Risk-mapping import pathways for risk-return opportunities

CEBRA 1606C

Stephen E. Lane[1], Tony Arthur[2], Sam Zhao[2], Wayne Atkinson[2], Christina Aston[2], Rob McGahy[2], and Andrew P. Robinson[1]

[1]CEBRA, The University of Melbourne
[2]Department of Agriculture and Water Resources

March 26, 2018

Centre of Excellence for Biosecurity Risk Analysis

Executive Summary

The development of methods to quantitatively assess whether steps in production and pre-export practices reduce phytosanitary risks presents a significant opportunity to build the Department of Agriculture and Water Resources (the department's) risk profiling capacity, and tailor biosecurity risk management activities to target intervention within individual import pathways.

The department is seeking to change pathway management strategies to better reflect biosecurity risk, and as part of this project requested consideration of the:

- Understanding of critical hazards/control points of a biosecurity import system and contribution to reducing biosecurity risk;
- Data collection requirements of such a system; and
- A way to risk-profile entities based on actions that they undertake offshore.

In this report, we focus on offshore fumigation of fresh garlic and oranges, and discuss insurmountable issues analysing intervention data for coconuts.

As a matter of policy, all fresh garlic imports are inspected on arrival, regardless of whether offshore fumigation is performed. In the time period covered by the data that were available to us, slightly less than half of fresh garlic consignments were fumigated offshore. Offshore fumigation reduced the contamination rate of live insects by about 59%, compared with consignments that were not fumigated. Similarly, for orange imports, offshore fumigation reduced the contamination rate by about 67%. Whilst the reductions in contamination rates were relatively high, it appears that the offshore treatments on these two pathways were not able to reduce the phytosanitory risks to acceptable levels: the contamination rates for those offshore treated fresh garlic and orange imports were about 9% and 34%, respectively.

For inspection data of consignments of fresh garlic that had been treated offshore, analysis with a Bayesian logistic model suggested that varying the concentration of methyl bromide applied did not result in statistically significant differences in contamination rates. Our analysis also suggested that there were no statistically significant differences between the outcomes of treatments provided by the fumigation providers.

A major bottleneck to analysis was the lack of available data in a computer accessible format. Some of the difficulties uncovered were:

- The lack of a clear and direct link between department databases;
- The storage of critical control point information in formats not amenable to numerical analysis (e.g., scanned phytosanitary certificates); and

- The difficulty in deciphering the provenance of some quarantine directives. For example, it was sometimes unclear whether fumigation was performed because insect contamination had been detected or because of a mandatory fumigation requirement.

These issues were exemplified in the case study on the import of (fresh and dried) coconuts, within which incorrect conclusions from analyses could be made primarily because of data provenance issues.

The timing of fumigation directions and treatments was clarified in the case studies on imports of fresh garlic and oranges. However, the analysis was time-consuming due to the requirement to manually extract information from phytosanitary certificates before analysis. Furthermore, many phytosanitary certificates were illegible, an issue for both this analysis and for any back-tracing that may be required for investigation.

This report provides material evidence that obtaining the data to help manage biosecurity risk will be simplified and improved by linking the department's databases. Furthermore, control-point data, especially phytosanitary certificates, should be captured electronically in a consistent database format, for the purposes of better understanding the impacts of critical control points of an import pathway.

Contents

List of Tables

List of Figures

1

Introduction

CEBRA project 1606C, *Risk-mapping import pathways for risk-return opportunities*, aimed to develop approaches, methodologies and tools that assist risk-profiling within import pathways (commodities). Such tools will help the Department of Agriculture and Water Resources (the department) to determine where to allocate resources and tailor strategies to best target risk. The development of methods to quantitatively assess how steps in production and pre-export practices reduce phytosanitary risks presents a significant opportunity to build the department's risk profiling capacity, and tailor biosecurity risk management activities to target intervention within individual import pathways.

At the beginning of the project, the department requested consideration of the:

- Understanding of critical hazards/control points of a system and contribution to reducing risk;
- Data collection requirements of such a system; and
- A way to risk-profile entities based on actions they undertake offshore.

Consideration of these ideas would enable the department to develop a tailored intervention strategy based on the current knowledge of the supply chain. Further, it will enable the department to articulate to National Plant Protection Organisations (NPPOs) what is required from a system approach (expectations) to managing pathway risk. In the long term, this may lead to managed pathways and the development of international commodity standards for production systems.

To achieve the department's desired outcomes, the project was to review available models for quantitatively assessing biosecurity risks in the import pathway of one or more imported plant products. A biosecurity risk rating was to be based on the recognition of offshore processes applied before export — such as production, cultivation, supply chain activities, sourcing, etc. — and the impact that these processes may have on reducing biosecurity risk. The project was to use a plant based case study to test the model and perform a gap analysis to determine if the department currently captures and stores the data required to apply such a model.

During the course of the project, it become clear that the United States Department of Agriculture (USDA) was already undertaking a similar project (Gottwald, pers.

comm.). The USDA were unable to share interim results from the project, but are willing to share results once their project is at a more satisfactory conclusion.

In order to maintain momentum and develop some useful inputs to support any conclusions the USDA may make, it was decided that case-studies for 1606C be developed. In particular, a number of fresh product pathways were selected: coconuts, garlic and oranges. These products were selected as they present a varying range of critical control points (CCPs) in the importation process, for example, (i) whether fumigation was performed offshore prior to export, or upon arrival; (ii) the approved establishment number for fumigation providers (when performed offshore); and (iii) the country of origin.

