau of Statistics. 1987. "Value of Agricultural Commodities Produced, Australia, 1985-86, Cat. No. 7503.0."

———. 2015. "Value of Agricultural Commodities Produced, Australia, 2013-14 , Cat. No. 7503.0."

———. 2017. "Data by Region edited by Australian Bureau of Statistics."

Australian Government. 2015. "Future of the Beekeeping and Pollination Service Industries in Australia: Government Response."

Australian Dept of Agriculture. 2014. "Inquiry into the Future of the Beekeeping and Pollination Services Industries in Australia. Submission 79."

Australian Honey Bee Industry Council. 2007. "The Future Development of the Australian Honey Bee Industry."

Australian House of Representatives. 2008. *More Than Honey: The Future of the Australian Honey Bee and Pollination Industries: Report of the Inquiry into the Future Development of the Australian Honey Bee Industry*. Canberra. http://www.aph.gov.au/parliamentary_business/committees/house_of_representatives_committees?url=/pir/honey bee/report.htm.

Australian Senate Standing Committees on Rural and Regional Affairs and Transport. 2014. "Future of the Beekeeping and Pollination Service Industries in Australia". http://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Rural_and_Regional_Affairs_and_Transport/Beekeeping/Report/index.

Bank of England, 2018 "Inflation Calculator" https://www.bankofengland.co.uk/monetary-policy/inflation Accessed 10 June 2018.

Barfield, Ashley Suzanne, John C Bergstrom, and Susana Ferreira. 2012. "An Economic Valuation of Pollination Services in Georgia." University of Georgia.

Barry, S, D Cook, R Duthie, D Clifford, and D Anderson. 2010. "Future Surveillance Needs for Honey bee Biosecurity." Rural Industries Research and Development Corporation 10: 107.

Bateman, Ian, G. M. Mace, C. Fezzi, G. Atkinson, and R. K. Turner. 2014. "Economic Analysis for Ecosystem Service Assessments." *Valuing Ecosystem Services: Methodological Issues and Case Studies*, 23-77. Edward Elgar Publishing.

Bator, F. 1958. "The Anatomy of Market Failure." *The Quarterly Journal of Economics* 72 (3): 351-376

Batra, S.W.T. 1995. "Bees and Pollination in Our Changing Environment." *Apidologie* 26: 361-361.
Bauer, D. M . 2014. " Valuing Pollination Services: A Comparison of Approaches." *Valuing Ecosystem Services: Methodological Issues and Case Studies*: 147 - 167
Bauer, D.M. and I Sue Wing. 2010. "Economic Consequences of Pollinator Declines: A Synthesis." *Agricultural and Resource Economics Review* 39 (3): 368-383.
Benjamin, Alison, and Brian McCallum. 2009. "A World without Bees." Random House.
Bommarco, Riccardo, Lorenzo Marini, Vaissi, Xe, and Bernard E. 2012. "Insect Pollination Enhances Seed Yield, Quality, and Market Value in Oilseed Rape." *Oecologia* 169 (4): 1025-1032. http://www.jstor.org/stable/23260134.
Brading, Patrick, Ahmed El-Gabbas, Samy Zalat, and Francis Gilbert. 2009. "Biodiversity Economics: The Value of Pollination Services to Egypt." *Egyptian Journal of Biology* 11 (1).
Burgett, Michael, Stan Daberkow, Randal Rucker, and Walter Thurman. 2010. "US Pollination Markets: Recent Changes and Historical Perspective." *American Bee Journal*.
Butler, C.G. 1943. "The Position of Honey-Bee in the National Economy. Adult Bee Diseases." *Annals of Applied Biology* 30 (2): 189-191.
Calderone, N.W. 2012 "Insect Pollinated Crops, Insect Pollinators and US Agriculture: Trend Analysis of Aggregate Data for The Period 1992 - 2009." *PLos ONE* 7 (5).
Carreck, Norman, and Ingrid Williams. 1998. "The Economic Value of Bees in the UK." *Bee World* 79 (3): 115-123. doi: 10.1080/0005772X.1998.11099393.
———. 2001. "The Economic Value of Bees in the UK." *Beeefarmers UK* 317 (3): 115-123. http://dx.doi.org/10.1080/0005772X.1998.11099393.
Centre for International Economics. 2006. "Future Directions for the Australian Honey Bee Industry" http://www.honey bee.org.au/pdf/CIE_FINAL_REPORT.pdf.
Chapman, Nadine C, Julianne Lim, and Benjamin P Oldroyd. 2008. "Population Genetics of Commercial and Feral Honey Bees in Western Australia." *Journal of economic entomology* 101 (2): 272-277.
Cheung, Steven, N. S. . 1973. "The Fable of the Bees: An Economic Investigation." *The Journal of Law & Economics* 16 (1): 11-33. http://www.jstor.org/stable/724823.
Clark, C. 1990. "Mathematical Bioeconomics." Wiley.
Coase, R. H. 1974. "The Lighthouse in Economics." *Journal of Law and Economics* 17 (2): 357-376.
Cook, David C, Matthew B Thomas, Saul A Cunningham, Denis L Anderson, and Paul J De Barro. 2007. "Predicting the Economic Impact of an Invasive Species on an Ecosystem Service." *Ecological Applications* 17 (6): 1832-1840.
Corbet, Sarah A, Ingrid H Williams, and Juliet L Osborne. 1991. "Bees and the Pollination of Crops and Wild Flowers in the European Community." *Bee World* 72 (2): 47-59.
Crop Pollination Association Inc http://www.aussiepollination.com.au/
CSIRO, 2014. Submission the Future of the Australian Honey Bee Industry www.aphref.aph.gov.au_house_committee__pir_honey bee_subs_sub033.pdf
———. 2017. Pollination Biosecurity CSIRO. 2017 Accessed 12 January 2017, https://csiropedia.csiro.au/pollination-biosecurity/.

