finalreport

Project code: W.LIV.0275

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Services Pty Ltd

Date published: October 2012

ISBN: 9781741919578

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Investigating incidence of Scabby Mouth during live export

Abstract

This project reviewed the scabby mouth vaccination protocols in place for sheep travelling to Middle East markets. The review involved a comprehensive literature review followed by extensive industry consultation. A study to determine the prevalence of scabby mouth at three distinct points along the live export supply chain was then undertaken. The prevalence and the evidence and information obtained by the literature search provided an in depth understanding of the disease. This and the incident pattern determined from the prevalence study suggested that the existing protocol for sheep travelling to Saudi Arabia could be re-evaluated.

The study recommends that, subject to the approval by appropriate authorities, a single vaccination strategy be considered to replace the current double vaccination strategy. In most instances this would entail a single vaccination at marking, however in the event that a vaccination at marking has not been administered, it is recommended that sheep should be vaccinated at least 21 days prior to delivery to the assemble facility. It is recommended that the disease prevention strategy embrace both the principles of exclusion and the principles of immunity. Any changes to the existing protocol should be conditional upon there being a stringent inspection procedure in place at the assembly facilities when sheep are delivered to the assembly facility coinciding with a research program to monitor and evaluate subsequent shipments.

The study concluded that the development of a killed or virulent field strain vaccine administered intramuscularly or subcutaneously would have immediate industry application and that the industry monitors any developments in this regard.

Executive summary

This project reviewed the scabby mouth vaccination protocols required for sheep travelling to Middle East markets. The review included a comprehensive literature search that was followed by extensive industry consultation. This was followed by a study that determined the prevalence of scabby mouth at three distinct points along the live export supply chain. Sheep were inspected on arrival at the assembly facility, at load out and on board prior to arrival at their destination. Prevalence was determined based on the existence of visual lesions.

The study had both cross sectional and longitudinal aspects and included sheep sourced from both Western Australia and the Eastern States. The study was strictly observational. There was no intervention and data was collected in keeping with normal commercial operations. It compared sheep that had been subjected to the vaccination protocol required for Saudi Arabia to sheep destined for other markets in the Middle East.

The literature search revealed a large body of work, mostly targeted at the unique features of the virus and its ability to evade the host's immune response. A detailed understanding of the mechanism involved is outlined in the review. Much of this work was conducted in the broader context of viruses and their evasive mechanisms rather than a focus on the disease itself. It appears, based on industry consultation and a review of industry material that this detailed understanding has not yet filtered through to the industry level.

The scabby mouth virus possesses immuno-modulatory factors that enable the virus to become established in an animal that would otherwise be considered immune. Vaccination does not prevent re-infection. The vaccine manufacturers acknowledge this but point out that *"the lesions involved in subsequent infections are less severe and that the disease resolves more quickly"* [7].

The study identified that a census (population study) was the preferred approach to determine prevalence within the live export supply chain. The low anticipated prevalence, and relatively small mob size determined by pens on board precluded the use of a 'sample' approach.

The consignments were split according to their sourcing and protocol requirements as follows:

1. Non-Saudi protocol (sourced from the Eastern States),
2. Non-Saudi protocol (sourced from Western Australia) and
3. Saudi protocol (all sourced from Western Australia).

The study compared sheep that had been subjected to the vaccination protocol required for Saudi Arabia to sheep destined for other markets within the Middle East. These divisions provided a fair representation from each group (see Table 1).

Table 1. The number of sheep in each group and category within the study

	Non-Saudi (ex E.S.)	Non-Saudi (Ex W.A.)	Saudi (All W.A.)
Lambs	13,344	34,497	19,604
Young Wethers	63,148	24,282	40,389
Wethers	64,253	31,898	53,570
Ewes	0	7,219	1,028
Rams	680	3,436	11,083
Damarra	345	957	4,963
Total	141,750	102,289	130,637
Overall Total	374,676		

A two-stage inspection system was developed to determine the prevalence of scabby mouth on board livestock vessels. Six voyages were studied incorporating twelve discrete consignments. Over 370,000 sheep were inspected over an eighteen-month period.

The overall prevalence of scabby mouth at receival was 0.03%. This represented 107 cases in a sample population of 389,666 sheep. The overall prevalence of scabby mouth at load out was 0.06%. This represented 211 cases in a population of 374,676 sheep. The overall prevalence of scabby mouth on board (prior to discharge) was 0.15%. This represented 566 cases in a similar population. The difference between these values was significant (Chi-square with a P value of < 0.0001 in each case) even at these low levels of prevalence.

The prevalence of scabby mouth on receival was very low in each of the three groups (0.02% in non-Saudi sheep sourced from the Eastern States, 0.02% in non-Saudi sheep sourced from Western Australia and 0.04% in the sheep subjected to the Saudi protocol, again sourced from Western Australia). There was no significant difference between the non-Saudi groups of sheep but the difference between the Saudi and the non-Saudi sheep was significant (Chi-square with a P value of < 0.001) (see Table 2).

Table 2. Overall prevalence at receival, load out and on board (prior to discharge) for each of the groups

	Non-Saudi (ex E.S.)	Non-Saudi (Ex W.A.)	Saudi (All W.A.)
Receival	0.02%	0.02%	0.04%
Load Out	0.01%	0.03%	0.12%
On board (prior to discharge)	0.04%	0.49%	0.01%

In the non-Saudi sheep (sourced from the Eastern States), this low initial prevalence of scabby mouth was maintained at load out (from 0.02% to 0.01%) and maintained throughout the voyage (0.04% at the point of discharge). This represented only 32, 20 and 55 cases respectively in a population of approximately 141,000 sheep.

In the non-Saudi sheep (sourced from Western Australia), the low prevalence of scabby mouth was also maintained at the point of load out (from 0.02% to 0.03%), but lifted quite sharply on board (to 0.49%). This difference was highly significant (Chi square value of 447 with P value of <0.0001). This represented 20, 32 and 502 cases respectively in a population of approximately 102,000 sheep.

In contrast, the Saudi sheep (all sourced from Western Australia), showed an increase in prevalence at the point of load out (from 0.04% to 0.12%) yet there was virtually no scabby mouth seen in these consignments prior to discharge at the voyage destination (0.01%). This represented 55, 159, and only 9 cases respectively in a population of approximately 130,000 sheep. All of these differences were significant (Chi-square with a P value of <0.0001).

The prevalence of scabby mouth differed between categories of sheep. This was more evident on board than at receival or load out. The prevalence of scabby mouth in the older wethers was consistently low throughout the study (0.02%, 0.05% and 0.06% at receival, load out and on board respectively). This represented only 34, 77 and 84 cases in a population of approximately 150,000 wethers. A consistent pattern was observed across all consignments.

The overall highest level of scabby mouth was seen in lambs (0.03%, 0.10% and 0.33% at receival, load out and on board respectively). This pattern was not consistent between the consignments and there were several consignments where the prevalence of scabby mouth in young wethers was higher (compared to lambs). The overall prevalence of scabby mouth in young wethers was slightly lower (0.03%, 0.03% and 0.17% at receival, load out and on board respectively). The differences between the load out and on board prevalence in each of the categories were significant (Chi-square with P value of <0.0001).

The study also compared crossbred lambs to merino lambs. Industry consultation had suggested that crossbred lambs may show a higher prevalence than merino lambs and whilst this was the case at load out (0.18% vs. 0.05%), it was not the case on board (0.10% vs. 0.45%). The prevalence was low in both groups at receival. These differences were significant (Chi-square) but it is difficult to draw any conclusion since the trend was reversed between load out and on board.

There was no discernable seasonal pattern to the prevalence based on the findings of the study.

The overall prevalence of scabby mouth within the live export supply chain is low, and much lower than reported in the research conducted 10 years earlier. The reason for this in unclear, but the low prevalence influences the current recommendations for a disease prevention strategy.

The study notes the low prevalence of scabby mouth in sheep sourced from the Eastern States (where scabby mouth vaccination is not routinely practised), but it is recognised that disease management in the Eastern States is made easier by the ability to empty the assembly facilities between consignments and the absence of sheds that might harbour the disease. Nevertheless it demonstrates that an exclusion policy, coupled with a rigorous inspection system at the point of receival, can be an effective disease management strategy.

In contrast, the assembly facilities in Western Australia have continuous throughput and significant numbers of carryover sheep. Most sheep are housed in sheds during their assembly period, which makes disease management more difficult. However, the disease incidence pattern also suggests that the use of a ‘live’ vaccine, as little as 5 days prior to delivery, may be responsible for contaminating the assembly environment. This may be directly responsible for the higher levels of scabby mouth seen in non-Saudi consignments sourced from the Western Australia. This conclusion is supported by both the findings of the literature review and industry consultation.

The study recommends that a single vaccination protocol (preferably at marking) be used to replace the double vaccination protocol (that is currently required for sheep travelling to Saudi Arabia). However, sheep that have not been vaccinated at marking should be vaccinated at least 21 days prior to delivery. It is recommended that any disease prevention strategy embrace both the principles of exclusion as well as the principles of immunity. Any changes to the existing protocol should be conditional upon there being stringent inspection procedures in place at the assembly facilities on delivery. It is suggested that inspectors be independent with the sole responsibility of rejecting sheep that are unfit for export.

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Acknowledgements

This study was made possible by the co-operation of industry, in particular, the staff at the assembly depots, staff on board livestock vessels, EMS, RETWA, Wellard’s Rural Exports, Mr Ron Piggott, students and staff at Murdoch University, Dr Jan Lievaart from Charles Sturt University and Mr Ian Whan of Alliance Resource Economics.

1 Introduction

Scabby mouth (Contagious Ecthyma, Contagious Pustular Dermatitis (CPD), Sore Mouth, Orf) is a viral disease of sheep and goats. It is reported in most sheep raising areas throughout the world. In Australia the disease is considered to be of little economic importance since animals usually recover without any significant loss of productivity. The disease is of concern when clinically affected sheep are offered for sale, for shearing or for slaughter at abattoirs [2]. Mortality due to scabby mouth is rare. The disease is of greater concern overseas where it is considered to be the cause of major welfare issues and economic loss [1]. In Australia incidents relating to scabby mouth have affected the trade of livestock to other countries.

The live sheep trade to Saudi Arabia has been disrupted on three occasions. Each time scabby mouth has been cited as the reason. Trade was first suspended in 1990. An attempt to re-open it in 1995 was unsuccessful and it wasn't until 2000 that trade relations were improved to the point that trade could be resumed. The resumption relied heavily on assurances about the prevalence of scabby mouth. Unfortunately, this trade was short lived as a further incident in 2003 led to the rejection of a vessel (the MV Cormo Express), again on the grounds of an alleged unacceptable level of scabby mouth. This incident was accompanied by considerable furore [3-6].

A major investigation was undertaken and it was another two years before it was possible for further shipments to proceed. Pivotal to the re-opening of the trade was a memorandum of understanding with Saudi authorities ensuring that rejected shipments will be unloaded into quarantine facilities. A new protocol was developed through the auspices of the Saudi Livestock Export Program (SLEP). This included the requirement that all sheep destined for Saudi Arabia to be vaccinated against scabby mouth at least twice prior to export. The industry accreditation program was replaced by government regulation and that the Saudi requirements were housed in this legislation. Based on these new arrangements, the trade to Saudi Arabia resumed in 2005 and has continued, without incident, to this date.

Other Middle Eastern countries do not require sheep to be vaccinated against scabby mouth, and to some extent there is less emphasis placed on the importance of the disease. Saudi Arabia is the only country in the Middle East to have rejected sheep shipments on the basis of scabby mouth (to date).

Many Western Australian sheep producers vaccinate against scabby mouth with Scabigard [7] at lamb marking, and it is likely that a large proportion of sheep exported to other Middle Eastern countries have had at least a single vaccination on farm. Sheep sourced from Eastern Australia are less likely to have been vaccinated against scabby mouth. Despite this, anecdotal evidence suggests that the current levels of scabby mouth in consignments sourced from Eastern Australia are very low. This situation has been borne out by the investigations of this study. The implications of this are discussed later in the report.

Recent science has shed new light on the understanding of the disease, particularly the ability of the virus to re-infect animals that have been recently vaccinated (or naturally exposed to the disease). This has implications in regards to the current protocols.

2 Project objectives

2.1 Primary objectives

The primary objectives of the project were to:

1. Review relevant literature relating to scabby mouth and scabby mouth vaccination as it affects sheep in Australia both on farm and in the live export industry.

2. Determine the current use of scabby mouth vaccination for both the Western and Eastern Australian sheep flocks.

3. Determine the incidence of scabby mouth of Australian sheep prior to departure and at the point of discharge in the Middle East.

4. Provide recommendations to industry on the current vaccination protocols for sheep destined for Middle East markets.

These objectives are discussed in more detail below.

2.1.1 Objective one - literature review

MLA/LiveCorp has previously conducted reviews and research into the use of scabby mouth vaccination protocols. Material from these reviews is pertinent to the project. It was expected that this would be brought together with literature (from the general agricultural, scientific and live export communities) that relates to scabby mouth prevention and control, both on farm and during the live export process.

2.1.2 Objective two - industry consultation

In determining the current use of on farm vaccination of scabby mouth, the consultant/research organisation was expected to consider:

a) Results from the MLA nation-wide survey of sheep health and welfare.

b) Current sales of scabby mouth vaccine obtained from vaccine suppliers.

c) Consultation with other relevant sources such as specialized sheep farm consultants and government departments.

d) Reports on the timing and frequency of on-farm vaccination of sheep.

2.1.3 Objective three - determine incidence

It was expected that the prevalence/incidence of Scabby Mouth during live export would be determined by the following:

1. Developing a simple scoring technique in order to grade the severity of scabby mouth infection.

2. Studying at least five shipments to the following destination countries:

    a) Saudi Arabia
    b) Oman
    c) Bahrain
    d) Kuwait

3. Utilising the first voyage as a pilot voyage to determine and test the most appropriate inspection procedures. This would include data collection and inspection procedures at the following points of supply chain:

    a) On entry to the assembly depot
    b) At load out or inspection at wharf
    c) At destination discharge ports

    Following completion of the pilot voyage it was expected that an appropriate statistical and risk factor framework would be developed. The methodology of data collection was to be reviewed after this voyage and presented in a subsequent milestone report (Milestone 3).

    Completion of milestone three was to be subject to a meeting with project team and representatives from MLA R&D management committee. This was identified as a go/no-go point for the remainder of the project.

4. The incidence/prevalence and severity of scabby mouth was to be determined for each class of animal at each of the destination discharge ports.

