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A Bio-Economic Evaluation of the American Foulbrood (AFB) Control Program in Western Australia

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A BIO-ECONOMIC EVALUATION OF THE AMERICAN FOULBROOD (AFB) CONTROL PROGRAM IN WESTERN AUSTRALIA

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ABSTRACT

American foulbrood (AFB) is considered the most significant brood disease of bees in Western Australia. The Department of Agriculture of Western Australia (DAWA) provides assistance to apiarists by way of quarantine and surveillance measures under the AFB control program. A bio-economic evaluation was considered necessary by the department for setting future policy direction. As a way forward, a number of risk analysis scenarios were simulated to estimate the future prevalence rate of AFB in the absence of the present program. This epidemiological investigation was complemented by an economic evaluation which identifies the extent of benefit that flows through to direct beneficiaries. The paper provides a comprehensive bio-economic analysis and suggests future policy direction in accordance with Centre for International Economic (CIE) guidelines for animal health issues.

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1. Background

American foulbrood (AFB) is considered the most significant brood disease of bees in Western Australia. The casual organism, *Paenibacillus larvae* is a spore forming bacterium, the spores being capable of withstanding environmental extremes for many years. The disease has been present in Western Australia since the late 1800's, with the compulsory reporting and destruction of diseased bees required since the turn of the 20th century. Antibiotics to control the disease are allowed in some countries, but their use only masks the presence of the organism, and has the potential to produce residues in honey.

Strategies are available to beekeepers to minimise the risk of AFB to their apiaries. Treatment of the disease with antibiotics (such as tetracycline and tylosin) may suppress clinical expression, but do not prevent or remove spores from affected hives. The use of treatments such as antibiotics may lead to unacceptable residues in honey. Treatment with tetracyclines is also applied to hives infected with European Foulbrood (EFB), but such treatment masks the presence of AFB thereby facilitating further spread of AFB bacterial spores.

Spread of AFB occurs when bees from a healthy hive rob infected hives (such as abandoned or neglected affected apiaries), with the use of infected bee equipment, feeding infected honey or pollen, moving hives, and when bees from an infected hive drift into clean hives.

The diagnosis of AFB is fairly straightforward, with the organism readily obtained from infected brood cells. A honey culture test (HCT) is available, but does not have either a sensitivity or specificity, and is best used as a screening test (Allan 1993). An enzyme linked immunosorbent assay is available for AFB, and a DNA polymerase chain reaction process is being developed to detect the organism. However, both these tests are applied to suspect brood, not honey, and at this stage offer little advantage over current microbiological testing. In addition, these newer tests are at present considerably more expensive than routine microbiological testing and the HCT.

The organism is difficult to grow in the laboratory, because the spores do not germinate on ordinary bacteriological media with ease. However, with appropriate technique, it appears possible to detect spores in honey in the year before disease occurs, so the bee keepers can be alerted to the impending disease ahead of time.
The consequences of the AFB for a hive is ultimately fatal, with brood failure and hive collapse. If infection is widespread, then the disease will destroy an apiary.

2. Economic Significance

The loss of a hive infected with AFB represents a substantial cost for the apiarists in terms of equipment, the value of the bees and any honey it contains, and the loss of future earnings From past and present evidence it can be estimated that there is a loss of 60kg of honey per hive infected with AFB. At current prices, this represents a loss of $192. A replacement hive costs in the order of $150, and a nucleus hive with a young laying queen bee costs $60. The total cost of lost honey plus replacement hives amounts to $402 for each infected hive. This estimate does not include the cost of labour to destroy the infected hive, and the loss of honey while building up new hives to production levels. For commercial producers with over 100 hives, even a few cases of AFB would quickly amount to heavy financial impost.

The Department of Agriculture of Western Australia (DAWA) has one inspector who spends approximately 40 percent of his time (85 days, implying a cost of $23,343) on AFB issues. This includes extension, collating disease information, direct contact with bee keepers, paper work and travelling. Total cost for this work is approximately $30,000. It is important to note that the AFB control program is a part of the overall Bee Disease Control Project and has overlapping economic significance for European Foul Brood and other bee diseases in addition to quarantine and surveillance measures.