Danka, Robert G, H Allen Sylvester, and Debbie Boykin. 2006. "Environmental Influences on Flight Activity of USDA–ARS Russian and Italian Stocks of Honey Bees (Hymenoptera: Apidae) During Almond Pollination." *Journal of economic entomology* 99 (5): 1565-1570.

Darwin, Charles. 1876. *The Effects of Cross and Self Fertilisation in the Vegetable Kingdom*. Chapter XI pp
424 - 425.
http://darwin-online.org.uk/converted/published/1881_Worms_F1357/1876_CrossandSelfFertilisation_F1249/1876_CrossandSelfFertilisation_F1249.html

Dawes, J and, and D Dall. 2014. "Value-Adding to Honey." Rural Industires Research and Development Corpoation, Publication No 13/123

De Barro, Paul. 2007. "The Future of the Australian Honey Bee Industry." www.aph.gov.au/.../House_of_Representatives_Committees?.../honey bee....

de Lange, Willem J, Ruan Veldtman, and Mike H Allsopp. 2013. "Valuation of Pollinator Forage Services Provided by Eucalyptus Cladocalyx." *Journal of Environmental Management* 125: 12-18.

Dijkstra, Jelte Pieter, and Manja M Kwak. 2007. "A Meta-Analysis on the Pollination Service of the Honey Bee (Apis Mellifera L.) for the Dutch Flora" Proceedings of the Section experimetnal and applied entolmology. Netherlands Entomologival Society,

Dollin, Anne. 2013. "Austroplebeia Cincta: A spectacular new species of stingless Bee for Australia." Aussie Bee online, Article 22 January.

Drucker, Adam G. 2004. "Economic Valuation of Bee Pollination Services: Implications for Farm Management and Policy." *Solitary bees: Conservation, Rearing and Management for Pollination. Fortaleza, Imprensa Universitária, 285p*: 125-134.

Dumas, Daisy 2015 The Unlikely New Capital of Global Chia Production Sydney Morning Herald. Accessed 18 December 2016, http://www.smh.com.au/national/the-unlikely-new-capital-of-global-chia-production-20151021-gkf357.html.

Edwards, Tom. 2015. "Chinese Developer Harvests First Crop in Western Australia's Remote Ord Valley." ABC Online Accessed 13 January 2017 http://www.abc.net.au/news/2015-09-29/kai-harvests-first-ord-crop/6806284.

Ellis, J.D. and Zettle Nalen. C M. 2016. "Varroa Mite**,** Varroa destructor Anderson and Trueman (Arachnida: Acari: Varroidae)." University of Florida IFAS Extension
http://edis.ifas.ufl.edu/in855

Fowler, Alisha. 2007 "Einstein on Bees." Accessed 1 January 2017, https://globalclimatechange.wordpress.com/2007/04/20/einstein-on-bees/.