5. The incidence/prevalence of scabby mouth was to be determined both within and between shipments.

6. The project was to run over a 12-month period in order to determine if there are seasonal effects (time of year) in the incidence of scabby mouth at the point of discharge.

7. Differences in the incidence/prevalence of scabby mouth were to be determined for sheep originating from Eastern and Western Australia.

2.1.4 Objective four - provide recommendations

Based on the associated results, the project was to provide an assessment of the current scabby mouth vaccination protocol for Saudi shipments of sheep and the efficacy of on-farm vaccination on shipments of sheep destined for the Middle East.

The final report was also expected to provide recommendations for further research in order to:

a) Justify the current Saudi two scratch vaccine protocol or;

b) Change the current Saudi protocol to a single scratch vaccine.

3 Method

3.1 Method

3.1.1 Method - literature review

The literature review was conducted in a conventional manner using recognised search engines such as Summon, Web of Science and Google Scholar. The initial search yielded limited information but as the project evolved a much greater body of work was uncovered including several very recent pivotal reviews and some promising new developments. Searches were repeated until it appeared that no new references were forthcoming and the literature review appeared to be exhaustive. The review adopts the Australian Veterinary Journal referencing style in recognition of the multiple contributions made by a few key authors.

3.1.2 Method – industry consultation

Initially, industry consultation was conducted by telephone. Several face-to-face meetings were also arranged. Three important parameters were obtained: 1) the number of doses used in each of the sheep producing states, 2) the second was an animal health survey conducted by MLA and 3) the trend in sheep population over the last 10 years. Other people were consulted including sheep producers, feedlot managers, livestock agents, consultant’s exporters, vaccinators and lamb markers (contractors). Importers and importing authorities were consulted. Consultation was ongoing throughout the course of the study.

3.1.3 Method – inspection procedures

The pilot voyages provided an insight into industry practices and inspection procedures. The general conclusion was that, where possible, data should be gathered in keeping with existing inspection systems using researchers to double check and validate the data. All exporters have existing systems that, with some modification, have the capacity to generate the data. This capacity is not always utilised under normal commercial conditions. Greater utilisation of this capacity was required for the nominated research voyages. These systems were utilised to provide the data required at receival and load out. On board inspection is not routinely practiced and new methodology was required to meet the requirements of the study.

The inspection of sheep on board represented a significant challenge. Several methods were trialled and evaluated. Initially procedures were set up for inspection at the point of discharge. This led to problems at a number of levels. First, it is almost impossible to stop the flow of sheep to allow the individual capture and inspection where required. Secondly, vigilance was required to ensure that mob integrity was maintained and thirdly unloading schedules were constantly modified, and generally continued throughout the night. Due to the unreasonable demands this placed on the researchers, a better method was developed that involved inspection of sheep in the pens prior to arrival.

The method involved a walk thru (or walk by) pens, with or without the assistance of on board stockmen. The method depended on the category of sheep, the stocking density, the configuration of the pens and the prevalence involved. Proper care was taken to ensure the process did not disrupt the sheep or cause unnecessary stress. The efficacy of the procedure was tested by repeating it with different levels of thoroughness with smaller numbers of sheep in discrete pens. The procedure was found to be repeatable, particularly if preceded by a screening inspection that first tested for the presence or absence of the disease [37]. The procedure was time consuming but it was found that 3-4 decks could be inspected in a single day. Consequently the entire consignment could be inspected over a three to four day period. Note that only single tiered vessels were utilised in the study.

To maintain consistency, a scoring system was developed to score the severity of lesions. Brightling (2001) developed a scoring system that was used in the trial work leading up to implementation of the SLEP program in 2000 [10, 12-14]. It graded lesions according to size and the system was described in the handbook provided to veterinarians and stockmen travelling on vessels that included Saudi consignments [20]. This study adapted this scoring system to better suit the requirements of the study (mild, moderate and severe) based on lesions that are visible using the inspection method described above (see table 3.). It was noted from the outset that neither system reflects the infectivity of the lesions, and/or the stage of development. Rather than impose yet another scoring system, notes as to the stage and apparent infectivity were kept separate to augment the findings. The various stages of the disease are better described in section 4.2.5.

Table 3. The severity scoring system used to grade scabby mouth lesions in this study

Score	**Description**
Score 0	No evidence of scabby mouth
Score 1	Mild
Score 2	Moderate
Score 3	Severe

The completion of the pilot voyages provided the opportunity to plan the best way to conduct the inspections, both on land and on the vessel. A census (population study) was identified as the preferred approach. It was recognised that this may not always be achievable, particularly if relying on persons outside the research team to collect and collate data. As it turned out, a full census was conducted on all of the research consignments. Nevertheless, a protocol was developed to assist veterinarians and/or stockmen to use a sample approach if and when a full population survey was not possible (see Appendix). This protocol embraced the principles described by Cameron (1998) whereby the inspection has two stages [37]. Stage One establishes the presence or absence of the disease while Stage Two involves a more detailed inspection to determine the prevalence.

3.1.4 Method – statistical framework and analysis of results

In statistical terms the project has been conducted as an observational study since there is no intervention with normal management practices. Where possible, a population survey (census) was conducted involving all the animals in the consignment. As mentioned, the rationale for this was developed whilst undertaking the pilot voyages. The population survey is better suited to industry practice and provides the biggest possible sample for statistical analysis. It provides information in a form that is most relevant to the industry and encourages the study to focus on existing practice and the possibilities for improvement. The population survey also safeguards against any tendency for the disease cluster as described by Cameron (1998) [37], whereby a sample survey may inadvertently result in skewed results.

Jan Lievaart PhD DVM MSc, Senior Lecturer in Veterinary Epidemiology at the Graham Centre for Agricultural Innovation at Charles Sturt University assisted in the development of a statistical framework. Ian Robertson, Dean of the Veterinary School at Murdoch University assisted this work.

The study has both longitudinal and cross sectional aspects. It is cross sectional to the extent that it undertakes measurements on animals at a three different points in time within the export process (receival, load out and on board). It is longitudinal to the extent that it monitors the same group of animals over time. The longitudinal aspect of the study determines the incidence of the disease (as defined by the new cases that develop) and/or the period prevalence of the disease, (as defined by prevalence over the time period). In this case the time period would be from receival to the point of discharge. The results of this study have been presented from the point of view of a cross sectional study (i.e. the prevalence is determined at three distinct points of time).

The prevalence is presented with the upper and lower confidence limits. In the absence of any detailed information about the sensitivity and specificity of the test a standard deviation of the sampling distribution has been taken as one. The effect of prevalence on the confidence interval is discussed in the appendix. The results of this study are presented using a statistical framework that includes the confidence width.

The terms of reference asked for a determination of prevalence that compares consignments (by consignment). They also asked that a comparison be made between consignments sourced from the Eastern part of Australia and those sourced from Western Australia (by origin). They asked that the prevalence be compared between sheep belonging to different categories (by category) and finally they asked that a comparison be made between sheep that are prepared with a different protocol (by protocol). These comparisons were made using the Chi-square test. A total of 12 consignments were compared involving over 370,000 sheep.

4 Literature review

4.1 Background

4.1.1 History

Saudi Arabia was Australia's largest market for live sheep exports during the 1980s. The market was closed in September 1990 following the rejection of consignments in late 1989. The reason was allegedly unacceptably high levels of scabby mouth. An attempt to re-open the trade in 1995 failed, again due to issues relating to scabby mouth. This consignment destined for Saudi Arabia was rejected and diverted to Jordan.

The importance of the Saudi trade was recognised and a concerted effort to re-open the trade was made by both industry and Government. A Government inquiry [8] was initiated to look at why the attempt in 1995 failed, the capability of the Australian industry to supply sheep, the Saudi requirement for sheep and the status of Saudi supply alternatives. It reviewed the outcomes of the most recent industry/government visits. The inquiry conducted a risk management assessment to examine the likelihood of further problems, the impact of further issues with scabby mouth and aspects of accountability. On the basis of this inquiry, a plan was developed for the resumption of the trade.

The inquiry noted that industry consultation early in 1995 concluded that there was a strong basis for resuming the live sheep trade to Saudi Arabia. The review also noted that research, conducted under the auspices of the working Group on Saudi Live Sheep had indicated that vaccination, whilst imperfect, could reduce the risk of scabby mouth in exported sheep to manageable levels. It is pertinent to note that the inquiry highlighted that despite this, a decision had been made not to include vaccination as a condition of the trade. Both the Australian Livestock Exporter's Association (ALEA) and the Sheepmeat Council of Australia (SCA) were strongly opposed to mandatory vaccination. ALEA's reasoning was that *"vaccination requirements would severely limit their ability to amass sheep with verifiable vaccination status in sufficient numbers for the trade"* and that *"exporters had developed procedures in ensuring that ship's could arrive at Middle East ports relatively free of scabby mouth*". SCA's reasoning was *"that many farms did not have scabby mouth in their flocks and that using a 'live' vaccine would introduce the disease to otherwise clean properties".* The review also noted that the Saudi Authorities clearly listed a requirement that *"sheep be free of contagious disease"* and *"be selected for export from farms on the basis of them being free from contagious disease".*

The inquiry concluded that it was an act of blind faith on the part of the industry to resume the trade in the knowledge that 1) scabby mouth is a contagious disease and endemic in Australia and 2) that the vaccination option had been rejected by industry. This is a harsh statement, but with the benefit of hindsight it is probably accurate. On the basis of this inquiry, the way forward focussed on three key areas. The first was a recommendation that the industry vaccinate and that this should include the consideration of a booster (or second vaccination) prior to export. The second was a requirement to have a fully effective and strictly controlled Quality Assurance system implemented. The third was to take a delegation to the Saudi authorities to resolve the issues of mutual concern. These issues related mainly to health certification.

Accordingly, the industry designed a number of trials aimed at evaluating the efficacy of a double vaccination protocol. These trials built on the earlier work conducted by Higgs in 1992 [9]. Agriculture W.A. conducted the trials as part of an R&D project funded by Meat and Livestock Australia (MLA) [10-14]. The trials looked at a range of possible protocols involving vaccination at marking, on-farm, and at the point of delivery at the feedlot. It is worth noting that even at this point it was recognised that the ideal time to vaccinate was at least 14 days before the anticipated challenge [13]. This would allow immunity to develop and reduce the risk of live virus being shed in scabs at the feedlot. It was noted, however, that this was practically impossible since most sheep are sourced and purchased much closer to the time of delivery. Discussions with the trade led to revision that allowed the vaccination to be applied closer to the time of delivery. The trade off between vaccinating at the optimum time and conceding to the logistics of the livestock export process exists today.

A quality control program was developed concurrently under the auspices of the Saudi Livestock Export Program (SLEP) [17]. As well as vaccination, these standards addressed a number of issues including conditions of accreditation, sourcing, age, identification, ports of discharge, veterinary accompaniment and stocking density. The SLEP standards were additional to the normal industry requirements (Livestock Export Accreditation Program (LEAP) standards) [18, 19]. Both the final draft SLEP standards and the LEAP standards were incorporated by reference to the *Australian Meat and Livestock Industry (Live Sheep Exports to Saudi Arabia) Order 2000.* The double vaccination became an export requirement. At the farm level, a ‘scratch to catch the market’ program was initiated that encouraged farmers to vaccinate lambs at lamb-marking [15, 16].

At a meeting with the Saudi Arabian Ministry in October 1998, delegates had the opportunity to clarify the Australian understanding of the Saudi position and the Australians put forward their own position on the same issues. The two major issues relating to scabby mouth were discussed. The first was that scabby mouth was endemic in Australia and that it was not possible to source animals from farms that were ’free’ from the disease. The second related to the unloading of animals, in the event that diseases such as scabby mouth were found. It would seem that although the Australian concerns were heard and understood, it is not clear as to the extent that the Saudi authorities were prepared to accede to these concerns. Ironically this would be borne out by later events. Of note also is the fact that although the meeting minutes refer at some stage to a tolerance level of 5%, the current review has not uncovered any evidence anywhere, (then or since) to suggest that the Saudi authorities have had anything other than a nil tolerance policy on the subject of scabby mouth.

In 1999, at a further meeting with Saudi and Australian delegates it was agreed that the trade re-commence on a trial basis using the double vaccination protocol. Seven shipments were monitored under an arrangement between industry (the Saudi Working Group), the Australian Government and the Kingdom of Saudi Arabia.

Initially, access to the trade was restricted to the trial participants. The trial shipments were successful and the trade was opened up to any commercial operators in 2000, but only if the commercial operator participated in the accreditation program and complied with the SLEP standards. In summary these standards called for:

- separate and additional accreditation to the LEAP standards
- stricter reporting requirements
- each shipment to be accompanied by a Government approved veterinary officer
- scabby mouth vaccination (including trace-back and audit of vaccinators)
- individual tagging of sheep (again with a trace-back system)
- restrictions in terms of age
- lighter stocking density
- auditing procedures.

Only accredited exporters were allowed to participate in the market and accreditation was conditional upon compliance with these standards and achieving lower than normal mortality levels. Compliance was good, and the program ran smoothly until 2003 when the MV Cormo Express was rejected, again due to alleged high levels of scabby mouth. This incident caused considerable furore. Efforts to find a new destination for these sheep were frustrated by many operational and political factors. The sheep were finally discharged in Eritrea 80 days later.

The actual prevalence of scabby mouth on arrival in Jeddah was never really determined. This is despite a clear scoring system set out in the handbook for shipboard veterinarians (SLEP). This handbook was provided to all veterinarians and stockmen travelling on vessels to Saudi Arabia [20]. This event highlights that although a scoring system had been developed, a method to properly determine the prevalence of scabby mouth in sheep in the pens on board had not been determined (or at least practised). It also points to the difficulty of undertaking such a task.

As a result of the public concern, the Australian government again closed the trade to Saudi Arabia and commissioned a review of the live export trade. This was conducted by Dr John Keniry and was subsequently referred to as the Keniry Report [21]. The recommendations stemming from the report are surprisingly general and there are only a few that apply to exports to Saudi Arabia. The report did, however, recommended that the trade not be resumed until robust contingency measures to deal with the rejection of a consignment due to scabby mouth (or any other ‘Type C’ disease) were in place. More specifically, this involved the provision of a quarantine facility that ensures that rejected shipments can be unloaded within 48 hours of arrival. This was addressed by industry through a memorandum of understanding to ensure that a quarantine facility was made available, close to the port of discharge, to deal with such disputes should they arise.