3. Surveillance Data and AFB Prevalence Rate

With a large number of registered apiaries, and the limited availability of departmental resources, beekeepers themselves are primarily responsible for surveillance of their hives, and reporting of diseases. The Department of Agriculture through its hive inspective activities can only offer a limited range of services. Emphasis is on following up reports, results from the HCT and a limited quantity of random inspections.

An area where surveillance is minimal, is that of feral bees. Because of the absence of EFB from WA, there is a large population of feral bees which may be infected with AFB, and serve as a source of infection for domestic bees. Responsibility for feral bees is a complex issue with different agency involvement. Inspection activities are listed below in Table 1. It is clear that only a small proportion of the state's 43,663 hives can be physically inspected by the departmental inspectors.

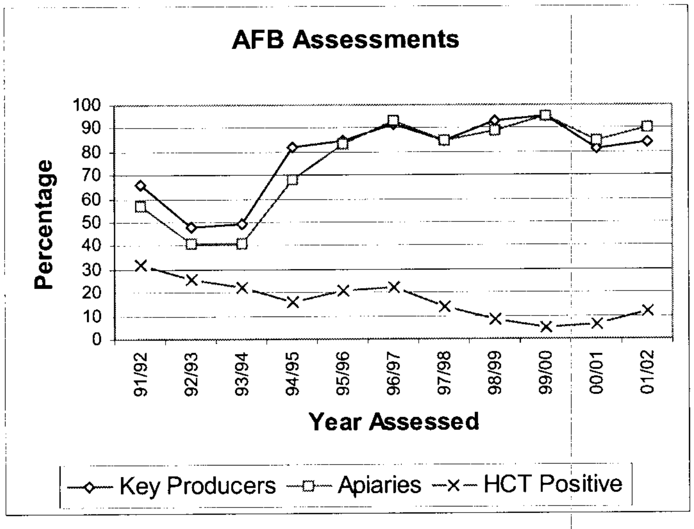
Table 1 Surveillance activities – hives inspected

Reason for Surveillance	**Period of Surveillance**					
	1996/97	**1997/98**	**1998/99**	**1999/00**	**2000/01**	**2001/02**
Random Inspection	782	688	665	1044	347	455
Suspect Disease	365	1824	930	657	666	468
Apiarist Notified	66	102	33	173	118	48
Non-compliance	237	96	190	66	311	21
Total	1450	2710	1818	1940	1442	992

Source Jeff Beard (Bee Inspector of The Department of Agriculture)

The apiary industry in Western Australia consists of a large number of registered beekeepers (904), managing approximately 44,000 hives. Ninety six (96) beekeepers with over 100 hives manage about 83% of all hives (36,064). At present, American foul brood (AFB) has been detected in about 12% of hives, an increase since 2000 when the organism was detected in around 5% of apiaries (Figure 1).

Figure 1: Prevalence rate assessment of AFB using honey culture test



4. Methodology

The data from Table 1 were used to estimate possible apiary infection rates in the absence of controls. Firstly, data on percentage of apiaries positive was subjected to linear regression analysis, which was then used to model the possible increase in percentage of apiaries infected. For each simulated year, a regression value was computed, and a component representing 20% of uncontrolled hives from the previous year incorporated. Data were made stochastic by using the mean value and standard deviation of current estimated prevalence to generate a normal distribution for the starting point of the regression line (@Risk® Palisade Corporation).

Secondly, because a linear growth in the rate of infection is unrealistic, the starting point as described above was used to generate an exponential growth model, of the form:

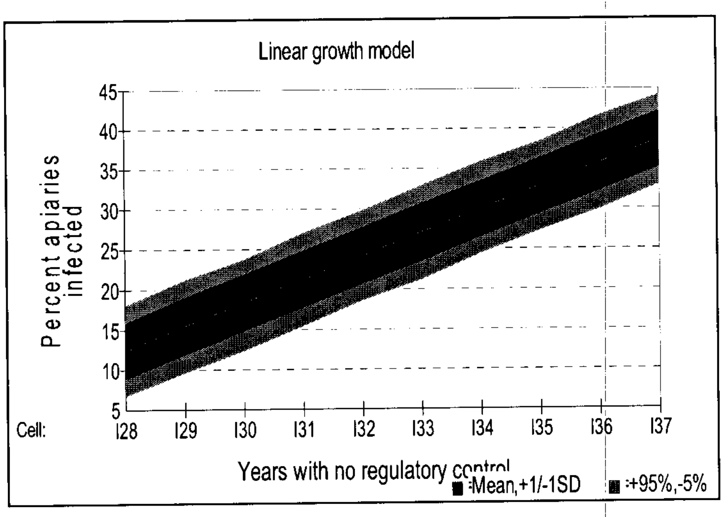
Infection rate year N = (Infection rate year N-1) * exp(kN)

Where k is the exponential growth factor. Because the method is using rate of infection (not absolute numbers), the formula must be prevented from exceeding 100%. This may be done by forcing the maximum, or adjusting the growth factor (k) such that the outcome does not exceed a pre-determined value. In this instance, the infection rate after 10 years was kept within 35 to 40% of apiaries, a figure comparable to that of the linear model, by adjusting the exponential growth factor. Data generated were then used to determine the number of apiaries infected. The scarcity of data on number of hives infected within an apiary makes estimating this number difficult. Commercial producers advise that when AFB is detected, it tends to be found in one to five hives. Apiary information was stratified on the basis of number of hives, and estimates made using this information as a random integer between 1 and 5 inclusive.

5. Results

The linear model predicted that apiary infection rate after 10 years would be around 38% (33-44% - 95% confidence intervals) (Figure 2). The exponential model predicted apiary infection rate to be around 36% (19-53%) after 10 years (Figure 3).

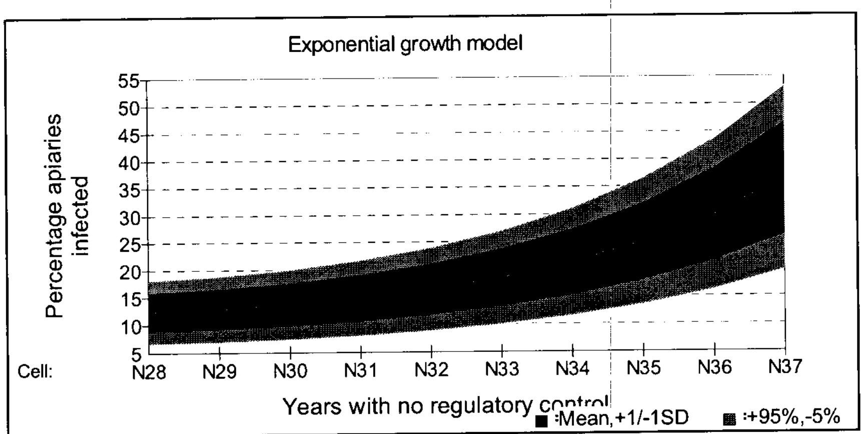
Figure 2: AFB prevalence in Western Australia over 10 years in the absence of AFB control program under the linear model.



The linear model assumes that the spread of AFB takes place in a linear fashion. In the absence of the AFB control program there will be a gradual and steady rise in the number of infected apiaries. It is important to note that the sample size is small. In addition, the reactionary behaviour of the apiarists and the role of feral bees will have substantial impact on the predicted prevalence rate.

The exponential model is presented in Figure 3. The assumptions for this model are similar to the linear model, that is, feral bee and apiarists' reaction will have significant impact on the prevalence rate of AFB. The main difference from the linear model is the growth rate of disease prevalence, which is assumed to grow at an exponential growth rate in the absence of the AFB control program.

Figure 3: AFB prevalence in Western Australia over 10 years in the absence of AFB control program under the exponential model.



Based on the abovementioned linear and exponential model a beneficiary analysis is conducted to establish the monetary benefits accrued to the apiarists in Western Australia. 1):

6. Beneficiary Analysis

This paper provides an economic evaluation in the form of beneficiary and impact analysis for the AFB control program. The analysis is based on the input provided by Hawkins (October 2002), who undertook an exhaustive review of the said activity. In addition, Hawkins estimated the spread of AFB in the absence of regulatory controls which comprise the quantitative input for the present analysis. The cost of the AFB control program is attributed to be approximately \$30,000 per year (Kate Ambrose; pers comm.), however, this could be higher if overlapping control and quarantine benefits (costs) from other bee diseases are included.