On arrival, consignments are inspected for pests of quarantine concern. We can then use this inspection data for our case studies to analyse how the various CCPs may affect arrival rates of such pests.

1.1 Imports of Coconuts

Coconuts were selected for analysis as a case study out of convenience; inspections data for coconuts had already been compiled and extracted for previous work. Fumigation is recorded if directed for consignments, but in this case it is not known whether this is performed as a result of an inspection failure, or as a mandatory requirement.

During the course of the project and after some excellent comments from a reviewer, it became apparent that analysis of the coconut imports data as it existed would be futile as there was too much ambiguity in the data set without further data linkage. Phytosanitary certificates are not linked with imports data — if required, these need to be linked manually, and it was decided that manual effort should focus on the garlic and oranges imports case studies.

Because of the ambiguity in deciding whether fumigation had been performed offshore, onshore as part of a mandatory requirement, or onshore following an inspection failure, changes in failure rates between different CCPs cannot be attributed with any certainty. As an example of this ambiguity, the current import conditions for Samoa state that mature coconuts are required to undergo Methyl bromide fumigation for 24 hours **or** husk removal. Thus in the current datasets, if fumigation is recorded, it is impossible to tell if it is because it was performed offshore, or because of an inspection failure.

The remainder of this report summarises the modelling results from the identified case studies and identifies barriers and constraints that were found during the data extraction exercise. The report is structured as follows: Chapters 2 and 3 detail the case studies and the results from the modelling of possible pathway critical control points, Chapter 4 documents the barriers found during extraction of the department's data, and Chapter 5 provides a consideration of future data needs. Finally, Chapter 6 provides some thoughts on future directions following this report.

2

Case Study: Imports of Fresh Garlic

The fresh garlic import pathway was chosen as a case study because it is: (i) imported from multiple countries; (ii) with more than one treatment type (fumigation at 40g/m3 at 21C[1] for 3 hours under normal atmospheric pressure or 32g/m3 at 21C for 2 hours under vacuum); and is (iii) undertaken either pre-shipment or on arrival in Australia. Given that all garlic is inspected on arrival there was an opportunity to compare the inspection data against the different regimes. Further, fresh garlic is frequently imported as a full container load (FCL) in single commodity shipments; this makes garlic a good candidate for extracting inspection data as single shipment entries reduce ambiguity in the analysis.

2.1 Data summary

This section describes the steps undertaken to obtain the inspection data and prepare it for analysis.

2.1.1 Extraction

The data used during this analysis were retrieved from two department databases: AIMS and Records Manager. Cargo type (FCL or air), inspection outcome[2] (OK, not OK), and reason for issue (e.g., actionable insects) were sourced from AIMS. These records were then cross-linked with Records Manager to get details on offshore fumigation. The fields of interest from the phytosanitary certificates included: the country of origin of the import, the approved establishment number[3], treatment type (fumigation or fumigation under vacuum), and the temperature and concentration at which methyl bromide is applied.

Retrieval of records and data entry took approximately ten minutes per record to complete.

[1] Dosage compensation allowed for temperature range between 10C and 21C.

[2] Note: for garlic, all consignments are inspected, *irrespective* of offshore fumigation status.

[3] We were only able to source this information from a single country. Due to errors in scanning or illegibility, 30% of entries were not linked to an approved establishment number.

The definition of a failure used is given in Appendix A; as described in that appendix, there are multiple modes of inspection failure. For the remainder of this chapter we focus on quarantine failures; in particular, those quarantine failures that were associated with the discovery of live insects — this is because we are interested in the offshore fumigation critical control point.

2.1.2 Analytic Timespan

The analysis was constrained to inspections from 1 March 2016 to 28 February 2017 (totalling 269 consignments). One year of data was chosen to limit any seasonal effects in the analysis, and to limit the time taken to retrieve the records.

2.1.3 Pathway Summary

Figure 2.1 shows a flow chart of the pathway. Of the 269 consignments, 10 were missing data on whether fumigation was performed offshore, and were removed from analysis.