In regards to why the prevalence of scabby mouth was allegedly higher than expected, the Keniry investigation leaned toward a lack of compliance to SLEP requirements. This suggested that the inquiry did not question the efficacy the double vaccination protocol. This is consistent with the earlier usage of the term booster in earlier reviews [8, 12] and suggests that the industry understood the vaccine to work in the same way as many other vaccines (i.e. it did not acknowledge the immune-suppressive capabilities of the virus nor the fact that the vaccine contains an virulent field strain live strain of the virus). The science in regards to this was only emerging around the time of the review. The emergence of new science relating to the immune response of sheep to scabby mouth infection is discussed in more detail under the heading of scientific developments [22].

The Keniry review concluded that the welfare of animals in the livestock export trade was a primary consideration in all areas of the industry and at all stages of the livestock chain from farm to discharge into the market. Furthermore it was deemed that the Australian Government was better suited than industry to safeguard the broader animal welfare interests of the Australian community. Consequently many of the roles and responsibilities were handed over to government, and the industry accreditation programs were incorporated into a regulatory framework to be enforced by the Australian Quarantine and Inspection Service (AQIS).

Thornber (2005), provides a precise outline of the developments of the new industry standards [23]. The overall result was that the components of the SLEP program were referenced into amendments to the Australian Meat and Industry Live-stock Act 1997 & 2000 and the Export Control Act 1982. The LEAP standards were revised to form the Australian Standards for the Export of Livestock (ASEL) [24] and a new Order was developed entitled Australian Meat and Livestock Industry (Export of Livestock to Saudi Arabia) Order 2005 [25, 26].

With these in place, the trade Saudi Arabia was recommenced in 2005, and no further incidents have occurred. Trade to other Middle East countries has continued without interruption throughout these developments.

4.1.2 Regulation

Scabby mouth is endemic in Australia. Consequently there are no specific interstate or within state regulations that relate to the disease. The disease is named in the Australian Standards for the Export of Livestock (ASEL version 2.2 - December 2008) [24] as a condition that renders an animal unfit to enter the export chain. Animals showing clinical signs of scabby mouth must be rejected (ASEL Number S1.7). ASEL also states that livestock sourced for export must meet importing country requirements.

The Export Control Act No.47 of 1982 (as amended November 2006) [27] contains generic regulations related to the administration of the standards and these apply to the export of any livestock out of Australia. Its relevance to Scabby Mouth occurs in relation to penalties involved for industry personnel in the event of false declaration or other digressions.

Currently, only Saudi Arabia has import requirements that specifically apply to scabby mouth and these are outlined in the Australian Meat and Livestock Industry (Export of Livestock to Saudi Arabia) Order 2005 [26].

In respect to scabby mouth the regulation reads as follows:

> *(1) An exporter must not export sheep or goats to Saudi Arabia unless a trained vaccinator has:*
>
> *(b) administered a second scabby mouth vaccination to the sheep or goats;*
> *(i) at least 14 days after the first such vaccination*
> *(ii) and not more than 56 days prior to the intended date of export*
> *(iii) and at least 5 days before their transport to the registered premises at which they will perform pre-export quarantine.*
>
> *(c) identified the sheep or goats with numbered and coded eartags as complying with paragraphs (b); and*
>
> *(d) with the assistance of the exporter, compiled records in relation to the sheep or goats that comply with subsection (2).*
>
> *(2) Records referred to in paragraph (1)(d) must:*
>
> *(a) specify the properties from which the sheep or goats originated; and*
> *(b) specify the number of animals vaccinated; and*
> *(c) specify the date or dates of vaccination; and*
> *(d) specify the batch numbers of the vaccine; and*
> *(e) specify the date or dates on which the vaccine was opened; and*
> *(f) describe the ear tags by which the animals were identified in accordance with paragraph (1)(c).*
>
> *(4) The exporter must collect and maintain the records of vaccination and identification for each consignment.*

In addition to these requirements, the importing country's (Saudi Arabia's) import permit requires that:

> *"animals found to show clinical signs of Scabby Mouth during the inspection 24 hours prior to loading for export will be removed from the consignment".*

Accordingly this appears on the Health Certificate issued by the attending AQIS office at the point of departure from Australia.

These regulations are subject to audit by officers authorised by the Commonwealth Department of Agriculture, Fisheries and Food (DAFF) and/or AQIS. Ultimately, the live export standards are enforced by the relevant Welfare Acts in each of the states.

It is important to note that the same orders place other restrictions on such things as the time in feedlot, the age of sheep, conditions over split port discharge, size of the consignment (in the case of goats), the sex of the livestock, domestication (in the case of goats), pulpy kidney vaccination, veterinary accompaniment, country declaration in regards to disease freedom and fodder requirements. Additional space is also required for Saudi consignments. These are described in the Annex attached to the Order [25].

The regulation outlined above represents the current regulation in regards to scabby mouth trade and sheep destined for Saudi Arabia. It is difficult to track the regulation that was in place at the time of earlier incidents involving scabby mouth. As outlined in Section 1.1.1, vaccination was not required at the time that a vessel was rejected in 1995. The *Australian Meat and Livestock Industry (Live Sheep Exports to Saudi Arabia) Order 2000* was in place at the time that the MV Cormo Express was rejected in 2003, however the specifics were referenced to both the LEAP standards that incorporated the Australian Livestock Export Standards (ALES) (as well as the SLEP standards). The SLEP standards at the time were under constant revision.

The April 2002 version [17] of the SLEP standards states that sheep must be vaccinated twice, at least eight days prior to export. At the same time, the assembly requirement was for sheep to spend three clear days in a feedlot. This required sheep to be vaccinated on farm at least five days before the day of delivery to the feedlot. Note that the current assembly requirements are for seven clear days in a feedlot and vaccination must take place at least five days prior to delivery. The current requirements therefore allow sheep an additional three days to recover from the vaccination and acquire immunity (before they are delivered and/or reach their destination).

4.1.3 Scientific developments

Sheep that develop immunity to scabby mouth, either through vaccination or natural exposure to the disease can be re-infected [1]. From early as 1984 the literature contains reports of vaccination failure[28]. Initially it was thought that this was due to the dermal nature of the infection and related to a sequestration of the disease before the animal could launch an appropriate immune response. More recently it has been shown that the ability of the virus to re-infect immune sheep is due to specific immuno-modulatory mechanisms that modify the sheep's immune response. Today there is a comprehensive understanding of these mechanisms [29, 30]. This understanding has emerged in scientific literature over a 10-15 year period.

Alcami (1995) studied the role of cytokines in the host immune response and reported "t*he discovery that certain poxviruses possess a fascinating machinery to counteract the host immune response".* Several other immuno-suppressive factors were identified and reported over a period from 1996-2002.

These scientific findings were emerging around the same time that the live export industry was attempting to re-establish the trade to Saudi Arabia through the auspices of the SLEP quality assurance program. It can take time for science to filter through to an industry level. However, the CSL Scabiqard Technical Update (2005) [7], stated that *“sheep that have been vaccinated with Scabiqard are susceptible to re-infection but that both the severity and duration of the disease is reduced” .*

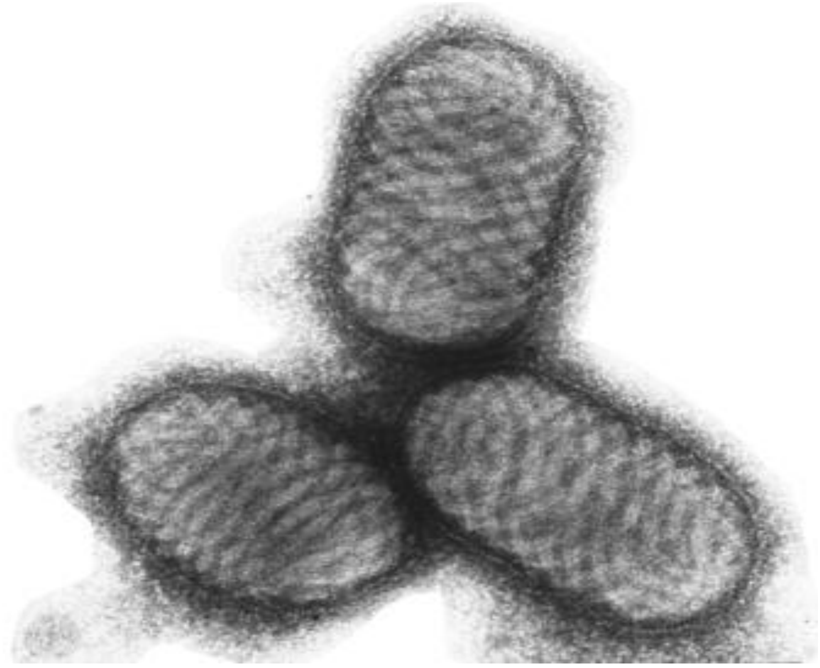
This has become the stock standard statement in regards to vaccination and it can be taken that the industry should have been aware of this by this time. The ability of the virus to re-infect immune sheep has important implications when it comes to determining a rational disease management and control strategy.

4.2 Literature review

4.2.1 Aetiology

Scabby mouth (orf, contagious ecthyma, contagious pustular dermatitis) is caused by a virus belonging to the genus *parapoxvirus* of the subfamily *chordopoxvirus* within the *poxvirus* family [29]. The virus consists of a double strand of DNA, making it a comparatively large virus. It has a distinctive shape under the electron microscope being ovoid and covered with thread shaped 'basket weave' tubules resembling a ball of yarn [30] (Figure 1.). The virus is 260 nm long and 160 nm wide. The genome sequence of the virus has been determined and published [40, 41] with a complete map of all the base pairs. The virus has a relatively high G+C content (64%) [30, 42].

Figure 1. The 'basket weave' patterns of the virus under electron microscope



Source: Moredun Institute

The virus is very similar to the other parapox viruses (such as bovine papular stomatitis) with only a few open reading frames distinguishing them apart. The virus is described as being composed of 140kbp linear ds DNA with closed hairpin loop ends and genes located on both strands with a bidirectional orientation [30]. The terminal 3 kbp DNA at each end forms an inverted terminal repeat (ITR). The conserved genes are found in the central region, whereas the variable genes are at the terminal ends. The terminal ends contain the genes responsible for the evasive mechanisms [30].

The genome contains 130 putative genes, 88 of these are shared with other viruses from the poxvirus family and 127 are shared with viruses from the same genus (e.g. bovine papular stomatitis) [40]. The remaining three genes differentiate the viruses within the genus. The genes responsible for the production of the immuno-modulatory factors (that interfere with the host and antivirus immune and inflammatory effector systems) are found in all the viruses belonging to the *parapox* genus [41].

4.2.2 Epidemiology

The scabby mouth virus has a worldwide distribution. In Australia it is thought to be the most common viral disease of sheep [36]. There is evidence that the disease has been present in Australia for a long time [43]. The disease is present in both the Middle East [29, 30, 33] and in other countries that supply Saudi Arabia (e.g. North Africa) [44].

Sheep of all ages are affected [1]. Most sources suggest that lambs are most commonly affected, with the disease being seen less often in older sheep [2, 29, 30]. A separate syndrome is seen in lactating ewes (involving udders), and another involves the legs of young sheep (strawberry footrot) [1]. A venereal form of the disease is also described [30].

Damage to the skin or buccal mucosa is essential for the establishment of infection with the scabby mouth virus [1, 30], [49]. A classic example of this is ‘thistle disease’ in which damage by thistles predicates a scabby mouth outbreak. Trailing oats (or other supplementary feed) in the paddock may enhance the spread of the virus. This is a common management practice in late summer and autumn. There is some evidence to suggest that moist humid conditions predispose animals to a scabby mouth outbreak [1, 30].

The disease is highly contagious. The virus is shed in scabs and transmission occurs through direct contact with infected animals or the shed scabs. There is no evidence of any airborne transmission nor does it appear to spread systemically to different parts of the body [33]. Lambs can spread the disease to the udder and teats of ewes whilst suckling [36].

The disease rarely causes mortality, although isolated reports of mortality up to 5-10% are recorded [45]. Morbidity is variable. Explosive outbreaks can cause morbidity of up to 100%. These usually involve precursory epithelial damage (e.g. thistle damage to the lips or mouth) [45]. Scabby mouth is usually seen as a smouldering disease that demonstrates a morbidity of 15 to 20% as the disease is passed around the mob.

The disease occurs most commonly in sheep and goats and less commonly in camels, deer, antelope [30]. Humans will sometimes contract the disease. There appears to be no cross infectivity between the camel and sheep strains, but other strains are less species specific [30, 46].

The virus can survive for years in the environment, particularly in dry areas such as lambing sheds or covered holding yards. It is destroyed by very high and very low temperature and can lose infectivity when exposed to rain on pasture [30]. The virus can exist for up to 15 years in sheds if kept at (or around) room temperature [30]. Wooden feed troughs could be a site for the survival of the virus.

It is suspected that sheep showing no clinical signs can carry the disease. The virus is thought to persist in wool or skin follicles [1, 47]. There is some suggestion that the disease emerges during time of stress, suggesting that lowered resistance triggers the re-emergence of the disease [1, 47]. There is also an anecdotal claim that stress can lead to an onset of the disease, particularly in young sheep. This presumes the persistence of a subclinical level of scabby mouth within the population or exposure to a contaminated environment.

Determinations of prevalence exist in the literature. Interpretation of these is difficult due to the inability to quantify the nature and extent of the disease challenge and an inability to properly ascertain the sheep’s immune status. Vaccination history is not always known, and the extent to which sheep are naturally exposed is rarely recorded. It is also difficult to determine to what extent farmers voluntarily retain lines of sheep that they know to have scabby mouth.

The most comprehensive study was undertaken by Robinson in New Zealand [2]. This study was conducted in response to concern about infection of the hands in meat workers at regional abattoirs. The study was undertaken over a three-year period from October 1979 to September 1982. Over 6.3 million lambs were processed during this period and the prevalence of scabby mouth was monitored throughout. The analysis determined the number of lines of animals showing lesions. The overall prevalence of scabby mouth was low (0.5%), with over 40,000 lines assessed and only 2.4% (968 lines) showing lesions. The within-line prevalence of infected lines was high (average within-line prevalence of 13.4%).

There was a seasonal pattern to the disease with most of the affected lines observed between December and February. It was not clear whether this reflected a seasonal turnoff, or whether it was linked to more abrasive ’dry’ feed. In the peak months the proportion of lines affected was high (9.3%).

The study determined that, if all the sheep in the affected lines were turned away, 1.25 million lambs would have been returned to the property. The conclusion was that the refusal to slaughter scabby mouth affected lines would represent a large commercial impost and would be unlikely to completely eliminate the disease in the meat workers. It was not recommended as a policy. This conclusion, however, did not address the possibility of any behavioural change by farmers in response to a return of infected mobs. It was also noted that over two-thirds of the cases occurred in meat workers that had not directly handled known infected sheep. Several explanations were suggested, the most plausible being that the virus may persist in wool or wool follicles for sometime after lesions resolve.