It is important to note that AFB is an endemic disease in Western Australia and at present, 12% of all hives are infected. The number of hives in Western Australia is approximately 44,000. In evaluating the benefits of the current project for AFB a 10 year future scenario has been estimated for the spread of the disease in the absence of regulatory controls. The linear and the exponential model for the estimation process has been discussed in the previous section. If the present project is abolished, the scenario after 10 years could be as follows:

Table 2 Number of hives infected with AFB in the 10th year after removal of regulatory control

Hives Infected	Average	Min	Max
Linear Model	1046	556	1555
Exponential Model	985	449	1677

Source: Chris Hawkins (2002): Additional notes prepared for the beneficiary analysis.

The range[1] for the infection is wide varying from a minimum of 449 apiaries to a maximum of 1677 apiaries, combining the linear and exponential model. In percentage terms the range of the AFB spread in the 10th year varies from 15% to 56%. The replacement cost of a hive is estimated to be $402 per hive, as mentioned earlier. In other words, the loss to the apiarists on the 10th year itself could vary from $180,498 to $674,154 due to AFB spread. Under the circumstance, it may be difficult to draw a significant statistical conclusion.

Nevertheless, analyses have been undertaken by taking into account all the 6 sets of values with different AFB spread rates. The quantification of spread is based on Figure 2 and Figure 3 of the Additional Note for Beneficiary Analysis (2002). Figure 2 and 3 depicts an asymptotically rising spread of the AFB disease in the absence of the project. Benefits have been calculated in the traditional manner for project evaluation, that is, the difference between the loss with the AFB project and without is regarded as the benefit for AFB project. The results in dollar terms have been presented in the following table.

Table 3: Stream of benefits generated due to the project for both the linear and exponential models

Year	Min (l)	Avg (l)	Max (l)	Min (e)	Avg (e)	Max(e)
1	$0	$36,042	$96,112	$0	$36,042	$84,098
2	$24,028	$90,105	$180,210	$12,014	$72,084	$132,154
3	$60,070	$151,376	$228,266	$42,049	$12,014	$192,224
4	$84,098	$180,210	$288,366	$60,070	$168,196	$276,332
5	$108,126	$228,266	$324,378	$72,084	$204,238	$336,392
6	$120,140	$264,308	$384,448	$90,105	$252,294	$408,476
7	$120,140	$264,308	$396,462	$84,098	$264,308	$456,532
8	$108,126	$264,308	$420,490	$78,091	$264,308	$492,574
9	$96,112	$264,308	$456,532	$72,084	$264,308	$528,616
10	$96,112	$300,350	$504,588	$60,074	$264,308	$552,644
PV Benefits	$530,211	$1,327,181	$2,137,436	$369,647	$1,233,318	$2,213,225
BCR	2.2	5.4	8.7	1.5	5	9

Note: (l) - l within parenthesis indicates linear model; (e) - e within parenthesis indicates exponential model. PV(present value) of benefits are the totals of the discounted value of benefits where the discount rate is 7 percent. BCR is the benefit cost ratio.
The cost of the project is approximately $30,000 per annum. The cost over the 10 year period has been discounted to arrive at the above mentioned BCRs.

[1] Range is a statistical term although it is self explanatory. This is quantified as the Max-Min values.

From Table 2 it can be observed the stream of benefits for the AFB project varies widely[2]. After discounting the benefit stream, the minimum benefit for the project is evaluated at $369,647 and the maximum benefit at $2.2 millions. These streams of benefits are direct and have been calculated by incorporating the replacement cost of apiaries only. Due to the wide variation of the benefit streams a sensitivity analysis is conducted by incorporating attribution rate.