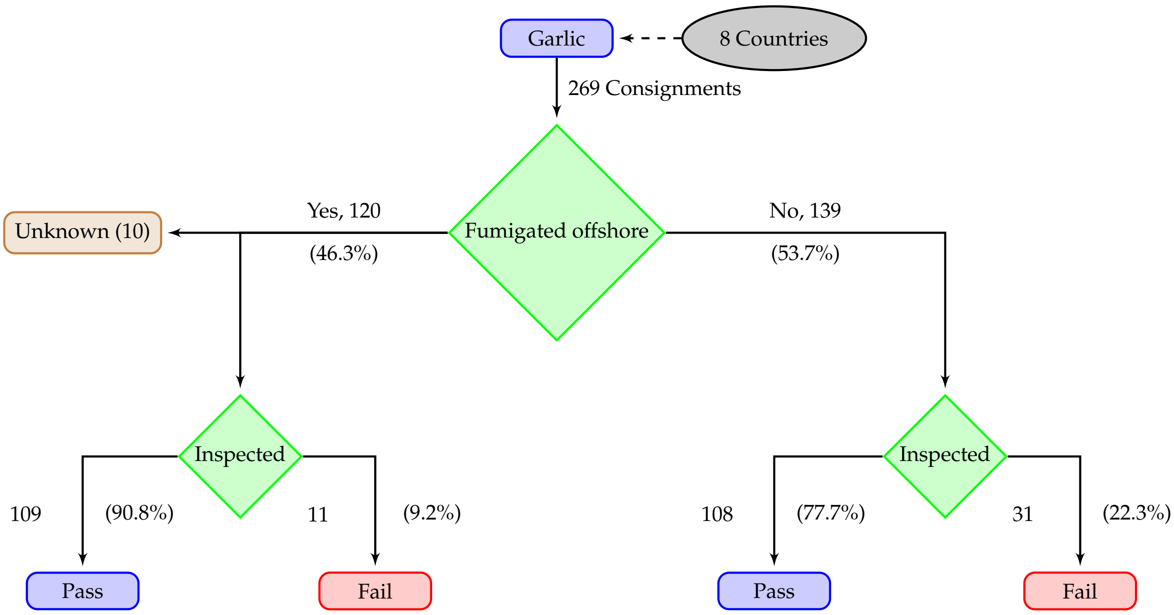

Figure 2.1: Garlic consignments flow chart with statistics for March 2016 to February 2017. Note here that inspection failures where consignments are *not* fumigated offshore (the right side of the flow chart) should not be interpreted as fumigation failures; these failures simply reflect the approach rate of pests.

Table 2.1 shows the number of failed and total inspections by country of origin, for consignments fumigated offshore and not fumigated offshore. Note that failures where the consignment has not been fumigated offshore are not deemed to be fumigation failures; these failures result from an inspection prior to onshore fumigation.

Table 2.1: Number of inspections and the number failed for quarantine reasons by country of origin, for consignments fumigated offshore and not fumigated offshore. For those consignments fumigated offshore the failures reflect failures of the offshore fumigation process; for those consignments that were not fumigated offshore, the failures simply reflect the approach rate of pests. Offshore fumigation is at the discretion of the importer, and the European Union has phased out use of methyl bromide.

	Not fumigated offshore			**Fumigation offshore**		
Country	Consignments	Fails	%	Consignments	Fails	%
A	20	7	35			
B	2	0	0	112	10	8.9
C	1	0	0	5	0	0.0
D	71	17	24	2	0	0.0
E	1	0	0			
F	2	1	50			
G	38	6	16			
H	3	0	0			
Missing	1	0	0	1	1	100.0

2.2 Analysis

2.2.1 Reduction in Approach Rate

Figure 2.2 shows the failure rate of consignments not fumigated offshore from countries A, D and G (which are the countries with highest number of consignments following country B, Table 2.1). The aggregated failure rate from these countries is shown as the dashed line, along with 90% confidence intervals for the failure rate from each country. It is apparent that there is no significant difference between the failure rates of these countries.

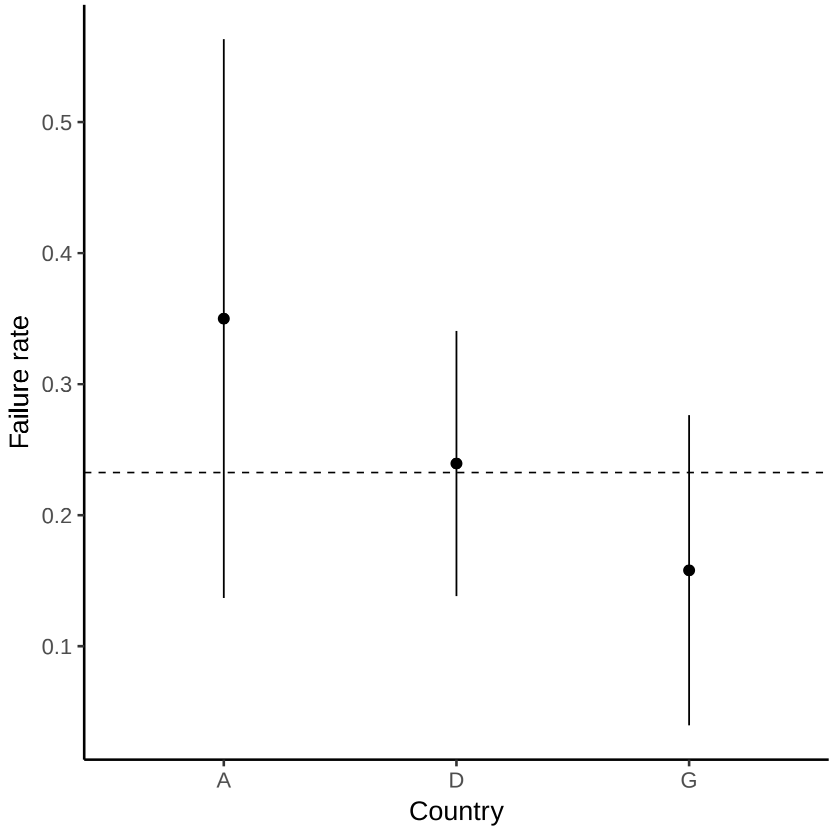

Figure 2.2: Failure rate of consignments not fumigated offshore from the three countries with the highest number of imports. The aggregated failure rate from these countries is shown as the dashed line, along with 90% confidence intervals for the failure rate from each country.

Making the assumption that the failure rates of consignments not fumigated offshore from each country are equal (Figure 2.2), we can interpret the aggregated failure rate of those consignments not fumigated offshore as an estimate of the approach rate of the pathway (this is the right-hand side of Figure 2.1). We can then compare this rate with the failure rate following offshore fumigation; this is the (relative) reduction in the approach rate due to pathway management[4] (in this case fumigation offshore).