Another major prevalence study was conducted in Australia in 1991. This study investigated the prevalence of scabby mouth within the live export supply chain. Higgs [9] studied 106 farms in Western Australia and found the disease present on 23% of these. On the farms where the disease was present, the overall prevalence was 6%. The overall prevalence in the sheep involved in the study was 1.3% (Table 4).

Table 4. On farm prevalence of scabby mouth (Higgs 1991) [9]

1991	23% of farms found to have the disease present.
1991	6% prevalence on infected properties.
1991	Overall prevalence was 1.2%

Higgs also studied sheep entering the assembly facility prior to live export. Four out of 18 farms (22%) had sheep showing signs of the disease. The disease prevalence in the sheep from these farms was 5.2% and the overall prevalence was 1.2% as shown in Table 5. These figures would indicate that there was little or no behavioural restraint shown by farmers when delivering sheep into the live sheep export market.

Table 5. Prevalence of scabby mouth on receival (Higgs 1991) [9]

1991	22% of farms found to have the disease present.
1991	5.2% prevalence in infected mobs.
1991	Overall prevalence was 1.3%

Higgs reported that veterinarians accompanying vessels to the Middle East make reference to scabby mouth as an incidental finding. Quantitative information was difficult to obtain. Anecdotal reports by Buchanan, (a veterinarian stationed in the Middle East with MLA), suggest that high levels of scabby mouth had been seen in lambs on arrival [48]. Regular monitoring had shown an average prevalence of 35-40% in lambs in 1997 as shown in Table 6.

Table 6. Prevalence of scabby mouth on arrival in Middle East (Buchanan 1997 & 1998) [48]

1997	35-40% in lambs % determined by regular monitoring (before 'scratch to catch the market' program [15].
1998	15% in lambs % determined by regular monitoring (after 'scratch to catch the market' program [15].

This level was reported prior to the 'scratch to catch the market' campaign that was initiated in 1997-1998 [15]. The same circular reports that regular monitoring of lambs after the initiation of the vaccination campaign had shown that the prevalence had dropped to 15%. The data to support these claims is not available, but the information is considered credible.

An epidemiological study by Cameron (2000) notes the tendency for disease to cluster and suggests a two staged approach to determining prevalence and/or disease presence, an initial screening of animals followed by a more detailed inspection depending on the results of the screening [37]. This two-stage approach has been adopted in the current review.

Another article by Higgs (2000) addresses several aspects of scabby mouth within the live export industry in Australia, including an attempt to model the disease from an epidemiological point of view [9]. The modelling was used to anticipate the outcomes of scabby mouth infection in a simulated shipping scenario. The flock was broken into three compartments. The first compartment was the number of infective sheep, the second compartment was the number of susceptible sheep and the third compartment was the number of recovered and/or immune sheep. The modelling assumed a transmission coefficient and varied the initial number of infective sheep at the outset of the epidemic. The model tracked the number of sheep in each of these compartments over time. This provided a sense of the epidemic.

Unfortunately, the assumptions used in the model need to be re-examined in the light of the current live export situation. The model assumes that immunity is absolute and that recovered or vaccinated sheep are unable to be re-infected. The second assumption was that transmission is unimpeded and the spread of the disease was even throughout the population. This assumes that all the susceptible sheep will eventually become infected. The model reflects the mixing of sheep within a single mob, in keeping with the simulated shipping scenario, but it does not reflect the extent of mixing that occurs in the normal commercial assembly process.

The modelling produced some interesting results, and provides a logical way to view the disease. The modelling showed that with a mob of predominantly susceptible sheep, a small number of infective sheep at the outset and a moderate transmission co-efficient, the peak prevalence actually occurred as the vessel arrived at the destination [9]. A higher number of infective sheep at the outset resulted in the peak prevalence occurring earlier. Similarly a higher transmission co-efficient resulted in the peak prevalence occurring earlier.

The message from this modelling was that if you are to have an epidemic it is probably better to get it over and done with as quickly as possible. This gives some support to the policy of vaccination prior to or at the point of assembly.

The model also assumes that the transmission is constant across the entire mob, and does not vary as the disease progresses. It is likely that transmission is influenced by an inter-play between immune status of the sheep, the challenge or infective dose and the virulence of the virus strain. Stock persons, who observe the disease on a regular basis, describe a stage of the disease that is characterised by a sticky exudate around day 6-7 of the disease as depicted in Figure 2. Infectiousness of the disease is related to the amount of viral antigen, as indicated by

Jenkinson [58]. It is likely that this exudate is rich with virus and that the sheep is highly infectious at this stage. Jenkinson also describes how the amount of viral antigen in the scab diminishes over the course of the disease and that there is little or no virus in the scab at the final stages of the disease. This suggests that the coefficient of transmission may vary as the disease progresses.

Figure 2. Sticky exudate (laden with virus)

4.2.3 Clinical signs

The disease is known for its characteristic lesions around the mouth and nostrils (Figure 3) however lesions can also occur around the feet and the mammary glands.

Figure 3. Typical clinical signs of scabby mouth

McElroy (2007) describes the characteristic visual lesions in some detail [50]. The infection begins with some reddening (erythema) of the skin. The skin may begin to weep slightly. Lesions progress through typical sequence of erythema, macule, papule, vesicle, pustule and then scab formation (figures 4-8). In the initial infection, the lesions will become proliferative and the pustules will give way to a thick overlying crust [49].

If the lesions become proliferative and/or infected with secondary bacteria the clinical signs can be quite spectacular involving the head and ears. Fissures develop in the scabs and this allows large scabs to be shed as the lesions develop underneath.

Lesions on the udder of sheep can be described in a similar way. There is some evidence that lesions develop in housed ewes prior to lambing, suggesting that infective material has survived in the sheds and that the distended udder becomes abraded on the bedding or floor surface. After lambing, the lamb will aggravate the severity of these lesions by suckling, become infected and provide a further avenue of cross infection [1].

Figure 4. Erythema (reddening of the skin) due to scabby mouth infection

The erythema develops into a macule/papule then into a vesicle and/or a pustule. All of these stages may be difficult to detect by visual observation of the sheep without restraint and close inspection, particularly if the lesions are on the inside of the mouth and/or lips.

Figure 5. Vesicles and pustules due to scabby mouth infection

Figure 6. Further development of pustules with some early scab formation

Note the slightly “weepy” nature of the pustules. These quickly form scabs. These lesions are more obvious and more easily observed by a normal inspection of the sheep.

Figure 7. Early scab development

Figure 8. Late scab development

Note that the scab is starting to detach. This has the potential to carry virus and may be responsible for directly infecting other sheep or contaminating premises.

4.2.4 Diagnosis

In Australia, scabby mouth (in its typical form) is unlikely to be confused with any other condition. Differential diagnosis is more difficult in other parts of the world where several important exotic diseases are known to occur.

Atypical forms will sometimes occur. The most common atypical form is known as strawberry footrot [1]. This disease is caused by secondary infection with the bacteria *Dermatophilus congolensis*. Lesions associated with this condition occur on the face but are mostly seen in the feet. Sheep will often exhibit lameness. This condition has been confused with other more serious diseases such as Foot and Mouth Disease (FMD) [51].

Scabby mouth will sometimes infect the nose or other parts of the body, without the lips being involved. These cases are more difficult to tell apart. *Dermatophilus* (dermo) infection, without the involvement of the scabby mouth virus, tends to be less ulcerative and less proliferative and has a ’furry’ appearance [44]. Photosensitivity (facial ecythma) can also produce lesions that could be confused with atypical cases of scabby mouth.

The situation overseas is somewhat different. There are several important diseases that need to be considered when investigating an outbreak of scabby mouth. The first is sheep (and goat) pox. This disease is also caused by a poxvirus, but one that belongs to a different genus [52]. The disease is endemic in the Middle East and North Africa and is seen regularly in these regions. The lesions of sheep pox and scabby mouth are indistinguishable[53, 54]. For these reasons, scabby mouth can be confused with sheep pox overseas. This leads to the possibility of misdiagnosis once the sheep have been unloaded, but more importantly, it can be an issue when attempting to clear the vessel prior to unloading. Sheep pox is a much more serious disease with far more extensive lesions, fever, haemorrhage and the potential to incur mortality as high as 50% [52].

Sheep pox is exotic to Australia [52], therefore, Australian sheep are susceptible to the disease and run the risk of becoming infected on arrival in the Middle East [55]. Understandably, investigations may conclude (even if only fleetingly) that the disease was brought into the feedlot with the sheep from Australia. The naive status of Australian sheep is of concern and the literature reports an outbreak of sheep pox in 2,600 merino hoggets from Australia, in a feedlot in Jordan [55]. Of the 2,600 sheep, 560 were severely affected (21.5%) and 229 died (8.8%). The outbreak occurred in 1995 and the diagnosis was based on clinical signs. The feedlots were depopulated, cleaned, disinfected and it was required that the next consignment of sheep from Australia be vaccinated against the disease immediately on arrival. No further problems were observed. This highlights the potential for Australian sheep to be implicated in a disease outbreak that is exotic to Australia.

Differentiating between the sheep poxvirus (SPV) and scabby mouth can be difficult. Both viruses cross react in agar gel immuno-diffusion and serum neutralisation tests. More recent advances with PCR technology have allowed SPV to be more easily identified. The same PCR test has been shown to be capable of differentiating SPV from goat pox virus (GPV) [54].

The other important disease to be considered is FMD. The lesions associated with FMD can sometimes be confused with atypical cases of scabby mouth. Hawkins (1991) describes an unusual outbreak of scabby mouth in Australia that strongly resembled FMD [51].

Sheep scab, caused by the mange mite *Psoroptes ovis,* should also be considered, but only due to its name. Sheep scab was eradicated from Australia in the late 1800s, but is still present in North Africa and parts of the Middle East [56]. It presents as an itchy mange and is not likely to be confused with scabby mouth at the clinical level [57].

A venereal form of the disease (scabby mouth) is also described, involving a thickening of the scrotal skin, lesions in the prepuce and on the vulva and/or vagina [1, 30]. This could resemble other diseases.

The disease is relatively easily diagnosed and the clinical signs are pathognomic. Misdiagnosis is rare [2], but atypical cases can pose problems [51]. The traditional way of confirming the disease has been through viral identification with electron microscopy [1]. This method is also capable of distinguishing between SPV and GPV [30]. This has benefits in the Middle Eastern countries. The histology associated with the disease is also characteristic [49, 58].

An ELISA test has been developed that reliably quantifies antibody levels [30], but this may have limited application as a diagnostic tool. High antibody titres do not necessarily indicate active disease and/or immunity. The ELISA test may have application in further determining the behaviour of the disease. Virus neutralization and complement fixation tests fall under the same category [30].

More recently the polymerase chain reaction (PCR) has been used to quickly diagnose the disease and this is likely to become the preferred technique [30, 53, 83, 84] particularly in humans where misdiagnosis is more common. Various genes have been used successfully (B2L, VIR, A29 and H3L). Restriction enzymes have been used to characterise different strains of the virus at a molecular level [30].

4.2.5 Pathogenesis

The virus targets live epithelial cells, specifically proliferating keratinocytes [49]. Skin abrasions or damage result in keratinocyte proliferation, allowing the virus to become established in the layers of the skin where cell replication is taking place.

Once established the virus produces a proliferative factor that encourages further cell replication, providing more tissue for it to target [33]. This accelerates the cell replication that is already occurring as part of the normal repair process [58]. This process, at its most extreme, can lead to the development of tumour like lesions [29].

A feature of the disease is balloon degeneration of the infected cells, a common feature of viral infection [1, 58]. McKeever (1998) describes the histopathology of the scabby mouth in some detail [49]. At a histological level, apart from the cell degeneration mentioned above, the lesion is characterised by an influx of polymorphonuclear cells (neutrophils) followed by an accumulation of basophils, dendritic cells, and lymphocytes (both B and T cells) [36]. Eosinophils are notably absent, although this is disputed by Jenkinson [58]. The presence (and decline) of these cells parallels the presence of virus in the infected cells [36]. The other characteristic histological finding is rete formation (or the formation of epidermal plugs or down growths). This reflects both the animal's efforts to re-establish an intact epithelium as well as the proliferative effects of the factors produced by the virus.

Jenkinson (1990) describes the response over time. In his study, the skin was initially scarified with a 16-gauge needle. The initial response was therefore an inflammatory response related to the scarification. Macules were evident histologically on day 1, papules by day 3, vesicles by day 4 and pustules by day 6. Scabs developed from day 10, although in some lambs scabs were not evident until day 16. In this experiment, lesions started to resolve from day 16-24 in the primary infections and the epidermis was almost back to normal by day 31 [58].

Importantly the study noted that lesions were always localised around the lines of scarification, and at the most found 2-3 mm from the primary point of infection. This confirms that there is no systemic spread of the virus and that multiple sites of infection are most likely caused by separate incidents of epithelial damage followed by exposure to the virus. The study notes that the gross pathology mirrored the histological findings. The incubation period (or at least the period in which the disease may not be evident to the naked eye) was short, approximately 2-3 days.

The study also pointed out that during the course of the disease, the greatest amount of viral antigen was concentrated in the peripheral areas of the lesion where both the inflammatory response and repair was most active. Viral antigen was evident by day 2 and reached a peak by about day 9. By day 12, the viral antigen was found only in the outer areas of the scab and no viral antigen was found in the scab at day 22. This reflects the infectivity of the disease as described anecdotally by people working within the live export supply chain.

Jenkinson also studied the histological response to a second challenge. The four lambs used in the initial study were challenged again 42 days after the initial infections had resolved. All four lambs developed lesions, although these were less severe and resolved more quickly than in the initial challenge [58]. Histopathology also showed that the disease followed a very similar course but that the lesions were less severe and the recovery much quicker. Macules were again observed at day 1 but papules appeared at day 2. The pustules and scabs developed much earlier (at day 3 and 5, respectively). Lesions started to resolve at day 7. The skin was apparently normal by Day 22 [59]. Lesions in re-infected sheep tended to be less proliferative and this is a feature of the disease, but it is not possible to clearly differentiate between an initial and subsequent infection based on histology. This study confirmed the findings of earlier work conducted in 1988 by the same group at the Moredun Research Institute in Edinburgh [49]. In this study 10 lambs were challenged again, two weeks after the initial lesions had completely resolved. All of these lambs also developed lesions. These histological studies confirm the cell-mediated response to infection.