7. Sensitivity Analysis

Some of the benefits of the program is due to the bio-security measures undertaken by individual apiarists who are likely to continue their activities in the absence of the Department's AFB control program. Therefore, a part of the above mentioned benefits of the AFB program could be attributed towards the effort of the bee farmers. Depending on the prevalence and the commercialisation of the bee industry this attribution rate could vary substantially. For the present analysis a range of 0.5 to 1 attribution rate has been incorporated in the sensitivity analysis. Table 3 presents the result of the analysis.

Table 4: Sensitivity analysis with attribution rate and benefit cost ratio

ATT/BCR	1.5	2.2	5	5.4	8.7	9
0.5	0.75	1.1	2.5	2.7	4.35	4.5
0.6	0.9	1.32	3	3.24	5.22	5.4
0.7	1.05	1.54	3.5	3.78	6.09	6.3
0.8	1.2	1.76	4	4.32	6.96	7.2
0.9	1.35	1.98	4.5	4.86	7.83	8.1
1	1.5	2.2	5	5.4	8.7	9

Note: BCR implies benefit-cost ratio, ATT implies attribution rate.

8. Direct and Indirect Benefits

Various scenarios of direct benefits have been presented in Table 2. As stated earlier, theses benefits are equivalent to the additional losses that the apiarist would suffer in the absence of the AFB control program. In other words, the benefits are equal to the value of the hives which the apiarists would be required to replace in the absence of the program. However, this would depend on whether the apiarists continue to destroy the hives affected by AFB as required under the current program. Nevertheless, they will suffer substantial production loss in case AFB affected hives are not eliminated.

One of the major indirect benefits for the bee program of surveillance and management of AFB, is the value of surveillance for exotic bee diseases, particularly European foulbrood (EFB), a disease which is present in other Australian states. American foulbrood inspections enable the detection of other brood diseases, and provide both an early warning system, and a confidence of freedom from such diseases. The current case for equivalence of WA apiary health with that of New Zealand rests heavily on the ability to detect European foulbrood at an early stage,

[2] Hawkins (2002, pp12): The epidemiology of AFB is not well understood.

and this is predicated on the extensive routine inspections for AFB and other bee diseases. Further, because there is an eradication program for AFB in New Zealand, maintaining our status, or even reducing the prevalence of AFB in WA, will be essential to the development of a New Zealand market for fresh WA honey.

A second benefit of the apiary industry in WA is the pollination effect—especially for Canola production in Western Australia. The estimation of downstream benefits varies substantially. For example, Gibbs and Muirhead (1998) has estimated the downstream benefit to be approximately $89 million. Nevertheless, Canola or other industries are slow to acknowledge these benefits, although there is an increasing use of commercial bees in horticultural, and some broadacre systems.

It would appear that application of the average agriculture multiplier could be a reasonable approach for the estimation of the positive externalities that takes place due to honey bee culture.

Islam (1999) estimated the average agricultural multiplier to be 2.6. Therefore, multiplying the benefits in Table 2 by the multiplier can provide the average downstream benefits for the bee industry. It is essential to note, that some these benefits do not accrue to the industry.[3]

9. Discussion on Policy Issues

The report estimated the direct benefits of the AFB projects which vary from $2.2 million to $370,000 over 10 years. Whatever be the true value of the benefits, the value accrues to the apiarists and no one else. In Western Australia, there are only 96 beekeepers with over 100 hives (Hawkins 2002). In other words, the majority of the direct benefit goes to these 96 apiarists Under Centre for International Economics (CIE) report (1998) to the Australian Animal Health Council (AAHC), this could be considered for cost sharing in the ratio of 4:1 (Industry/Government). The cost sharing classification is also supported by the independent consultant Hassall and Associates (2001) in their report to the Department of Agriculture.

The concern here is improving the efficiency of the apiary inspection activity in the face of increasingly restrictive state budgetary provisions. The apiary inspection program originated in response to beekeepers' desire to effectively manage AFB on an industry basis. Options for dealing with the disease other than by burning infected hives are limited, and some apiarists would like regulatory assistance to minimise the risks of spreading AFB to neighbouring beekeepers. Mandatory inspection and treatment of infected hive boxes, while maintaining appropriate barrier hygiene, seemed to be the appropriate answer when the AFB program commenced.