Franke, R.H. and Bernake, B.S. 2009. "Principles of Economics. Brief Edition." Boston: McGraw-Hill Irwin

Free, J.B. 1970. "Insect Pollination of Crops." Academic Press London and New York.

———.1993. "Insect Pollination of Crops." Second Ed. Academic Press London and New York.

Freeman III, A Myrick, Joseph A Herriges, and Catherine L Kling. 2014. "The Measurement of Environmental and Resource Values: Theory and Methods." Routledge.

Gallai N, Salles J and Vaissières, B 2012. "Land Use Change as a Determinant of the European Agricultural Vulnerability Confronted with Pollinator Decline."

Gallai, Nicola and Vaissière, Bernard E. 2009. "Guidelines for the Economic Valuation of Pollination Services at a National Level."

Gallai, Nicola, J-M Salles, J and Settele, and B Vaissiere. 2009. "Economic Valuation of the Vulnerability of World Agriculture Confronted with Pollinator Decline." *Ecological Economics* 68 (3): 810-821. doi: 10.1016/i.ecoleocon.2008.06.114.

Gardner, Victor Ray. 1913. "A Preliminary Report on the Pollination of the Sweet Cherry." Oregon Agricultural College Press.

Gemmill-Herren, Barbara. 2016. "Pollination Services to Agriculture. Sustaining and enhancing a key ecosystem service." FAO - Routledge.

Gibbs, Diana MH, and Ian F Muirhead. 1998. "The Economic Value and Environmental Impact of the Australian Beekeeping Industry. A report prepared for the Australian beekeeping industry." https://honeybee.org.au/doc/Muirhead.doc

Gill, R A. 1989. "The Social Value of Commercially Managed Honey Bee Pollination Services in Australia."

Gill, R.A. 1990. "The Value of Honey bee Pollination to Society" *VI International Symposium on Pollination 288*, Gill, R A.1991a. "The Value of Honebee Pollination to Society " *Apiacta* 4.

Gill, R.A. 1991. "The Applicability of the Economic Surplus Model to the Valuation of Honey bee Pollination Services in Australia." http://ageconsearch.umn.edu/bitstream/145866/2/1991-05-05.pdf.

Gill, R.A. 1996. "The Benefits to the Beekeeping Industry and Society from Secure Access to Public Lands and their Melliferous Resources." *Honey bee Research and Development Council of Australia. August*.

Gordon, J. and L. Davis. 2003. "Valuing Honey bee Pollination." Rural Industries Research and Development Corporation Publication No 07/077.

Groves, R.H. R. Boden and W.M. Lonsdale, 2002. "The Impacts of Alien Plants in Australia." *Biological invasions: economic and environmental costs of alien plant, animal, and microbe species*: 11-24. WWF - CSIRO

Halter, Reece 2014. "Australian Honey Bees Unable to Make Honey." The Huffington Post http://www.huffingtonpost.com/dr-reese-halter/australian-honey bees-unable-to-make-honey_b_4670475.html.

Houthakker, Hendrik S, and Lester D Taylor. 1970. "Consumer Demand in the United States."

Hein, Lars. 2009. "The Economic Value of the Pollination Service. A Review across Scales." *Open Ecology Journal* 2: 74-82.

Hufschmidt, Gabi. 2011. "A Comparative Analysis of Several Vulnerability Concepts." *Natural Hazards* 58 (2): 621-643. doi: 10.1007/s11069-011-9823-7.

Industries Commission Assistance. 1985. "Industries Assistance Commission Report on Biological Control of Echium Species (Including Paterson's Curse/Salvation Jane)," *30 September 1985*, *Industries Assistance Commission Report ; No. 371*. Canberra: Australian Government Publishing Service.

Karasinski, J.M. 2016a. "The Economic Importance of Australian and Westen Australian Honey bees 1989 - 2014: Preliminary Estimates." Presentation made to the Bee Industry Council of Western Australia. November.

———.2016b. "Valuing the Services of Honey bees." Presentation made to the Centre for Integrative Bee Research, University of Western Australia. December.