The fact that the lambs in both studies were so easily re-infected raised questions about the role of the humoral response to infection and the level of immunity conferred by either natural or artificial exposure to the disease. The Moredun group had reported in 1987 that sheep that had been either naturally or experimentally infected with scabby mouth virus developed a detectable antibody response. Furthermore, sheep that were re-infected (or had pre-existing titres of virus specific antibody) developed a more rapid and greater antibody response than those sheep with no evidence of a pre-existing infection [59]. The group concluded serum antibody responses to this virus are of limited significance in overall protection and recovery from the disease and that "*it seems likely therefore, that recovery from the disease is the result of cell-mediated immune mechanisms*". This was consistent with earlier work by Buddle that showed that the passive transfer of colostrum containing antibody to the scabby mouth virus did not confer protection against the disease [60].

This conclusion remained unchallenged for some 10 years until a pivotal study reported by Lloyd in 2000 demonstrated that sheep without an antibody response were unable to clear the virus from their skin. This was demonstrated by using a lymphocyte subset depletion technique [61]. It was concluded that antibody must have a role in the final stages of the disease.

Over the past 10-15 years research on the scabby mouth virus has made a major contribution to the understanding of viral mechanisms of immune evasion [68] or 'viral subversion of the immune system' [69]. This research has been led by researchers at the Moredun Research Institute in Scotland [22, 32-36, 62, 71, 75-77].

The *parapox* viruses have developed extraordinary evasion strategies through the acquisition (pirating) of genes from their host at some earlier time in the evolution of the disease. These 'stolen' genes are expressed in order to block or subvert the key molecular elements of the host anti-virus immune and inflammatory response [35]. They benefit the virus by nullifying or stalling the host's response for sufficient time to allow the virus to replicate and become established. The virus also possesses factors that encourage the proliferation of epithelial cells and/or hold epithelial cells in a suspended state (suspended apoptosis). Both these mechanisms provide the virus with a greater amount tissue in which to replicate and establish [70].

Knowledge and understanding of these factors has been greatly enhanced by the ability to map the virus's genome. This has enabled scientists to identify the exact polypeptides involved and hypothesise how they may modify the immune response of the animal. The mode of action of these polypeptides falls under the following broad headings:

- Factors that interfere with interferons.
- Factors that inhibit or modulate cytokines and chemokines [68].
- Factors that stimulate endothelial cells.
- Factors which are immuno-suppressive via a mechanism that is not yet well understood.

Factors that interfere with interferons

Interferons were discovered because of their ability to protect cells from viral infection. The scabby mouth virus possesses the ovine interferon resistance protein (OVIFNR) [33], which is similar to a factor (E3L) found in the vaccinia virus [71]. It acts to inhibit an interferon induced PKR kinase pathway [35]. This pathway acts to shutdown the protein synthesis involved in viral replication. Inhibition of this pathway leads to sustained protein synthesis and the completion of the virus life cycle. The interferon-induced pathway is normally activated as part of the anti-viral state within infected cells [36, 72]. The same pathway is also involved in apoptosis so that OVIFNR will also inhibit programmed cell death [35] . Interferons are important in the immune responses to viral infection [36, 73], and it is suggested that the scabby mouth infection is only eliminated once interferon levels overwhelm the production of this immuno-modulatory factor [62].

Factors that inhibit or modulate cytokines and chemokines

The importance of viral homologues of cytokines and their role in *parapox* infections was reported in 1995 [31], and the factor involved was sequenced as early as 1994 [74]. Cytokines are part of the initial inflammatory response and are responsible for some of the vascular changes associated with inflammation as well as the recruitment and activation of neutrophils, monocytes and lymphocytes at the site of inflammation.

The scabby mouth virus produces a viral homologue of interleukin-10 (IL-10) [75]. This homologue is one of the factors that have been pirated from the host at some earlier time. The viral homologue of IL-10 is for the most part identical to the host's ovine IL-10 but differs over an important section [34, 75]. This slightly modifies its activity so that it has only an immuno-suppressive capability rather than the activity of the host interleukin, which has both immuno-suppressive and immuno-stimulatory capabilities. The viral homologue of IL-10 is thought to act as an immunosuppressive virokine that down regulates the T-cell mediated immune response, and inhibits cytokine synthesis by the host [33]. Accordingly it can be seen that not only has the virus pirated the factor, but it has also modified it slightly for its own benefit.

It is thought that in primary infections the virus replicates and produces an abundance of these immuno-suppressive proteins, and that it takes time for the host to mount an immune response sufficient to overwhelm these [62]. This was confirmed by an experiment that prepared a viral strain that did not possess the IL-10 homologue. In this experiment the disease followed a similar course to that of a re-infection (i.e. less severe lesions and earlier resolution) [36]. This prompted researchers to look at the possibility of using this factor as the basis of a vaccine [62]. The obvious obstacle was that for this to be effective, the host would have to mount an immune response toward a factor that is essentially the same as its own. Consequently the host may not recognise the factor as foreign and mount an immune response.

Factors that stimulate endothelial cells

The scabby mouth virus also produces a viral homologue of vascular endothelial growth factor, vVEGF. vVEGF stimulates keratinocyte proliferation and inhibits apoptosis. This results in a much greater number of available cells suitable for viral replication. As such, it is not an immuno-modulator but more of a virulence factor [36]. As with the interleukin gene, scientists have experimented with recombinant viruses that lack the vVEGF gene and have found that the experimental infection leads to smaller lesions that resolve quicker [78]. Again this has prompted researchers to look at this factor as the basis for a vaccine [36].

Factors which are immuno-suppressive via a mechanism that is not yet well understood

The full sequencing of the scabby mouth virus genome has revealed a fourth immuno-modulatory polypeptide named GIF**.** This factor acts to inhibit the viral granulocyte/macrophage colony stimulating factor stimulatory factor (GM-CSF). The function of this protein in scabby mouth virus infection is less known, but it is consistent with what is known about the other immuno-suppressive factors described above. This factor is expressed later in the viral life cycle.

It is clear from the studies that have been undertaken that there is a dynamic interaction between the scabby mouth virus with its immuno-modulatory proteins and the host's immune response. Haig (2002) describes it as "*a war of critical mass*" in which the virus is able to replicate for a period of time before the host can mount a sufficient immune response. This view recognises the proliferative factor that provides a greater number of proliferating cells and encourages the replication of the virus. It concludes that "*in the face of a large quantity of virus immuno-modulatory and virulence proteins, the host immune response, although adequately stimulated is unable to clear the virus until the host produces more immune effector molecules than the virus can block or subvert*“ [62].

In summary infection with scabby mouth virus initially produces a cell-mediated response as described above, but a humoral response is later required to overwhelm and eliminate the virus. Evasive mechanisms are involved that hold the immune response at bay and give the virus time to replicate and become established. Some of these immuno-modulatory factors are peculiar to the virus, whereas others are actually factors that occur naturally in the host, having been hijacked from the host at some earlier time [35]. These evasive mechanisms explain why sheep can be repeatedly infected with the virus and develop clinical signs of disease. Subsequent infection leads to milder symptoms and quicker recovery, linked to an anamnestic response that involves both cell mediated and humoral mechanisms.

4.2.6 Control

Pfizer (formerly CSL) produce the only scabby mouth vaccine used in Australia (Scabigard ™) [63]. The vaccine includes an virulent field strain live strain of the virus that is ‘scratched’ into the axilla region of sheep or under the tail in goats and fat tailed sheep to produce a mild ‘controlled’ form of the disease at a protected site. The vaccine is administered using a special applicator that scarifies the skin prior to applying the live virus.

In some countries, the demand for the vaccine can fluctuate and is influenced by regional outbreaks of the disease. Matching supply to demand can be challenging for the vaccine manufacturers. The UK is currently going through a period of supply shortage (July 2011). Demand in Australia is more constant since the vaccine is used preventatively and has strong links to marketing protocols.

Administering the vaccine requires some skill and vaccination technique is important for the vaccine to be effective. Successful vaccination is evidenced by a ‘take’ at the site of vaccination. The ‘take’ consists of a more or less continuous line of pustules along the track of the scratch.

These should be visible between 4 to 7 days after vaccination. These pustules turn into scabs and these drop off in about 2 to 4 weeks. The vaccine suppliers claim that immunity develops in about 2 weeks [63]. The vaccine suppliers also claim that failure to 'take' may be due to poor vaccination techniques, improper handling of vaccine resulting in loss of potency, or because the sheep are already immune from previous vaccination or infection [64]. When a take has not occurred, the vaccine supplier recommends that re-vaccination be considered (www.pfizeranimalhealth.com.au).

Neither the vaccine nor previous exposure to natural infection, as described above, provide lifelong protection against re-infection. Re-infection after vaccination usually results in clinical disease of reduced severity and duration. [7] In this form (i.e. reduced severity and duration of clinical disease), the vaccine provides 12 months protection against re-infection (www.pfizeranimalhealth.com.au).

Trials with the vaccine were conducted by Higgs, with the first trial conducted in 1992. A disease prevalence of 13% in controls and 1.6 % in vaccinated sheep was recorded. The study was undertaken in Australia under simulated shipping conditions and involved 2,640 sheep from 25 properties. The study involved only adult sheep (2 tooth hoggets). The vaccination was administered 16-21 days prior to delivery to the feedlot. These results are shown in Table 7.

Table 7. Vaccination trial (Higgs 1992) [9]

	Vaccination at marking	Vaccination well prior to delivery to assembly depot	Vaccination just prior to delivery to assembly depot	Prevalence (simulated on board conditions prior to discharge)
Treatment		☐		1.6%
Controls	–	–	–	13%

The 'scratch to catch the market' campaign was part of an overall scabby mouth awareness campaign that included a number of trials aimed at determining the efficacy of vaccination [15, 16.] The campaign was an initiative of MLA and the W.A. Department of Agriculture. The trials evaluated a number of protocol options and built on the work of Higgs. They were conducted from late 1997 through to early 2000. At the same time, the Saudi Livestock Export Program [10-14] was developed in a bid to re-open the trade to Saudi Arabia. The trials monitored sheep through the live export supply chain, and prevalence was determined on board the vessels prior to discharge.

The initial studies, late in 1997, showed a disease prevalence of 9.2% and 6.5% in lambs vaccinated at marking compared to 41.2% in the unvaccinated controls. The level seen in unvaccinated lambs is consistent with the anecdotal statements made by Buchanan.

Further trials to evaluate the efficacy of a second vaccination given on entry to the feedlot were conducted in 1998. The prevalence of scabby mouth in the sheep that received two vaccinations (marking and on entry to the feedlot) was reduced to only 2.9% compared to 8% in the sheep that had only received the one vaccination at marking. This trial involved about 2,000 sheep.

The trial was repeated with slightly different results. The sheep that received two vaccinations had a disease prevalence of 2.3% on arrival compared to only 2.2% in the sheep that had only received one vaccination at marking. The trial involved less than 2,000 sheep, although there were 23 farm groups involved.

A further component of this trial compared unvaccinated lambs to lambs that had received just the one vaccination on entry to the feedlot. The vaccinated sheep had a disease prevalence of

3.2% compared to 9.8% in the controls. Again there was only a small number of sheep involved despite the number of farm groups.

Further trial work continued. It was acknowledged that ideally, vaccination against scabby mouth should be given at least 14 days before any anticipated challenge to allow sufficient time for immunity to develop before sheep were delivered to the feedlot. A trial was designed to evaluate this strategy. The trial showed a disease prevalence of 0.3% in the sheep that were vaccinated 4-11 days prior to delivery to the feedlot compared to 1.9% in the group that were vaccinated within 24 hours of delivery and 12.1% in the control group as shown in table 8. None of these sheep had been vaccinated previously. Again the study involved a relatively small number of 800 sheep.

The final study in the series of experiments conducted by MLA and the Western Australian Department of Agriculture examined vaccination technique. This inferred that vaccination technique had been implicated in those cases where vaccination failure had been observed. The carefully vaccinated sheep had a disease prevalence of 3.9% on arrival in the Middle East. The unvaccinated sheep had a prevalence of 5.65%. These results are summarised in Table 8.

Table 8. Vaccination trials (Norris 1997, 1998 & 2000) [10-14]

	Vaccination at marking	Vaccination well prior to delivery to assembly depot	Vaccination just prior to delivery to assembly depot	Prevalence (on arrival in the Middle East)
1997				
Treatment	☐	–	–	9.2%
Treatment	☐	–	–	6.5%
Controls	–	–	–	41.2%
1998				
Treatment	☐	–	☐	2.9%
Control	☐	–	–	8%
1998				
Treatment	☐	–	☐	2.3%
Control	☐	–	–	2.2%
1998				
Treatment	–	–	☐	3.2%
Controls	–	–	–	9.8%
1998				
Treatment	–	☐	–	0.3%
Treatment (II)	–	–	☐	1.9%
Controls	–	–	–	12.1%
2000				
Treatment (careful vaccination)	–	–	☐	3.9%
Control	–	–	–	5.6%

Mercante (2008) [82] describes the experimental use of an virulent field strain live vaccine, administered intramuscularly. The results of field trails indicate that it may have the potential to be developed into a commercial vaccine.

The literature contains several papers that recommend methods to disinfect sheds and premises. This has application in the live export trade, since many sheep are housed in covered sheds during their assembly period, 7 to 10 days prior to the loading of the vessel. Several products are promoted as being effective against the scabby mouth virus. These include 3% iodophor solution (FAM) [86] and 1% formaldehyde [87]. Hypochlorite is recommended by the OIE (World Organisation for Animal Health) as an effective treatment against all the pox viruses. The recommendation states that surfaces must first be thoroughly cleaned since the product is rapidly inactivated.

Gallina (2010) evaluated several products (all of which were quaternary ammonium compounds) in an experimental situation [87]. These products, Lysoform casa, Biocidal ZF and sodium hypochlorite were all found to be effective. Sodium hypochlorite was found to be corrosive to farm buildings if applied liberally, whereas the other products had better material compatibility [87]. Ethanol was also tested and found to be ineffective.

These experiments suggest that disinfection of premises is a realistic option at the commercial level. The products need to be evaluated in terms of effectiveness and cost.

4.2.7 Treatment

There is no universally agreed treatment for the disease [1]. Suggested treatments generally address secondary infections and are unlikely to affect either the course or duration of the disease. The use of vaccination in the face of a disease outbreak [1] represents a real option. If the virus has mechanisms that overwhelm the sheep's initial immune response, then the sooner an animal is exposed to the virus, the sooner the sheep will be in a position to overwhelm the disease. If the disease is considered in terms of an epidemic, it may take some time before all the sheep in a mob are challenged through natural exposure. Vaccination may hasten recovery and/or minimize the extent of the lesions. Ideally, of course, sheep should be vaccinated at least 14-21 days prior to any anticipated challenge.