Use of antibiotics such as sulfathiazole, oxytetracycline, and tylosin may arrest the appearance of the disease if fed to bees. However, antibiotics do not prevent the production of bacteria and bacterial spores, or reduce the risk of spread throughout an apiary or to other apiaries.. Further, in the current consumer climate, which demands

[3] Hawkins (2002, pp 12) *Justification for the continued involvement of the Department of Agriculture in AFB management is largely associated with indirect benefits.*

foods be produced without use of antibiotics and other chemicals, the use of these products in beehives could have major repercussions in domestic and export markets.

Although AFB is endemic in Western Australia, the pattern of occurrence is by no means uniform. There are places where beekeepers indicate that it keeps recurring, and other areas where it is seldom found at all. As Frank Pellet[4] (Ref: Bee Talk, July 1991) noted,

The incidence of AFB in a given area could be significantly reduced over time, by thorough inspection and burning infected hives, but then, in time it always came back, bad as ever.

Although Pellet was speaking from practical experience, most commercial apiarists recognize that AFB is only likely to recur in specific locations, and under well recognized circumstances.

The situation in feral bees is unclear. The actual density of feral hives is unknown, and varies between locations, determined to some extent on available water supply during summer. Where feral hives and swarms have been examined (Australia, New Zealand) the role of feral bees as a reservoir for AFB spores is very limited. It is difficult to estimate the transmission of AFB by feral bees in Western Australia.
Beekeeper opinion is divided on the issue of regulatory management. To quote Richard Taylor[5] (1991): *Mandatory inspection of apiaries is something whose time has long since come and gone. AFB is a manageable problem that can be left in the hands of beekeepers themselves. This is not going to eliminate AFB, to be sure, but neither is anything else. It is not a proper area of government.*

However, there was a range of opinions regarding regulatory control of AFB in the WA AFB forum, which was held in August 2002. It takes a strong, united industry to manage a disease such as AFB, because of its seemingly erratic appearance in apiaries. The New Zealand apiary industry has taken on an ambitious eradication program, with the work of eradication, including inspection and beekeeper training, undertaken entirely by the industry. However, legislative support is still necessary for this to be effective.

10. Conclusion

From various quantitative analyses, expert opinion and literature review the following key features of AFB control program have been identified and are required to be taken into consideration;

- In Western Australia AFB is an endemic disease. Although there is a substantial feral bee population, and until the role of this feral population is adequately researched, the potential for eradication will not be known.

[4] Frank Pellet has been the chief apiarist of Iowa for many years.
[5] Richard Taylor published the article "Have Inspection Programs Outlived Their Usefulness?" in July 1991 edition of "Bee Culture"

- Estimation of the quantified benefits and beneficiary analysis for the apiary inspection program varies widely, and BCR estimates should be viewed conservatively. It is likewise difficult to quantify the amount of public benefit and industry benefit accruing from the activity, and
- The down stream benefits of the project have been estimated with an average agriculture multiplier, as horticultural and broadacre farming systems are reluctant to recognise pollination benefits. Other benefits, such as early detection of exotic diseases, and the ongoing demonstration of freedom from exotic diseases have not been quantified in this analysis. However, it should be noted that disease freedom reduces costs of production, and enables access to markets of comparable (equivalent) disease freedom.
- In a trading environment where the use of antibiotics is increasingly considered undesirable in food production, the bee industry needs to re-evaluate its role in the management of AFB. The legislation is sufficiently flexible to accommodate a wide range of industry and government participation.
- Industry management of AFB could be a real possibility. This was demonstrated by New Zealand. The effectiveness of New Zealand program rests on the inherent unity and mobilisation of the apiary industry in that country, a situation not duplicated in Western Australia. Other countries, such as the UK which are attempting to control AFB, maintain a substantial role for government.
- Given that the majority of benefits accrue to the bee keepers a moderate contribution from the bee industry towards the cost of the program could be justified.
- Approximately 83% of the hives belong to the commercial bee keepers in the Western Australia who produce approximately 90% of the entire honey production. Therefore, the AFB control program can not be treated as a public good. Under CIE norms this could be considered for cost sharing by the bee industry on a 4:1 (Industry/Government) basis. The cost sharing classification is also supported by the independent consultant Hassall & Associates (2001).

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