———. 2017a "The Economic Valuation of Australian Managed and Wild Honey bee Pollinators." Presentation to the WA Beekeeprs Executive Meeting.
———. 2017b "The Economic Valuation of Australian Managed and Wild Honey bee Pollinators." Presentation to the WA Branch of the Agriculture and Natural Resource Economics Society.
———. 2017c "Different Ways Used to Measure the Importance of Australia's Managed and Wild Honeybee Industry." BeeInformed Vol 16 Issue 1 April p.7
———. 2018a "The Economic Valuation of Australian Managed and Wild Honey Bee Pollinators 2.0" http://www.aussiepollination.com.au/index.php/ct-menu-item-28
———. 2018b "The Economic Valuation of Australian Non Bee Insect Pollinators in 2014 -2015
Jiandong, An, and Chen Wenfeng. 2011. "Economic Value of Insect Pollination for Fruits and Vegetables in China." *Acta Entomologica Sinica* 54 (4): 443-450.
Kasina, J. M., J. Mburu, M. Kraemer, and K. Holm-Mueller. 2009. "Economic Benefit of Crop Pollination by Bees: A Case of Kakamega Small-Holder Farming in Western Kenya." *Journal of Economic Entomology* 102 (2): 467-473. doi: 10.1603/029.102.0201.
Ken, T, A Marma, M.S. Munawar, T Partap, U Partap, P Phartiyal, HK Sharma, and NB Tamang. 2012. *Value of Insect Pollinators to Himalayan Agricultural Economies*: International Centre for Integrated Mountain Development (ICIMOD).
Keogh, RC, PW Anthony, APW Robinson, and IJ Mullins 2010. "Pollination Aware. The Real Value of Pollination in Australia " Rural Industries Research and Development Corporation,Publication No 10/081 Canberra.
Kevan, Peter G, and Truman P Phillips. 2001. "The Economic Impacts of Pollinator Declines: An Approach to Assessing the Consequences." *Conservation Ecology* 5 (1): 8.
Klein, A-M, Ingolf Steffan-Dewenter, and Teja Tscharntke. 2003. "Pollination of Coffea Canephora in Relation to Local and Regional Agroforestry Management." *Journal of Applied Ecology* 40 (5): 837-845.
Klein, A M, Vaissiere, B E , Cane J H, Steffan -Dewenter, I, Cunningham, S, Kremen, C and Tscharntke, T 2007. "Importance of Pollinators in Changing Landscapes for World Crops." *Proc R.Soc.B* 274 (303-313). doi: doi:10.1098/rspb.2006.3721.
Klein, Alexandra-Maria, Ingolf Steffan-Dewenter, and Teja Tscharntke. 2003. "Bee Pollination and Fruit Set of Coffea Arabica and C. Canephora (Rubiaceae)." *American Journal of Botany* 90 (1): 153-157.
Klein, Alexandra–Maria, Ingolf Steffan–Dewenter, and Teja Tscharntke. 2003. "Fruit Set of Highland Coffee Increases with the Diversity of Pollinating Bees." *Proceedings of the Royal Society of London. Biological Sciences* 270 (1518): 955-961.
Kling, Catherine L., Kathleen Segerson, and Jason F. Shogren. 2010. "Environmental Economics: How Agricultural Economists Helped Advance the Field." *American Journal of Agricultural Economics* 92 (2): 487-505. http://www.jstor.org/stable/40647999.
Langridge, D.F., and R.D. Goodman. 1981. "Honey Bee Pollination of the Apricot CV. Trevatt." *Animal Production Science* 21 (109): 241-244. http://www.publish.csiro.au/?paper=EA9810241.
Lefebvre, Diane, and Jacqueline Pierre. 2006. "Spatial Distribution of Bumblebees Foraging on Two Cultivars of Tomato in a Commercial Greenhouse." *Journal of Economic Entomology* 99 (5): 1571-1578. doi: 10.1093/jee/99.5.1571.