The disease is self-limiting and healing occurs over a period of 14-28 days. Treatments that involve repeated identification and handling of sheep may be counterproductive due to the stress involved; however there may be situations where the individual treatment of sheep is indicated. Apart from addressing the obvious secondary infections, a treatment involving anti-nucleoside phosphonates has been proposed. The product, Cidofovir, has also been shown to result in milder lesions that resolve more quickly [30]. The product is applied as a cream (1% w/v) for four consecutive days. Furthermore, the scabs of the treated animals contained significantly lower amounts of viable virus and less contamination of the environment. The same product (cidofovir) has been combined with sucralfate (a product with wound healing properties) so that it can be applied as a spray [30]. It should be noted that Cidofovir is not registered for use in any animal species in Australia and that there are likely to be significant regulatory hurdles to its registration for use in sheep.

Options to treat secondary infections include systemic antibiotics [45, 85], topical antibiotics and more astringent treatment such as iodine or methylated spirits aimed at drying out the lesions.

4.2.8 Zoonoses

Scabby mouth virus is a zoonotic pathogen and is an occupational hazard to those who handle sheep and goats. Infection is seen most often in meatworkers and shearers. The infection appears as discrete lesions usually on the hands [2] of meatworkers, but may be found in the under arm or armpit area of shearers that are shearing infected sheep (figure 9). Sometimes the infection is accompanied by a low grade fever [30].

The disease is of concern to slaughtermen in the Middle East, particularly during the festival of sacrifice. Many of the slaughtermen are Turkish and travel throughout the Middle East specifically to assist in the religious festivities [88]. It is also seen in individuals who are not occupationally exposed. Uzel (2005) points out that the "uncontrolled " slaughtering of animals by non-professionals can lead to cases of the disease and that these cases may be commonly misdiagnosed [88]. Scabby mouth should be considered in the differential diagnosis of hand lesions of people exposed to sheep or infected premises to prevent over treatment and complications.

Figure 9. 'Orf' on a human hand

Source – Moredun Institute

4.3 Discussion

The unique features of the scabby mouth virus have been described in the literature review. The virus produces immuno-modulatory factors that suppress the host's immune response. This enables the virus to become established in an animal that might otherwise be considered immune. The mechanisms involved are well understood within the scientific community.

There is a significant gap between the level of understanding within the scientific community compared to that demonstrated by the agricultural community. Industry misconceptions exist. Formal industry consultation conducted as part of the current review showed that few industry participants are aware of the immune evasion strategies of the virus. The relatively common use of the word 'booster' when describing the second vaccination in either on-farm or industry disease prevention programs suggests that the vaccine is viewed in a similar way to other industry vaccines and that the immune evasion strategies of the virus have been overlooked.

These misconceptions are not surprising since the major industry circulars also claim varying expected length of protection from re-infection after vaccination. The DPI Vic factsheet on Scabby Mouth AG1015 (revised July 2007) [65] states, "*animals that recover from scabby mouth develop lifelong immunity*". The New South Wales Agriculture Agfacts A3.9.41 [66] on Scabby Mouth (revised March 2004) states "*sheep which recover from scabby mouth have a lifelong immunity against severe infection*". The West Australian Department of Agriculture Farmnote No. 17/2005 [67] however states that "*recovered animals develop immunity which is often long term provided that there is regular exposure to the virus*" and that " *vaccinated sheep are susceptible to re-infection but the disease is mild and short-lived in animals with previous immunity*".

This chapter looks specifically at how to apply the scientific knowledge about scabby mouth at the industry level. This is not as straightforward as it might initially seem. Inevitably, the disease prevention strategy will be compared to other strategies, particularly those that utilise vaccination. This was evident when undertaking industry consultation. Most industry participants viewed the disease in a similar way to other industry diseases such as enterotoxaemia (pulpy kidney) and discussion followed a similar path (e.g. the need for a 'booster' to lock in the immune response). Very few participants made reference to the fact that the current vaccine includes an virulent field strain live virus and even fewer made reference to the unique features of the disease. At another level, discussion falters due to confusing terminology and an imprecise definition of what constitutes immunity. This chapter considers these aspects to ensure that the industry adopts a disease prevention strategy that is both effective and rational.

Scabby mouth shares similarities and differences to other diseases. Exposure to the scabby mouth virus either through natural infection or by vaccination evokes an immunological response that is similar to any other infection (at least in the initial phases). The point of difference lies with the unique features of the virus that enable it to establish in the face of what is a normal immune response. This has implications for both the initial and subsequent infections and shapes the characteristics involved.

The clinical signs of scabby mouth in the initial infection are severe and involve extensive lesions on the lips, mouth and/or face. Recovery is protracted over a period of 21-35 days. The host launches a normal immune response, however aspects of this response are suppressed or modified by the immuno-modulatory factors produced by the virus. There is a delay before the immune response can escalate to the point at which it can overwhelm the immune-modulatory factors produced by the virus and eliminate the disease. The disease is highly contagious throughout the early stages of the disease and there is significant potential for the virus to infect premises via the detached scabs. The characteristics are summarised in Table 9.

Table 9. Characteristics of initial scabby mouth infection (natural exposure)

	Characteristics of initial scabby mouth infection
Clinical signs	Severe
Recovery	Protracted (21-35 days)
Immune response	Normal immune response, however the response is overwhelmed by the immuno-modulatory factors produced by the virus. There is a delay before the immune response can overcome the immune-modulatory factors produced by the virus and eliminate the infection.
Potential to infect other animals	Highly contagious
Potential to infect premises	Significant

The characteristics of subsequent infections can also be compared. This is where scabby mouth differs from many other diseases. In many other diseases, the anamnestic response prevents clinical disease and the infection will usually resolve with no or few clinical signs being evident. In many cases the infection will go unnoticed. In a subsequent scabby mouth infection, the anamnestic response is subverted by the immune-modulatory factors produced by the virus and the host is unable to quickly overwhelm and eliminate the virus. Consequently clinical signs are evident. The lesions contain live virus and have the capacity to cross infect other animals. There is also a significant potential that premises may be contaminated by direct contact or by the presence of scabs that are shed as part of the healing process.

The characteristics of a subsequent scabby mouth infection are outlined in Table 10. The clinical signs are less severe. The immune response is again subjugated by the immune-modulatory factors produced by the virus, but the host is better prepared to overwhelm and eliminate the infection. Consequently the recovery is less protracted. The unique features of the scabby mouth virus challenge the conventional perception of immunity held at the industry level where it is generally considered that an animal is immune if its immunological response prevents the re-establishment of clinical disease. In the case of scabby mouth, an animal can be immune and still develop clinical disease, even though "*the lesions are less severe and recover more quickly*".

Table 10. Characteristics of subsequent scabby mouth infection (natural exposure)

	Characteristics of subsequent scabby mouth infection
Clinical signs	Less severe
Recovery	Less protracted (14-21 days)
Immune response	Anemnestic response. The immune response is again subjugated by the immuno-modulatory factors produced by the virus, but the anamnestic mechanism leads to a quicker and more potent response. Consequently the immune response is delayed but not to the extent of the initial infection. Prior exposure does not prevent re-infection.
Potential to infect other animals	Highly contagious
Potential to infect premises	Significant

Another feature of scabby mouth is that epithelial damage is required for the disease to establish. This is clearly stated in the literature. This means that the introduction of disease into the live export supply chain may be of little consequence if sheep were to maintain intact epithelial surfaces in the mouth and on the lips. Anecdotal reports suggest that this does happen and that the disease can run its course in infected animals without involving other sheep. In other cases active spread is observed, suggesting that either 1) some level of epithelial damage is occurring within the mouth and lips of sheep under normal grazing and feeding conditions and/or 2) that the feedstuffs used in the live export chain are particularly abrasive and predispose sheep to virus infection.

In many cases, the literature indicates that the on-board and assembly situation provide ideal conditions for the spread of the disease [9]. Higgs refers to the crowding and the abrasive nature of the pellets used by the industry. On face value this would seem to be the case, but it should be noted that sheep are quite capable of eating pellets without abrading their mouths, and that despite their close proximity, spread does not necessarily occur.

The interactions discussed above have important implications for disease management and control, and pose many dilemmas in regards to how best use the available scabby mouth vaccine. As mentioned, the scabby mouth vaccine should not be confused with other industry vaccines that offer better protection from expression of clinical signs following re-infection. There are a number of considerations. Firstly the vaccination is dermal and requires considerable skill in the way it is administered. Secondly, it offers only partial protection by lessening the severity and hastening the recovery of lesions on re-infection. Thirdly, it has the capacity to introduce the virus onto farms that have no prior history of the disease. Fourthly, because the disease is relatively widespread, it is almost impossible to know the full history of exposure prior to vaccination. This makes it very difficult to judge the effectiveness of the vaccination at either the farm or industry level. There is no real way of determining the occurrence or magnitude of field challenges when they occur. On the strength of these considerations, Haig (2002) questions the rationality of many existing disease management and control strategies [34].

The characteristics of an initial scabby mouth vaccination are summarised in Table 11.

Table 11. Characteristics of initial scabby mouth vaccination

	Characteristics of initial scabby mouth vaccination
Clinical signs	Vaccination is evidenced by the presence of a 'take'. This represents a more or less continuous line of active infection.
Recovery	Protracted (21-35 days)
Immune response	Primary immune response to 'live' virus. Vaccination mirrors that of an active infection although lesions are smaller and confined to the limits of the scratch.
Potential to infect other animals	Contagious
Potential to infect premises	Significant

Saudi Arabia requires that sheep be vaccinated twice, once at marking and again at least five days prior to them being delivered to the assembly centre. This means that these sheep are probably in their most infectious state at the point of delivery to the assembly facility.

Furthermore, it is pertinent to point out that that the protocol requires that *"any sheep showing clinical signs of scabby mouth during inspection 24 hours prior to loading for export will be removed from the consignment"* [25]. In practice this means that sheep must show signs of clinical disease in the form of a 'take' but must not show signs of clinical disease in the form of lesions on the lips or mouth. This may be a pedantic point but it represents an extremely fine distinction. The characteristics of a second or subsequent scabby mouth vaccination are outlined in Table 9.

Protection against some diseases (i.e. enterotoxaemia) is strengthened if a booster vaccination is utilised to 'lock in' the anamnestic response. There is no such evidence in the case of scabby mouth. Any benefit from a second vaccination appears to be related to the time since the last vaccination. There is no scientific evidence to suggest that two vaccinations are better than one.

Up until now, many cases of vaccination failure may have been wrongly attributed to poor vaccination technique (including the applicator). A better understanding of the immunosuppressive capabilities of the virus suggests that this may not be the sole cause of vaccination failures. It is pertinent to note that the final trial undertaken by Norris examined vaccination technique. Despite the overall prevalence in this trial being low, it was noted that several lines within the carefully vaccinated sheep showed a high prevalence of the disease (10.5, 13.3 and 20%). It was concluded that "*factors other than vaccination technique*" were responsible for contributing to the high levels of scabby mouth. Accordingly, expectations of the vaccination's effectiveness should be modified in the light of a better understanding of the immuno-suppressive capabilities of the virus.

Table 12. Characteristics of subsequent scabby mouth vaccination

	Characteristics of subsequent scabby mouth vaccination
Clinical signs	Vaccination is evidenced by the presence of a 'take'. This represents a more or less continuous line of active infection.
Recovery	Less protracted (14-21 days)
Immune response	Anemnestic response. Vaccination mirrors that of an active infection although lesions are smaller and confined to the limits of the scratch. Prior vaccination (or exposure) does not appear to preclude the development of a 'take'. It is unclear as to whether a booster is required to 'lock in' the anamnestic response.
Potential to infect other animals	Contagious
Potential to infect premises	Significant

A final point of discussion stemming from the literature is the potential to develop a new industry vaccine that provides better protection against re-infection. MLA funded work on a new vaccine for scabby mouth in the early 1990s, but this was before the immuno-modulatory factors produced by the virus were described. Haig (2000) suggests that although existing vaccines will produce the correct type of antiviral immune response, complete immunity will not be delivered whilst the challenge virus produces the immuno-modulatory proteins [36, 62] and that "*the next generation of vaccines should also include protection against the virus's immuno-modulatory proteins*" [36]. Haig suggests that although the immune-modulatory proteins have host specific areas that allow the protein to interact with the host and suppress the immune response, they also have 'virus specific' peptide regions that could be amplified to produce a vaccination against these factors as well as the virus itself [36, 62].

The literature does not contain any evidence that this has been acted upon, although the article by Mercante (2008) [82], describes the experimental use of an virulent field strain live vaccine, administered intramuscularly. The results of field trails indicate that it may have the potential to develop into a commercial vaccine. An initial trial on a small number of sheep (two groups of 10 lambs and 10 adult sheep and a control of 5 lambs and 5 adult sheep) showed sheep to be resistant to re-infection after further challenge 30 days later. This was followed by a field trial involving 300 sheep that demonstrated similar results. This is a promising finding.

This discussion highlights the more contentious issues that have emerged when attempting to apply the findings of the literature review to the industry situation. The major points are summarized below.