[4]This assumes that country B would have had a similar approach rate in consignments that were not fumigated offshore.

We estimate the (relative) reduction in arrival rate as $1 - \mathrm{FR}/\mathrm{AR}$, where FR is an estimate of the failure rate of those consignments fumigated offshore, and AR is an estimate of the arrival rate (the failure rate of those consignments not fumigated offshore). We calculate this to be 58.9% (95% CI: 23.3, 78.3%); in other words, the offshore pathway management may have reduced the approach rate by 58.9%.

2.2.2 Country

For this analysis, and all further analyses in this chapter, we restrict the data to consignments that were fumigated offshore.

The vast majority of consignments (fumigated offshore) are exported by country B (Table 2.1). There is limited information in this table for analysing differences in failures between specific countries, so we do not pursue an analysis by specific country any further.

Collapsing the importing countries other than country B into a single category, we see that they are slightly more likely to provide consignments that fail, with a difference of 3.6%, but this is not statistically significant (95% CI: -19.9, 27.1%).

2.2.3 Fumigation Concentration

The concentration of methyl bromide to be applied per cubic metre is specified in the import conditions for garlic (found in BICON). For fumigation performed under vacuum, the ambient temperature should be 21C with methyl bromide applied at 32 $\mathrm{g/m^3}$. For fumigation not under vacuum, Table 2.2 provides the details. An inspection of the data shows that only one did not apply at least the prescribed concentration of methyl bromide[5].

Table 2.2 shows the number/percentage of failures by concentration of methyl bromide applied. This table doesn't tell us anything about the supplier risk of the pathway, but may indicate issues with the fumigation prescription.

Table 2.2: Amount of methyl bromide to be applied per cubic metre for given ambient temperature settings. Also shown is the number of total and failed inspections by concentration of methyl bromide applied, for consignments fumigated offshore. Inspections missing temperature ranges are due to missing information on Records Manager.

Temperature range	Concentration ($\mathrm{g/m^3}$)	Consignments	Fails	%
≥ 21	32	3	0	0.0
$\geq 16, < 21$	40	48	2	4.2
$\geq 11, < 16$	48	21	4	19.0
$\geq 10, < 11$	56	40	4	10.0
		8	1	12.5

[5]This could be a *discretion* issue — the temperature was recorded at 20.8C. The border control officer may have rounded the number up to 21C which would then be compliant.

To investigate the effect of fumigation concentration on the number of failed inspections, we fit a Bayesian logistic regression model (2.1):

$$y_i \sim \text{Binomial}(n_i, p_i)$$
$$p_i = \text{logit}^{-1}(\mu + \alpha_i) \tag{2.1}$$

where y_i is the number of failed inspections in the i^{th} fumigation concentration group out of n_i consignments; p_i is the probability of a failed inspection, modelled on the logit scale; μ is the intercept, and α_i the group-specific intercepts to be estimated. For further details, see Appendix B.

Figure 2.3 shows the estimates and posterior intervals for the difference in predicted fumigation failure rate between pairs of fumigation concentrations. In particular, these differences show no significant difference from 0.

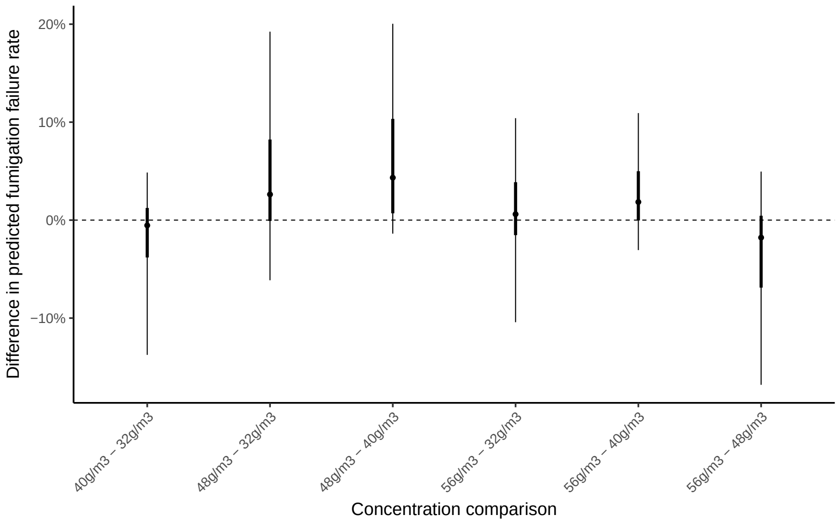

Figure 2.3: Posterior (50%/90%) intervals for the difference in predicted fumigation failure rates between pairs of fumigation concentrations, fitted to the data in Table 2.2.

2.2.4 Fumigation Provider

In this analysis we look at whether there are any differences between fumigation providers (where given) in failure rates of consignments. Table 2.3 shows the number/percentage of failures by fumigation provider (recoded for privacy). A number of providers only performed one fumigation in the analysis period, thus Table 2.3 shows these observations collapsed in to a single category, `Singles`. There were 8 consignments in which the fumigation provider was not legible, which were thus removed for the analysis in this section.

To investigate the effect of fumigation provider on the failure rate of consignments, we fit a logistic regression model to the data in Table 2.3. We use an identically structured model to that in (2.1).