Losey, J. E. and Vaughan, M. . 2006 "The Economic Value of Ecological Services Provided by Insects." *BioScience* 56 (4): 311-323.
Losey, John E, and Mace Vaughan. 2006. "The Economic Value of Ecological Services Provided by Insects." *Bioscience* 56 (4): 311-323.
Majewski, Janusz. 2014. "Economic Value of Pollination of Major Crops in Poland in 2012." *Economic Science for Rural Development (Latvia)*.
Manning, Robert. 2006. "Fatty Acid Composition of Pollen and the Effect of Two Dominant Fatty Acids (Linoleic and Oleic) in Pollen and Flour Diets on Longevity and Nutritional Composition of Honey Bees (Apis Mellifera)." Murdoch University. http://researchrepository.murdoch.edu.au/434/.
———. 2016. "Honey Bee Pollinated Agriculture Crops in Australia" personal communication.
Marshall, Alfred. 1920. "Principles of Economics. An Introductory Volume." 8th Ed London.
Mbura, John., Gerard Hein, L, Gemmill, B and Collette, L 2006. "Economic Valuation of Pollination Services: Review of Methods " *FOA*
McGregor, S.E. 1976a. "Insect Pollination of Cultivate Crop Plants."
———. 1976b. "Insect Pollination of Cultivated Crop Plants." Vol. 496: Agricultural Research Service, US Department of Agriculture.
Meade, J. E. 1952. "External Economies and Diseconomies in a Competitive Situation." *The Economic Journal* 62 (245): 54-67. doi: 10.2307/2227173.
Melhim, Almuhanad, Alfons Weersink, Zach Daly, and Nicholas Bennett. "Beekeeping in Canada."
Mikkelson, David 2008. "Einstein on Bees" Accessed 1 January 2017 http://www.snopes.com/quotes/einstein/bees.asp.
Monck, Michael, Jenny Gordon, and Kevin Hanslow. 2008. "Analysis of the Market for Pollination Services in Australia." Rural Industries Research and Development Corporation. Publication No 08/058.
Morse, R.A. and Calderone, N.W. 2000. "The Value of Honey Bees as Pollinators of US Crops in 2000" Cornell University N.Y.
Munawar, Muhammad Sidddique, Shazia Raja, Mahjabeen Siddique, Shahid Niaz, and Muhammad Amjad. 2009. "The Pollination by Honey Bee (Apis Mellifera L.) increases Yield of Canola (Brassica Napus L.)." *Pakistan Entomologist* 31 (2): 103.
Muth, Mary, Xa, K, Randal Rucker, xa, R, Walter Thurman et al. 2003. "The Fable of the Bees Revisited: Causes and Consequences of the U.S. Honey Program." *The Journal of Law & Economics* 46 (2): 479-516. doi: 10.1086/377290.
Nerlove, Marc. 1956. "Estimates of the Elasticities of Supply of Selected Agricultural Commodities." *Journal of Farm Economics* 38 (2): 496-509.
Nicola, Gallai, and Salles Jean-Michel. 2013. "Land Use Change as a Determinant of the European Agricultural Vulnerability Confronted with Pollinator Decline." *Final program*: 574.
Nightingale, Tom. 2012. "Dangerous Mite Threatens Billion Dollar Bees." *ABS online*
Ninan, Karachepone Ninan. 2014. "Valuing Ecosystem Services: Methodological Issues and Case Studies." Edward Elgar Publishing.

NSW Dept of Primary Indsutry. 2012. "American Foulbrood." Accessed 13 December 2016, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0010/333388/European-foulbrood-and-its-control.pdf.

———. 2018. "American Foulbrood." Accessed 9 Janaury 2018, http://www.dpi.nsw.gov.au/animals-and-livestock/bees/pests-diseases/foulbrood-disease/american-foulbrood

Olmstead, Alan L. and Donald B. Wooten. 1987. "Bee Pollination and Productivity Growth: The Case of Alfalfa." *American Journal of Agricultural Economics* 69 (1): 56-63. http://www.jstor.org/stable/1241306.

Olschewski, Roland, Teja Tscharntke, Pablo C Benítez, Stefan Schwarze, and Alexandra-Maria Klein. 2006. "Economic Evaluation of Pollination Services Comparing Coffee Landscapes in Ecuador and Indonesia." *Ecology and Society* 11 (1): 7.

Parkin, Michael 2010. "Economics. 9th Ed". Boston, San Francisco, NY Addison-Wesley.

Partap, T and U Partap. 2001. "Declining Apple Production and Worried Himalayan Farmers: Promotion of Honey bees for Pollination."

Partap, Uma and Tang Ya. 2012. "The Human Pollinators of Fruit Crops in Maoxian County, Sichuan, China: A Case Study of the Failure of Pollination Services and Farmers' Adaptation Strategies." *Mountain Research and Development (Online)* 32 (2): 176-186.

Paton, D 2008. "Securing Long Term Floral Resources for the Honey bee Industry " Rural Industries Research and Development Corporation, No 10/087 Canberra.

Paudel, Yagya Prasad, Robert Mackereth, Rodney Hanley, and Wensheng Qin. 2015. "Honey Bees (Apis Mellifera L.) and Pollination Issues: Current Status, Impacts and Potential Drivers of Decline." *Journal of Agricultural Science* 7 (6): p93.