4.4 Summary

The major points stemming from the literature review can be summarized as follows:

- Scabby mouth has been prominent as a cause of disruption of the trade of live sheep to Saudi Arabia over the last 20-25 years.
- The scabby mouth virus has been studied extensively over the past 10-15 years and the level of understanding of the disease within the scientific community is high.
- This level of understanding has been slow to filter through to the farm (or industry) level where misconceptions still exist.
- The scabby mouth virus has unique features that enable it to suppress the host's immune response. The virus produces immuno-modulatory factors that allow the virus to become established, resulting in clinical disease in an animal that would otherwise be considered immune.
- The initial infection is characterised by a normal immune response, however the immune response is subjugated by the immuno-modulatory factors produced by the virus. There is a delay before the immune response has the critical mass to overwhelm and eliminate the infection.
- A subsequent infection is characterised by a normal anemnestic response, however the immune response is again subjugated by the immuno-modulatory factors produced by the virus. The anamnestic mechanism leads to a quicker and more potent response. Consequently the immune response is delayed but not to the extent of the initial infection. Prior exposure does not prevent re-infection.
- In this regard, scabby mouth is different to other diseases in which the anemnestic response leads to a rapid and more potent humoral response that usually overwhelms and eliminates the infection before clinical signs become evident.
- Terminology in regards to immunity can be confusing. It is generally considered that an animal is immune if its immunological response prevents the re-establishment of clinical disease. However, with scabby mouth clinical disease can re-establish in an immune animal, however "*the lesions are less severe and recover more quickly*".
- The disease is highly contagious throughout the early stages of the disease in both the initial and subsequent infections. There is significant potential for the virus to infect other animals and/or contaminate premises via detached scabs.
- Damage to the intact epithelium of the mouth or lips, is required for the disease to become established.
- The current industry vaccine Scabigard^{TM}, includes an virulent field strain live virus. The lesions produced by vaccination are therefore characterised in a similar way to the initial and subsequent infection de*scribed above.*
- *The vaccination is evidenced by a 'ta*ke'. This represents a more or less continuous line of active infection that is seen along the limits of the scratch. Lesions at the vaccination site mirror that of an active initial infection except that they are restricted to the margins of the scratch.
- Vaccination does not prevent animals developing clinical signs of the disease on subsequent infection (as acknowledged by the vaccine manufacturers).
- The effectiveness of the vaccine is defined as "*the lesions involved in subsequent infections are less severe and that the disease resolves more quickly"*.
- Many cases of apparent vaccine failure may reflect the immune-suppressive capabilities of the virus rather than faulty vaccination technique or non-compliance.
- The Saudi protocol requires that sheep be vaccinated twice, once at marking and again at least five days prior to them being delivered to the assembly centre.
- As a result, sheep arriving at the assembly facility are probably in their most infectious state at the point of delivery.

- Furthermore, the Saudi protocol also requires that *"any sheep showing "clinical signs" of scabby mouth during inspection 24 hours prior to loading for export will be removed from the consignment".* The 'take' is an indication of active infection. In practice this means that sheep must show signs of clinical disease in the form of a 'take' but must not show signs of clinical disease in the form of lesions on the lips or mouth. This represents an extremely fine distinction.
- There is no scientific evidence to suggest that two vaccinations are better than one, (i.e. that a 'booster' vaccination is required to lock in an anamnestic response).
- The ideal time (from a industry point of view) to vaccinate sheep with the current live vaccine would be 21 days prior to delivery to the assembly facility. It is acknowledged that this provides a logistical challenge with the current purchasing arrangements and may be impractical under normal commercial operations.
- The development of an effective 'sterile' vaccine (preferably delivered either subcutaneously or intramuscularly) would have immediate application within the industry. MLA has previously invested in such research, without success. However, this was before the immune-modulatory factors produced by the virus were described.

5 Industry consultation

5.1 Vaccine sales and usage

Vaccine sales were obtained from contacts within Pfizer Animal Health. Sales have waned over recent years, but are in accord with a reducing sheep population. There are notable differences in usage between Western Australia and the Eastern States.

The national vaccine usage is summarized below. These figures parallel the estimates of the size of the sheep flock provided by MLA (fast facts). The national sales of Scabigard vaccine have fallen from 13.3 million doses in 1995 to 8.8 million doses in 2009. These are displayed in Table 13. During the same period in question the national flock size has reduced from an estimated 115 million to 77 million.

Table 13. National sales of Scabigard vaccine

Scabigard	Year	Vials	Doses
	2005	53,194	13,298,500
	2006	53,957	13,489,250
	2007	42,823	10,705,750
	2008	38,516	9,629,000
	2009	35,323	8,830,750

*Source: Mike Dandy - Pfizer 2011

The same trends can be seen in each of the States, however Western Australia has by far the greatest level of vaccination in relation to the size of its sheep flock. This reflects the marketing opportunities associated with the Saudi Arabian live export market and a greater focus on live exports generally. In Western Australia the sales of scabby mouth vaccine have fallen from 7.1 million doses in 2005 to 4.3 million doses in 2009 as shown in Table 14.

Table 14. Sales of Scabigard vaccine in Western Australia

Scabigard	Year	Vials	Doses
	2005	28,529	7,132,250
	2006	30,972	7,743,000
	2007	22,742	5,685,500
	2008	18,376	4,594,000
	2009	17,366	4,341,500

*Source: Pfizer - Mike Dandy 2011

In 2009, of the 4.3 million doses used in Western Australia, close to one million doses would have been required for the second vaccination as part of the protocol requirements for the Saudi market (based on the number of sheep exported). The same number of sheep would need to have been vaccinated at marking. This would leave about 2.3 million doses that have been used as part of disease management strategies. Industry consultation suggests that nearly all these doses would have been used on lambs at marking. Some of this would be to address disease concerns, but the balance would be ‘just in case’ to ensure marketing options.

The flock size in Western Australia reduced from an estimated 30 million in 2005 to 17.7 million in 2009. As a very rough rule of thumb it could be calculated that approximately 20% of the Western Australian sheep flock are vaccinated on an annual basis. This would suggest that a very large percentage of lambs are vaccinated at marking given a normal age structure with a relatively young age of turnoff.

The vaccination of late pregnant ewes aimed at imparting immunity to lambs via the colostrum is discussed in the literature but appears to be rarely practiced by Australian farmers.

Compared to Western Australia, the number of doses sold in Victoria is relatively small. The estimated flock size is similar to that of Western Australia but the number of doses sold in 2009 was low, only 700,000 doses as shown in Table 15. This represents only about 4% of the sheep flock (as a rough rule of thumb). In this State, it is likely that only farmers who perceive they have a scabby mouth problem undertake vaccination.

Consultation with producers and other industry personnel in Victoria revealed that there is some resistance toward vaccination. Some sheep producers had geared up to 'scratch to catch the market' only to find that commercial pressures mostly related to price meant that exporters to Saudi avoided the Eastern States. To date, there is virtually no market incentive to vaccinate sheep at marking since very few Saudi consignments have been sourced from the Eastern States. This is not to say that they would not quickly resume the practice of vaccinating lambs if there were sufficient incentive. The flock size in Victoria reduced from an estimated 30 million in 2005 to 17.7 million in 2009.

Table 15. Sales of Scabigard vaccine in Victoria.

Scabigard	**Year**	**Vials**	**Doses**
	2005	5,449	1,362,250
	2006	3,468	867,000
	2007	3,204	801,000
	2008	3,302	825,000
	2009	2,807	701,750

*Source: Pfizer - Mike Dandy 2011

The practices vary in the other states. New South Wales has the largest sheep population but vaccinated a little over 2 million sheep in 2009. This represents only 9% of the estimated flock of 26.4 million. Very few sheep are exported live from this state. South Australia vaccinated about 1.2 million sheep in 2009. This represents about 12% of the estimated flock of 10 million (as a rough rule of thumb).

These vaccine sales are consistent with the results of a national survey conducted by MLA. This survey found that the 74% of Western Australian producers vaccinated their lambs at marking. This was in contrast to sheep producers in New South Wales, Victoria and Queensland who did not vaccinate against scabby mouth at all (76%, 89% and 91% respectively). These figures were also related to the extent to which the producers marketed their sheep into the live export market.

5.2 On farm management practices

It is difficult to determine an accurate prevalence of on farm scabby mouth from industry consultation. A more formal approach is required. On farm studies have been conducted and are cited in the literature review. In these studies, the proportion of farms with evidence of scabby mouth in weaner sheep was 24% [9-16]. Industry consultation would suggest that the current level is much lower. There are claims that the lower prevalence is due to the success of the 'scratch to catch the market' campaign and the widespread practice of vaccinating lambs at marking. However, the same low prevalence is claimed in the Eastern States where vaccination at marking is not commonplace. The findings of this study showed that the current levels of scabby mouth in sheep sourced for the live export process (from the Eastern States) are also low.

Informal consultation with a small number of farmers indicated that scabby mouth is viewed as a disease of little commercial significance. Many farmers reported that their farms were free of the disease and that they had never seen sheep with scabby mouth within their farm boundaries. Farmers that claimed to have the seen the disease generally allowed the disease to run its course. The disease was only a problem when it interfered with marketing options.

Many farmers that claimed to be free of the disease expressed concern about using a live virus vaccine and were apprehensive about the possibility of introducing the disease onto the property. These farmers pointed out that if the use a live virus on lambs at marking resulted in clinical disease (particularly on the lips), that this could very likely spread to the udders of the ewes and result in the whole flock being affected. Other farmers considered vaccination at marking to be an effective disease management procedure.

A disease free status is required for all sheep entering the live export assembly facilities. The onus is therefore on the buyer and producer to ensure that sheep with scabby mouth are not delivered to the feedlot. Furthermore it is a requirement that sheep destined for Saudi Arabia are vaccinated at marking. The onus is again on the buyer and producer to ensure that this has been undertaken. Consultation with producers indicated that this was well understood.

Most assembly facilities have an effective inspection system on receival. Discussion with feedlot managers indicated that most mobs showing scabby mouth are rejected outright and returned to the farmer. Occasionally cases are marked and removed at the draft. The management of these cases varies but feedlot managers have a good sense of the level of infectivity of these animals and will manage them accordingly.

Rejects are part of the carryover involved in many consignments in Western Australia and, to a lesser extent, in Eastern Australia. The re-inclusion of these sheep can be a contentious issue. Woolly sheep that arrive at the assembly facility to be shorn are not inspected as thoroughly on receival since they are generally assessed more carefully after shearing. Most assembly facilities have a system of recording scabby mouth cases with linkage back to the producer.

A strong message resonating from the industry was the difficulty of vaccinating large numbers of sheep at very short notice. The repeated mustering and handling involved to administer the vaccination 5 days prior to delivery was also noted. The timing will often clash with other activities and this creates pressures, not only to ensure that the vaccination is done properly, but also to ensure that the timing of the vaccination falls outside the designated period prior to export. There was strong anecdotal evidence that the vaccination can in some cases cause an outbreak of the clinical disease.

5.3 Summary of industry consultation

The major points stemming from industry consultation can be summarised as follow:

- There are significant differences between States in regards to on-farm vaccination.
- The majority of producers in Western Australia vaccinate lambs at marking (74%) whereas only a small proportion of producers in the Eastern States vaccinate lambs (10-25%).
- Vaccine sales in each of the States reflect the on-farm management practices.
- This reflects the differences in marketing options and marketing strategies between States.
- Vaccine sales in Western Australia include the doses required to meet the Saudi protocol for sheep travelling to Saudi Arabia (i.e. second vaccination prior to delivery).
- Vaccine sales have declined in direct proportion to the reduction in the flock size in each of the States.
- Disease prevention in the Eastern States is made easier by an interrupted throughput and the ability to empty the assembly facility between consignments (‘all in - all out’).
- Disease prevention in Western Australia is made more difficult by a greater throughput and a larger number of carryover sheep. It is also made more difficult due to the extensive use of sheds (that are known to harbour the virus for a longer period than open paddocks).
- The disease prevention strategy in the Eastern States has a focus on excluding the disease from the live export supply chain.
- The disease prevention strategy in Western Australia relies to a greater extent on vaccination and immunity.
- The use of designated inspectors to inspect sheep on arrival at the assembly facility is a key element of the disease prevention strategy. This provides a strong feedback signal to producers contemplating the delivery of infected sheep. Independent inspectors undertake the most effective inspection.
- There is anecdotal evidence to suggest that the use of the live vaccine immediately p*rior to the delivery of sheep to assembly facilities* may be responsible for introducing the virus into the facilities and infecting sheep destined for other markets (i.e. non Saudi destinations).
- There is a trend toward younger sheep in export consignments. As the age of sheep being exported to Saudi Arabia becomes younger, the time between marking and delivery to the assembly facility is shortened correspondingly.
- The requirement to re-muster sheep to administer the second vaccination, five days prior to delivery to the assembly facility represents a significant commercial and logistical impost on the industry.
- The reduced flock size is likely to tighten the supply of sheep, particularly those eligible to meet the Saudi market requirements. It is likely that broader attempts will be made to source sheep that meet the Saudi market requirements. This may include sourcing sheep from the Eastern States in the near future.
- Anecdotal reports suggest that the prevalence of scabby mouth within the Australian sheep flock has reduced considerably since earlier estimations conducted in 2000.

6 Determination of prevalence

6.1 Pilot voyages

Two pilot voyages were undertaken to evaluate inspection methods and test data recording management systems. The pilot voyages identified that although each assembly facility collects essentially the same information; there are subtle differences between receival and load out procedures. There were differences in the data collecting systems; some utilising spread sheet programs (with or without facilitating macros), and others utilise data base programs to manage the data. To cater for such differences in was necessary to monitor a number of consignments in a range of situations to assess the full spectrum of possibilities that might be encountered. Three consignments were monitored as part of the pilot voyages.

The first consignment included approximately 45,000 sheep sourced from Victoria and South Australia. The sheep were assembled in Portland. There were some sheep in the feedlot prior to the receival dates (2nd and 3rd February 2010), but the balance was delivered over a two-day period. The consignment was managed on an all-in all-out basis. Inspection procedures were undertaken diligently as part of a normal inspection procedure.

The second consignment included approximately 35,000 sheep loaded at Fremantle (on the same vessel and voyage as the first consignment). It was possible to resource a presence at receival and load out for these sheep. Some on board data was collected to rehearse inspection procedures. The sheep were discharged at three ports in the Persian Gulf.

A third consignment that included approximately 40,000 sheep sourced from Western Australia was also scrutinised. This consignment included several large lines of lambs. The sheep were received over a protracted period, with two main days of receival (February 2010). It was only possible to monitor the sheep that were received on these two days. The voyage duration for the sheep on this voyage was 35 days.

Investigations on both these voyages provided enough information to determine a method by which to undertake the experimental voyages:

- As far as possible, inspection procedures on receival should be ‘piggy backed’ on top of existing industry procedures.

- Consignment size should be restricted to no more than 35,000 to 40,000 sheep (unless additional resources are engaged).

- Where possible, existing inspection procedures should be subjected to a double check to enable data to be validated independently by the research team members.

- Only single tiered vessel should be utilized for the study (to allow proper scrutiny of sheep on board).

- A disease mapping approach prior to arrival was considered best suited to determine the prevalence on board livestock vessels. This should involve an initial inspection to establish the presence or absence of disease in a mob, followed by a more detailed inspection to determine prevalence.

The option to collect data independently was explored. Independent collection of data would have required considerable additional resources and it would not have been possible to cater to all deliveries or guarantee the integrity of the consignments. The independent collection of data was not considered to be viable option.

Data collection templates were developed to cater for the range of data collection systems involved. This enabled data to be transferred in the most effective way, with minimal duplication of data entry.