Figure 2.4 shows the estimates and posterior intervals for the predicted fumigation rate by supplier; no contrasts/differences between suppliers are shown due to the amount of comparisons that would be required. All intervals are clearly overlapping, suggesting little statistical evidence for a difference between fumigation providers.

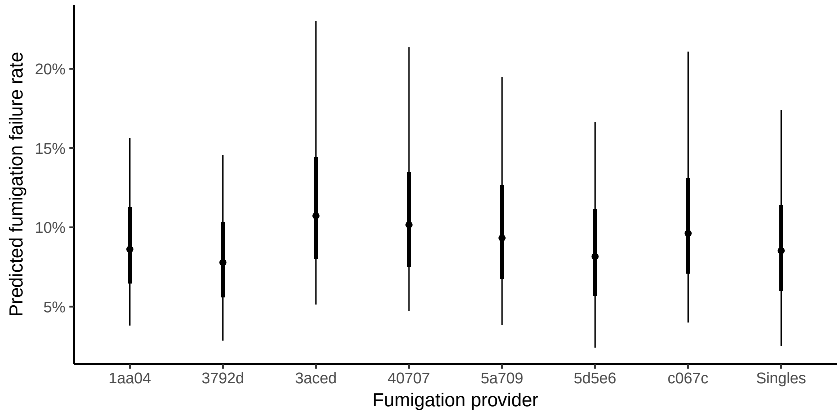

Figure 2.4: Posterior (50%/90%) intervals for the predicted fumigation failure rate by supplier.

Table 2.3: Number of failed and total inspections by fumigation provider, for consignments fumigated offshore. Supplier IDs have been recoded for privacy. All providers that performed a single fumigation during the analysis period have been aggregated into the `Singles` category.

Provider	Consignments	Fails	%
3792d	26	2	7.7
40707	26	1	3.8
c067c	15	3	20.0
5d5e6	11	2	18.2
Singles	8	1	12.5
3aced	7	0	0.0
5a709	6	1	16.7
1aa04	5	0	0.0

2.3 Notes and Conclusions

This analysis looked at the garlic pathway with the following aims: to investigate any possible difference in quarantine failure rates in the characteristics of consignments fumigated offshore.

We found that the offshore pathway management (in this instance by fumigation) may have reduced the approach rate by 58.9%; however this is from an already large approach rate without the offshore pathway management.

In regards to consignments that had fumigations performed offshore, the vast majority came from country B. Of particular concern is the large quarantine failure rate: 9.2% (95% CI: 5.2, 15.7%) of consignments fumigated offshore were found to contain (possibly) live insects, indicating a possible issue with the CCP.

We also investigated the effect of the concentration of methyl bromide applied. Again, no differences between concentration levels were found, which is reassuring as it gives us confidence in the prescribed concentration levels of methyl bromide to be applied.

Finally, we found that in this analysis (Section 2.2.4) no differences between fumigation suppliers were found.

3

Case Study: Imports of Oranges

Oranges were chosen as a case study as they require some form of treatment offshore, or an area freedom declaration on the phytosanitary certificate. A large fraction is pre-cleared offshore, with no further inspection, as the offshore inspections are undertaken by departmental staff. Only a very small percentage are not treated offshore ($< 5\%$). Inspection is then required on arrival, which provides an unbiased dataset for modelling.

A complication of the treatments performed offshore is that they are done in particular for two specified pests: washing, brushing and waxing (WBW) is used to target Asian Citrus Psyllid, and in-transit cold storage is used for fruit fly.

3.1 Data summary

3.1.1 Extraction

This section describes the steps undertaken to obtain the inspection data and prepare them for analysis.

The data used during this analysis were retrieved from three department databases: AIMS, Incidents and Records Manager. The variables extracted were: inspection (whether performed or not), inspection outcome (OK, not OK), and reason for issue (e.g. actionable insects) were sourced from AIMS and Incidents. These records were then cross-linked with Records Manager to get details on offshore treatment. Fields recorded include: the country of origin and the treatment type. Also noted was whether the consignment was pre-cleared, and thus released on documentation after arrival in Australia.

Retrieval of records and data entry took approximately ten minutes per record to complete.

The definition of a failure used is given in Appendix A; as described in that appendix, there are multiple modes of inspection failure. For the remainder of this chapter we focus on quarantine failures; in particular, those quarantine failures that were associated with the discovery of live insects — this is because we are interested in the offshore treatment critical control point.

3.1.2 Analytic Timespan

The analysis was constrained to inspections of 490 consignments from 1 May 2016 to 1 April 2017. One year of data was chosen to limit any seasonal effects in the analysis, and to limit the time taken to retrieve the records.

3.1.3 Pathway Summary

Figure 3.1 shows a flow chart of the pathway. Of the 490 consignments, 3 were missing data on whether treatment was performed offshore, and were removed from analysis. Of the 465 consignments treated offshore, 153 were precleared and no onshore inspection was performed (released on docs). 2 records that weren't precleared were not inspected. Of the remaining 310 inspected consignments treated offshore, but not precleared, 106 failed inspection. 4 consignments not treated offshore were not inspected. Of the remaining 18 consignments inspected, 11 failed inspection.