Pearson, Gwen 2015. "Bees Are Great at Pollinating Flowers, but So Are Vibrators." Wired.com. Accessed 22 January 2016, https://www.wired.com/2015/05/bees-great-pollinating-flowers-vibrators/.

Perman, R. 2003. "Natural Resource and Environmental Economics." Pearson Education.

Pigou, A.C. 1920. "The Economics of Welfare." London: Macmillan and Co

Pindyck, R and Rubinfeld, D.I. 2009. "Microeconomics 7th Ed." Pearson International Edition

Rader, Romina, Ignasi Bartomeus, Lucas A Garibaldi, Michael P.D. Garratt, Brad G Howlett, Rachael Winfree, Saul A Cunningham, Margaret M Mayfield, Anthony D Arthur, and Georg KS Andersson. 2016. "Non-Bee Insects Are Important Contributors to Global Crop Pollination." *Proceedings of the National Academy of Sciences* 113 (1): 146-151.

Robinson, W. S., R. Nowogrodzki, and R. A. Morse. 1989. "The Value of Honey Bees as Pollinators of U.S. Crops." *American Bee Journal* 129 (6): 411-423. http://search.proquest.com/docview/15249517?accountid=10382

Rodriguez, V. B. Cid Riley, Walter Shafron, and Ray Lindsay. 2003. "Honey bee Industry Survey." *Rural Industries Research and Development Corporation, Pub* (03/039).

Roubik, David W. 2002. "Tropical Agriculture: The Value of Bees to the Coffee Harvest." *Nature* 417 (6890): 708-708.

Rucker, Randal R, Walter N Thurman, and Michael Burgett. 2012. "Colony Collapse Disorder: The Economic Consequences of Bee Disease." Montana State University, Department of Agricultural Economics and Economics.

Rural Industries Research and Development Corporation, "Pollination Aware - Papaya Case Study 22." (RIRDC Publication No 10/129).
Russo, Carlo, Richard Green, and Richard E Howitt. 2008. "Estimation of Supply and Demand Elasticities of California Commodities." *SSRN 1151936*.
Shammout, A, Nizar Haddad, and Omar Abuobeid. 2014. "The Monetary Value of Ecosystem Services Provided by Insects (a Case Study for Selected Crops in Jordan)." *Jordan Journal of Agricultural Sciences* 10 (1): 16-33.
Siebert, John W. 1980. "Beekeeping, Pollination, and Externalities in California Agriculture." *American Journal of Agricultural Economics* 62 (2): 165-171. http://www.jstor.org/stable/1239682.
Southwick, Edward E., and Lawrence Southwick. 1992. "Estimating the Economic Value of Honey Bees (Hymenoptera: Apidae) as Agricultural Pollinators in the United States." *Journal of Economic Entomology* 85 (3): 621-633. doi: 10.1093/jee/85.3.621.
Spangenberg, J.H. and Settele, J,. 2010. "Precisely Incorrect? Monetising the Value of Ecosystem Services" *Ecological Complexity* 7 (3).
Spangenberg, J.H. Gorg, C, Truong, D T, Tekken,V Bustamante, J V and Settele, J. "Provision of ecosystems services is determined by human agency, not ecosystem functions: Four Case Studies" in *International Journal of Biodiversity Science, Ecosystem Services & Management* 10 (1): 40-53. doi: 10.1080/21513732.2014.884166.
Spangenberg, Joachim H., Bondeau, Alberte, Carter,Timothy R., Fronzek, Stefan, Jaeger, Jill, Jylhä, Kirsti, Kühn, Ingolf,Omann, Ines, Paul, Alex, Reginster, Isabelle, Rounsevell,Mark, Schweiger, Oliver, Stocker,Andrea, Sykes, Martin T and Josef Settele. 2012. "Scenarios for Inverstigating Risks to Biodiversity " *Global Ecology and Biogeograpghy* 21: 5-18.
Stiglitz, J.E. Walsh,C.E., Chow, J., Guest, R., Richmond, W., and Tani, W. 2014. "Principles of Economics, First Australian Edition." Milton Qld: John Wiley and Sons, Australia.
Sumner, Daniel A. 2006. "Economics and Agricultural Supply in California: The Activities and Role of the Giannini Foundation." *of the Giannini Foundation to the Changing Context of California Agriculture*: 129.
Temple, M.L, B.J. Emmett, P.E. Scott, and R.J. Crabb. 2001. "Economic Policy Evaluation of DEFRA's Bee Health Programme."Adas Consulting Ltd., Woodthorne, Wergs Road Wolverhampton. Report to Department for Environment Food and Rural Affairs, London, UK.
ten Brink P. Badura T. Bassi S., Daly, E. Dickie, I. Ding H., Gantioler S., Gerdes, H., Kettunen M., Lago, M., Lang, S., Markandya A., Nunes P.A.L.D., Pieterse, M., Rayment M., Tinch R., 2011. "Estimating the Overall Economic Value of the Benefits Provided by the Natura 2000 Network. Final Report to the European Commission, DG Environment on Contract." Institute of European Environmental Policy. ENV.B.2/SER/2008/0038.
Thapa, R.B. 2006. "Honey bees and Other Insect Pollinators of Cultivated Plants: A Review." *Journal of the Institute of Agriculture and Animal Science* 27: 1-23.
The White House, United States Government 2016. Photos and Facts: What You Can Learn from the White House Honey bees. Accessed 20 December 2016.
https://www.whitehouse.gov/blog/2015/06/16/photos-and-facts-what-you-can-learn-white-house-honey bees.