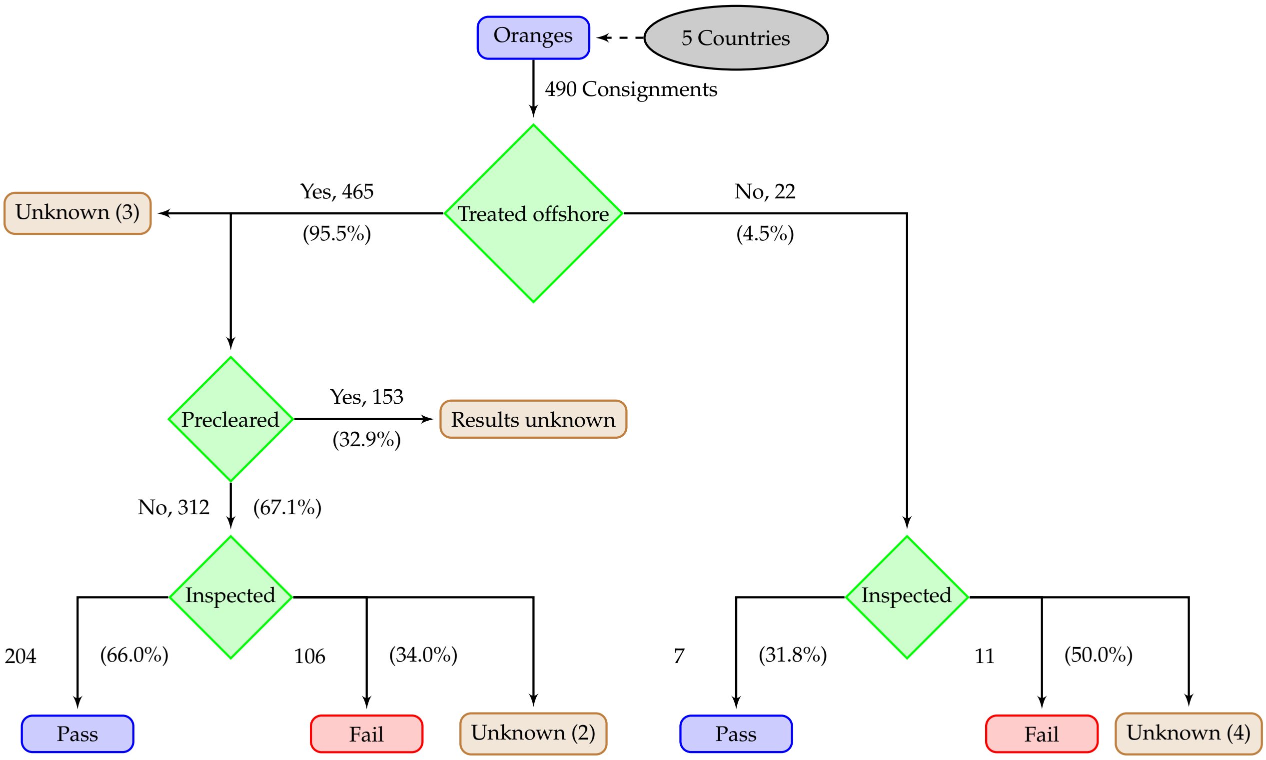

Figure 3.1: Oranges consignments flow chart with statistics for May 2016 to April 2017. Note here that inspection failures where consignments are *not* treated offshore (the right side of the flow chart) should not be interpreted as treatment failures; these consignments would only require treatment following inspection, as a result of inspection failure.

Table 3.1 shows the number of failed and total inspections by country of origin, for consignments treated offshore and not treated offshore. Note that failures where the consignment has not been treated offshore are not deemed to be treatment failures; these failures result from an inspection prior to onshore treatment.

There are two primary treatment types for consignments of oranges: washing, brushing and waxing (WBW) and in-transit cold storage. Currently, only one country uses WBW, hence we make no further comparison between treatment types here. This is because the treatment is confounded with the country of origin, which we prefer as a comparison as it is a finer grouping variable.

Table 3.1: Number of failed and total inspections by NPPO/country of origin, for consignments treated offshore (and not precleared) and not treated offshore. Note that failures where the consignment has not been treated offshore are not deemed to be treatment failures.

	Not treated offshore			**Treatment offshore**		
Country	Consignments	Fails	%	Consignments	Fails	%
C	11	9	82			
E	7	2	29	250	89	36
A				48	14	29
B				12	3	25
D				2	0	0

3.2 Analysis

3.2.1 Country

For this analysis we restrict the data to consignments that were treated offshore, not given preclearance, and subsequently inspected.

The vast majority of consignments (treated offshore) are exported by country E (Table 3.1). To investigate if there is a country effect on the number of failed inspections, we fit a Bayesian logistic regression model, identical in form to the one in Chapter 2 (Equation 2.1), but with α_i the effect of country on the log-odds of a consignment failing an inspection. For further details, see Appendix B.

Figure 3.2 shows the posterior predicted median and 50%/95% posterior intervals for the difference in treatment failure rates between NPPOs. In particular, the figure shows that all differences contain 0, thus we'd conclude that there's not enough data to suggest that the NPPOs are different from each other in terms of failure rates.

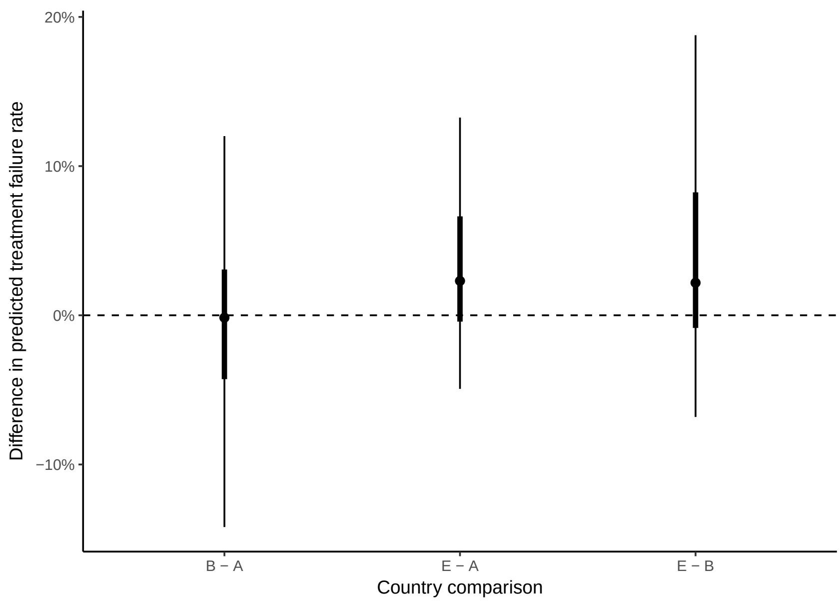

Figure 3.2: Posterior (50%/90%) intervals for the difference in predicted treatment failure rates between countries. Note, 34% of consignments treated offshore failed inspection. Table 3.1 shows the failure rates by country.

3.2.2 Reduction in Approach Rate

Table 3.1 shows that the failure rate of oranges that are not treated offshore is much bigger for country C, and Figure 3.2 shows that there are no differences in failure rates between countries. Oranges from country E may or may not have been treated offshore (depending on area freedom declarations), and the failure rates between both treated and untreated oranges from country E are similar. Thus, we remove these consignments from the following analysis.

If we make the assumption that the approach rate for consignments not treated offshore can be estimated from the failure rate of country C, then an estimate of the reduction in the approach rate due to treatment can be made by comparing country C's failure rate to the aggregated failure rate from all other countries.

We estimate the (relative) reduction in arrival rate as $1 - \text{FR}/\text{AR}$, where FR is an estimate of the failure rate of those consignments treated offshore, and AR is an estimate of the arrival rate (the failure rate of those consignments not treated offshore). We calculate this to be 66.5% (95% CI: 41, 79.2%); in other words, the offshore pathway management may have reduced the approach rate by 66.5%.

3.3 Notes and Conclusions

The vast majority of imported oranges originate from a single country, and are mostly treated offshore. A small number are sourced from areas with declarations of area freedom from Asian Citrus Psyllid, whilst many are pre-cleared for import, and are subsequently not inspected on arrival. See Figure 3.1 for further details.

In regards to consignments that had treatments performed offshore, the vast majority came from a single country. The failure rates varied slightly between NPPOs (Table 3.1), but there was not enough evidence to suggest that these differences were large.

We found that the offshore pathway management (in this instance by treatment) may have reduced the approach rate by 66.5%; however this is from an already large approach rate without the offshore pathway management. Furthermore, this observation needs to bear in mind our assumption that the approach rate can be estimated from imports coming from a single country. Whilst the reduction in approach rate is pleasing, the quarantine failure rate of consignments treated offshore still remains large, with 34% (95% CI: 28.9, 39.4%) of consignments containing live insects.

We must be clear, however, that WBW and in-transit cold storage treatments in this case are targeted towards particular quarantine pests. There is no guarantee that these treatments will be successful in mitigating the risk of off-target quarantine pests. No Asian Citrus Psyllid has been found during inspection, and whilst we can't definitively say this is due to WBW[1], it is a reasonable assumption. The reduction in approach rate does however suggest that some form of treatment does have an effect in lowering quarantine pest risk, which is a pleasing confirmation.

[1]It could be due to low approach rates for this particular pest, excellent orchard biosecurity, etc.

4

Barriers Identified During Data Extraction

For the coconuts case study, we did not crosscheck fumigation records within the Records Manager database; hence it is not possible to tell if fumigation directives are as a result of inspection or were performed pre-inspection. The lack of clear pathway interventions lessens the value of the coconut data for pathways modelling, but at the same time, strengthens the argument for updating data collection to include such information.

From both the garlic (Chapter 2) and oranges (Chapter 3) case studies, we found that data extraction was very time consuming. To establish when and where fumigation was performed required the linking of AIMS records to data stored in the Records Manager database. Documentation in Records Manager consisted of scanned PDFs of the fumigation records, which required manual data entry to input required information. On average this took approximately ten minutes per record to link, extract and record the required data.

Many issues were uncovered regarding free-text fields; because these fields can have any sort of information filled out, we found that phytosanitary details were not consistently recorded, or were indeed missing. This cascaded through many related fields: treatment certificates and treatment details were not always available. As an example, as per Section 2.2.4, fumigation provider details were only available for garlic imports originating in a single country. A further limitation here regarded import permit data: information was not always included in the entry, such that if a consignment was cleared on documents, we cannot tell whether any treatments were mandated for the pathway.