Thomson, Margie 2007. "Footnote 2 Transcript of Evidence " In *Standing Committee of Primary Industries and Resources* Canberra The Pariliament of Commonwealth of Australia

Tietenberg, Thomas H, and Lynne Lewis. 2010. "Environmental Economics and Policy." Addison-Wesley.

Tisdell, Clement A. 2009. "Resource and Environmental Economics: Modern Issues and Applications." *Resource and Environmental Economics: Modern Issues and Applications.*

Turner, Billie Lee, Pamela A Matson, James J McCarthy, Robert W Corell, Lindsey Christensen, Noelle Eckley, Grete K Hovelsrud-Broda, Jeanne X Kasperson, Roger E Kasperson, and Amy Luers. 2003. "Illustrating the Coupled Human–Environment System for Vulnerability Analysis: Three Case Studies." *Proceedings of the National Academy of Sciences* 100 (14): 8080-8085.

U S Dept Agriculture. 2014. "Field Crop. Final Estimates 2007-2012." http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1046

U K National Audit Office. 2009. "The Health of Livestock and Honey Bees in England " March. https://www.nao.org.uk/press-releases/the-health-of-livestock-and-honey bees-in-england-2/.

Ulubasoglu, Mehmet, Debdulal Mallick, Mokhtarul Wadud, Phillip Hone, and Henry Haszler. 2010. "Food Demand Elasticities for Australia." https://www.deakin.edu.au/__data/assets/pdf_file/0020/405227/2010_10.pdf.

———. 2016. "Food Demand Elasticities for Australia." *Australian Journal of Agricultural and Resource Economics* 60 (2): 177-195. doi: 10.1111/1467-8489.12111.

Vanyi, Georgina Arvane , Csapo,Zsolt and Karpati,Laszlo 2010. "Positive Externality of Honey Production 120th EAAE Seminar External Cost of Farming Activities: Econmic Evalaution, Environmental Repercussions and Regualtory Framework.

VegiBee. 2016. The Vegibee Garden Pollinators. Accessed 27 December 2016, http://vegibee.com/index.php/about-vegibee-garden-pollinators/.

Voorhies, Edwin C, Frank E Todd, and John Kenneth Galbraith 1933 "Economic Aspects of the Bee Industry." Bulletin 555, September. University of California, College of Agriculutre, Agriculture Excperiment Station. Berkley, California.

Walsh, Bryan. 2013. "The Plight of the Honey bee." *Time Magazine*: 31-37.

Willig, Robert D. 1976. "Consumer's Surplus without Apology." *The American Economic Review* 66 (4): 589-597. http://www.jstor.org/stable/1806699.

WA Dept of Agriculture 2016a. "European Foulbrood of Bees." Accessed 13 December 2016, https://www.agric.wa.gov.au/bees/preventing-spread-american-foulbrood-disease.

———. 2016b. Preventing Spread of American Foulbrood Disease. Accessed 13 December 2016, https://www.agric.wa.gov.au/bees/preventing-spread-american-foulbrood-disease.

Deliberately Left Blank