5

Consideration of Future Data Requirements

There are some clear conclusions for future data requirements from the case studies undertaken for this report:

- How entries are recorded in AIMS.
    - Free-text fields are difficult to analyse (especially when missing). Limiting these should be possible, but would require considerable investment into appropriate selection boxes for entering records. Furthermore, many fields should be made compulsory; this would require more time in data entry, but is likely to result in higher quality data. Re-training of staff would also be required from such a change.
- How entries are recorded in Records Manager.
    - If documentation such as fumigation records are required to be stored, it makes sense to digitise such information so that it is easily extractable for reporting and data analysis. Consideration into electronic data capture or data entry at the time documents are received could be considered. This is especially so for traceback requirements; in Section 2.1 we noted that up to 30% of approved establishment numbers were illegible or missing from the phytosanitary certificate.
- Critical control points within a pathway.
    - The case studies provided show that even with offshore fumigation in some situations, quarantine interceptions may be made. Clearly, this is an indication that there may be a failure somewhere else on the pathway. Whilst we wait in anticipation for the results from the USDAs investigation, some consideration should be made of how to capture critical control points within managed pathways from countries of import.

6

Future Directions

There are a clear number of future directions that the department may take following this project. We are well aware that towards the end of this project, a new team (Biosecurity Integrated Information Systems Taskforce, BIIST) has been created to review and modernise access to many of the departmental databases underpinning these pathway analyses. Models such as those used in this report, should be developed and investigated once the BIIST has had time to develop appropriate systems.

As discussed in the introduction (Chapter 1), the USDA are undertaking a project that is highly aligned with the original scope of this project. This should be a high priority for the department (and CEBRA) to follow up. Depending on the findings from the USDA project, a new project could be canvassed that would seek to develop their work in an Australian context. Such a project is likely to have impact, however capturing offshore process such as production, cultivation, and supply chain activities for example, may prove costly.

In connection with the USDA research, more general models could possibly be investigated. Given the constant changes to biosecurity requirements, flexible modelling approaches such as Bayesian networks may be appropriate. The data requirements for a Bayesian network are likely to be more than the requirements identified in this report, and expert elicitation is likely to be required — unfortunately, the cost of flexibility is that such networks will be highly pathway specific, with limited adaptability between pathways.

Finally, some alternative case studies may be useful for future work. Due to the investment by the department in recording and reporting on the cut flowers pathway, we suggest that this would be an appropriate case study for future work.

Appendix A

Classification of Failure Modes

In Chapters 2 and 3 we study offshore fumigation and its relationship to quarantine failures. Here we provide how the various failure modes are defined from the raw data[1]. These descriptions use the field names as supplied to CEBRA, and may differ slightly from the AIMS and Incidents databases:

Document failures defined by `non.compliance.detected` equal to `Y` and the direction results being one of: `documentation not ok`, `documents are unsatisfactory`, `no documents presented`[2].

Incident failures defined by `!is.na(incident.id)` and `non.compliance.detected` equal to `Y`. This definition is applied because compared to the Incidents database, AIMS is more reliable. Here the field `non.compliance.detected` is from AIMS, and `incident.id` is from Incidents.

Inspection failures defined by `direction.category` equal to `inspection` and `non.compliance.detected` equal to `Y` plus those quarantine entry lines that had the destruction or re-export direction results, namely: `goods destroyed`, `goods destroyed - see comments`, `goods destroyed by deep burial`, `goods re-exported`, `deep burial supervised by qtn`.

Quarantine failure defined by `incident.failure` equal to `1` and `dat.cebra.aims['present.in.aust']` equal to `Uncertain`, `No`, `NA`. A quarantine failure must be by an incident, however the direction result of `qtine breach - see comments` is applied due to some sorts of documentation breach, is not generally related to incidents.

As we are particularly interested in the offshore fumigation critical control point (CCP), live insect quarantine failures would demonstrate some breakdown of that CCP. Hence we also extract that information from the dataset; from the description fields, we indicate an insect infestation if the text `Animals` is found in the `hazard.name` field, or the text `Invert` is found in the `infestation.type` field. The insect is classed as alive if the `infestation.condition` is not `Dead` or missing.

[1] These are defined from the combination of AIMS and Incidents data, based in part on analysis of fields in those databases.

[2] And some similar direction descriptions.

Appendix B

Bayesian Logistic Regression

This appendix provides some more detail on the Bayesian logistic regression used to analyse the effects of various characteristics on inspection failure for the case studies.

Many of the predictors in the datasets used for the case studies consist of a large group, and many small groups. For example, Table 2.3 shows that the bottom four providers of fumigation for fresh garlic have less than eight consignments. Further compounding this issue is the low number of fails. The low numbers may magnify issues with *separation* in the logistic regression; separation leads to infinite estimates of regression coefficients, rendering the analysis moot. Bayesian logistic regression was chosen due primarily to its ability to compensate for possible issues with separation. It does this by setting priors on coefficients, which restrict the values they can take; the priors chosen below are general enough to provide protection against separation, whilst at the same allowing the data to speak for themselves.

The model, along with the specification of the priors is:

$$\begin{aligned} y_i &\sim \text{Binomial}(n_i, p_i) \\ p_i &= \text{logit}^{-1}(\mu + \alpha_i) \\ \mu &\sim \text{Normal}(0, 10) \\ \alpha_i &\sim t_7(0, \sigma_\alpha) \end{aligned} \tag{B.1}$$

where y_i is the number of failed inspections in the i^{th} group of the relevant predictor out of n_i consignments; p_i is the probability of a failed inspection, modelled on the logit scale; μ is the intercept; and α_i the effect of the predictor on the log-odds of a consignment failing an inspection. To complete the specification of the model, we require priors for the intercept (μ) and α_i, the group-specific intercepts. The prior specifications we have chosen provide some regularisation, in that they prevent outlandishly large coefficient estimates, but are sufficiently weak so that they do not overwhelm the likelihood.