6.2 Experimental voyages

6.2.1 Voyage I

The first experimental voyage monitored two discrete consignments with sheep sourced from both Victoria and Western Australia. Consignment one, involving approximately 38,000 sheep was assembled at the Kobo feedlot in Portland (May 2010). No scabby mouth cases were observed on receival, and only two suspect cases were observed (and removed) at load out. The consignment was destined for the Persian Gulf (Bahrain, Kuwait and United Arab Emirates). The sheep were not subjected to the Saudi vaccination protocol.

The vessel was topped up in Fremantle with a further 33,000 sheep. These sheep were assembled in the Peel feedlot (June 2010). Nine cases of scabby mouth were identified (and removed) at receival. A further 32 cases of scabby mouth were identified (and removed) at load out. This consignment was also destined for the Persian Gulf. The sheep were not subjected to the Saudi vaccination protocol.

The voyage was completed in 26 days. On board inspections took place 3 to 5 days prior to arrival at the first port. The on board results from this voyage are summarised in Table 16 and 17 respectively. The distribution of the disease is shown in a disease map (see Appendix).

Table 16. On board prevalence of scabby mouth in each category - Consignment one

	Total	Cases	Prevalence	Confidence LL*	Confidence UL*
A Wether	1,680	0	0.00%	0.00%	0.22%
B Wether	12,845	13	0.10%	0.05%	0.17%
C Wether	790	0	0.00%	0.00%	0.47%
A Young W	8,807	0	0.00%	0.00%	0.04%
B Young W	9,844	4	0.04%	0.01%	0.10%
Hoggets	2,240	1	0.04%	0.00%	0.25%
Horned Rams	113	0	0.00%	0.00%	3.21%
Polled Rams	92	0	0.00%	0.00%	3.95%
Ram Hoggets	107	3	2.80%	0.58%	7.98%
Total	**36,518**	**21**	**0.06%**	**0.04%**	**0.09%**

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

Table 17. On board prevalence of scabby mouth in each category - Consignment two

	Total	Cases	Prevalence (%)	Confidence LL*	Confidence UL*
A Wether	1,302	5	0.38%	0.12%	0.89%
B Wether	2,853	12	0.42%	0.22%	0.73%
C Sp. Wether	2,873	6	0.21%	0.08%	0.45%
WT Young W	6,681	63	0.94%	0.73%	1.20%
A Ewes	2,750	6	0.22%	0.08%	0.47%
B Ewes	1,002	5	0.50%	0.16%	1.16%
A MW Lamb	5,155	40	0.78%	0.55%	1.06%
B MW Lamb	2,486	26	1.05%	0.68%	1.53%
A XB Lamb	4,945	25	0.51%	0.33%	0.75%
Horned Rams	182	0	0.00%	0.00%	2.01%
Polled Rams	207	0	0.00%	0.00%	1.77%
Ram Hoggets	765	3	0.39%	0.08%	1.14%
Lamb Rams	1,498	7	0.47%	0.19%	0.96%
Dam. R Lmbs	315	2	0.63%	0.08%	2.27%
Dam. E Lmbs	642	2	0.31%	0.04%	1.12%
Mixed Lambs	552	4	0.72%	0.20%	1.84%
Store Wethers	249	0	0.00%	0.00%	1.47%
Total	**34,208**	**206**	**0.60%**	**0.52%**	**0.69%**

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

6.2.2 Voyage II

The second experimental voyage also monitored two discrete consignments (consignments three and four). Both consignments were sourced from Western Australia. Consignment three, involving 51,000 sheep was assembled at the La Bergerie feedlot over a two-day period (July 2010). Sixteen scabby mouth cases were identified on receival, and 65 cases identified at load out (all of which were removed). Research staff collected severity score information. These sheep were subjected to the Saudi vaccination protocol.

Consignment four consisted of nearly 25,000 sheep and was assembled at the Peel feedlot (July 2010). Thirty seven cases of scabby mouth were identified and removed at receival and a further 65 cases were identified and removed from the consignment at load out. Both consignments were destined for Saudi Arabia (Jeddah). Accordingly both consignments were subjected to the Saudi protocol.

The voyage was completed in 13 days. On board inspections took place 3 to 5 days prior to arrival at the first port. Very few cases were observed in either consignment and any cases early in the voyage had resolved prior to discharge (see Table 18 and 19).

Table 18. On board prevalence of scabby mouth in each category - Consignment three

	Total	Cases	Prevalence (%)	Confidence LL*	Confidence UL*
A Wether	1,664	0	0.00%	0.00%	0.22%
B Wether	3,450	0	0.00%	0.00%	0.11%
C Wether	2,062	0	0.00%	0.00%	0.18%
A Y Wether	3,911	0	0.00%	0.00%	0.09%
B Y Wether	18,177	0	0.00%	0.00%	0.02%
C Y Wether	10,974	0	0.00%	0.00%	0.03%
RL	2,061	0	0.00%	0.00%	0.18%
A XBL	3,359	0	0.00%	0.00%	0.11%
Ewe	1,028	0	0.00%	0.00%	0.36%
Ram Hoggets	2,886	1	0.03%	0.00%	0.19%
Dam. R Lmbs	1200	0	0.00%	0.00%	0.48%
Dam. E Lmbs	592	0	0.00%	0.00%	0.62%
Total	**51,364**	**1**	**0.00%**	**0.00%**	**0.01%**

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

Table 19. On board prevalence of scabby mouth in each category - Consignment four

	Total	Cases	Prevalence (%)	Confidence LL*	Confidence UL*
A Wether	9,323	0	0.00%	0.00%	0.04%
B Wether	10,217	3	0.03%	0.01%	0.09%
Ram Hogget	1,680	0	0.00%	0.00%	0.22%
Damarra	2,284	3	0.13%	0.03%	0.38%
Ram Lamb	1,482	0	0.00%	0.00%	0.25%
Total	**24,932**	**6**	**0.02%**	**0.01%**	**0.05%**

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

6.2.3 Voyage III

The third experimental voyage involved three discrete consignments (consignments five, six and seven). All three consignments were sourced from the Eastern States. Consignment five, involving approximately 30,000 sheep was assembled at an Adelaide feedlot (August, 2010). Eleven scabby mouth cases were observed and removed on receival, and 14 cases identified and removed at load out. The consignment was destined for the Persian Gulf. These sheep were not subjected to the Saudi vaccination protocol.

Consignment six consisted of nearly 22,000 sheep and was assembled at a Portland feedlot (August 2010). Four cases of scabby mouth were identified and removed at receival and a further two cases were identified (and removed) from the consignment at load out. The consignment was also destined for the Persian Gulf. Accordingly the consignment was not subjected to the Saudi protocol.

Consignment seven consisted of approximately 17,000 sheep and was assembled at a Portland feedlot. Fourteen cases of scabby mouth were identified and removed at receival and a further 2 cases were identified and removed from the consignment at load out. The consignment was also destined for the Persian Gulf. The consignment was not subjected to the Saudi protocol.

The voyage was completed in 23 days. On board inspections took place 3 to 5 days prior to arrival at the first port. The on board results from consignments five, six and seven are summarised in Tables 20, 21 and 22.

Table 20. On board prevalence of scabby mouth in each category - Consignment five

	Total	Cases	Prevalence (%)	Confidence LL*	Confidence UL*
A Wether	2,290	0	0.00%	0.00%	0.16%
B Wether	3,897	3	0.08%	0.02%	0.22%
C Wether	262	0	0.00%	0.00%	1.40%
A Y Wether	4,618	16	0.35%	0.20%	0.56%
B Y Wether	9,030	7	0.08%	0.03%	0.16%
CSp Y Wether	3,397	0	0.00%	0.00%	0.11%
XB Lambs	926	0	0.00%	0.00%	0.40%
Merino Lambs	5,881	0	0.00%	0.00%	0.06%
Rams	50	0	0.00%	0.00%	7.11%
Ram Hoggets	82	0	0.00%	0.00%	4.41%
Total	**30,433**	**26**	**0.09%**	**0.06%**	**0.13%**

Table 21. On board prevalence of scabby mouth in each category - Consignment six

	Total	Cases	Prevalence (%)	Confidence LL*	Confidence UL*
A Wether	1,258	0	0.00%	0.00%	0.29%
B Wether	3306	0	0.00%	0.00%	0.11%
C Wether	310	0	0.00%	0.00%	1.18%
C Sp Wether	3,958	8	0.20%	0.09%	0.40%
B Y Wether	9,636	0	0.08%	0.00%	0.04%
Merino Lambs	3.011	0	0.00%	0.00%	0.12%
XB Lambs	562	0	0.00%	0.00%	0.65%
Total	**22,041**	**8**	**0.04%**	**0.02%**	**0.07%**

Table 22. On board prevalence of scabby mouth in each category - Consignment seven

	Total	Cases	Prevalence (%)	Confidence LL*	Confidence UL*
A Wether	1,905	0	0.00%	0.00%	0.19%
B Wether	3,924	0	0.00%	0.00%	0.09%
C Wether	150	0	0.00%	0.00%	2.43%
C Sp Wether	4,537	0	0.00%	0.00%	0.08%
B Y Wether	3,775	0	0.00%	0.00%	0.10%
Merino Lambs	2,951	0	0.00%	0.00%	0.12%
Polled Rams	110	0	0.00%	0.00%	3.30%
Horned Rams	126	0	0.00%	0.00%	1.89%
Total	**17,478**	**0**	**0.00%**	**0.00%**	**0.02%**

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

6.2.4 Voyage IV

The fourth experimental voyage monitored two discrete consignments (consignments eight and nine) sourced from Western Australia. Consignment eight, involving approximately 31,000 sheep was assembled at the Peel feedlot (October 2010). Only one scabby mouth cases was identified on receival, but 24 cases were identified and removed at load out. Research staff collected severity score information. These sheep were subjected to the Saudi vaccination protocol.

Consignment nine consisted of nearly 24,000 sheep and was assembled at the La Bergerie feedlot (October 2010). There was only one case of scabby mouth identified at receival and only one further case identified and removed from the consignment at load out. Both consignments were destined for Saudi Arabia (Jeddah) and therefore subjected to the Saudi protocol.

The voyage was completed in 14 days. On board inspections took place 3 to 5 days prior to arrival at the first port. Very few cases were observed at the end of the voyage (Table 23 and 24).

Table 23. On board prevalence of scabby mouth in each category - Consignment eight

	Total	Cases	Prevalence (%)	Confidence LL*	Confidence UL*
A Wether	10,232	0	0.00%	0.00%	0.04%
B Wether	6,722	0	0.00%	0.00%	0.05%
Polled Rams	1,516	2	0.13%	0.02%	0.48%
Horned Rams	1,511	0	0.00%	0.00%	0.24%
Ram Hoggets	2,016	0	0.00%	0.00%	0.18%
Ram Lambs	2,141	0	0.00%	0.00%	0.17%
XB Lambs	6,330	0	0.00%	0.00%	0.06%
Total	**30,468**	**2**	**0.01%**	**0.00%**	**0.02%**

Table 24. On board prevalence of scabby mouth in each category - Consignment nine

	Total	Cases	Prevalence (%)	Confidence LL*	Confidence UL*
A Wether	1,905	0	0.00%	0.00%	0.19%
B Wether	3,924	0	0.00%	0.00%	0.09%
C Wether	150	0	0.00%	0.00%	2.43%
C Sp Wether	4,537	0	0.00%	0.00%	0.08%
B Y Wether	3,775	0	0.00%	0.00%	0.10%
Merino Lambs	2,951	0	0.00%	0.00%	0.12%
Polled Rams	110	0	0.00%	0.00%	3.30%
Horned Rams	126	0	0.00%	0.00%	2.89%
Total	**23,714**	**0**	**0.00%**	**0.00%**	**0.02%**

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

6.2.5 Voyage V

The fifth experimental voyage monitored only one consignment (consignment ten). The consignment was sourced from Western Australia and involved approximately 68,000 sheep assembled at the Peel feedlot (November 2010). Eleven scabby mouth cases were identified and removed on receival, and no further cases were identified at load out. These sheep were destined for the Persian Gulf and were not subjected to the vaccination protocol.

The voyage was completed in 24 days. On board inspections took place 3 to 5 days prior to arrival at the first port. A significant number of cases were observed toward the end of the voyage (see Table 25).

Table 25. On board prevalence of scabby mouth in each category - Consignment ten

	Total	Cases	Prevalence (%)	Confidence LL*	Confidence UL*
A Wether	5,107	0	0.00%	0.00%	0.07%
B Wether	6,865	0	0.00%	0.00%	0.05%
C Wether	12,456	30	0.24%	0.16%	0.34%
Store Wether	428	0	0.00%	0.00%	0.86%
A Y Wether	13,690	89	0.65%	0.52%	0.80%
B Y Wether	2,873	32	1.11%	0.76%	1.57%
Trial Y Wether	1,034	0	0.00%	0.00%	0.36%
A M Lambs	4,270	29	0.68%	0.46%	0.97%
B M Lambs	6,994	89	1.27%	1.02%	1.56%
HDL	340	0	0.00%	0.00%	1.08%
XB Lambs	6,330	0	0.00%	0.00%	0.06%
Dorper Lambs	677	0	0.00%	0.00%	0.54%
Ram Hoggets	974	0	0.00%	0.00%	0.38%
Polled Rams	869	9	1.04%	0.47%	1.96%
Horned Rams	439	1	0.23%	0.01%	1.26%
A Ewes	1,735	1	0.06%	0.00%	0.32%
B Ewes	1,730	16	0.92%	0.53%	1.50%
Total	**68,049**	**296**	**0.43%**	**0.39%**	**0.49%**

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

6.2.6 Voyage VI

The sixth experimental voyage involved two discrete consignments (consignments eleven and twelve). Both consignments were sourced from the Eastern States. Consignment eleven, involving approximately 13,000 sheep was assembled at an Adelaide feedlot (April 2011). No scabby mouth cases were observed at receival, and no cases were identified at load out. These sheep were not subjected to the Saudi vaccination protocol.

Consignment twelve consisted of approximately 23,000 sheep and was assembled at the Cape Nelson feedlot (April 2011). Three cases of scabby mouth were identified and removed at receival but no further cases were identified at load out. The consignment was also destined for the Persian Gulf and loaded on the same vessel.

The voyage was completed in 28 days. On board inspections took place 3 to 5 days prior to arrival at the first port (see Table 26 and 27).

Table 26. On board prevalence of scabby mouth in each category - Consignment eleven

	Total	Cases	Prevalence (%)	Confidence LL*	Confidence UL*
A Wether	483	0	0.00%	0.00%	0.76%
B Wether	3,296	0	0.00%	0.00%	0.11%
C Wether	470	0	0.00%	0.00%	0.78%
C Sp. Wether	2,828	0	0.00%	0.00%	0.13%
B Y Wether	5,179	0	0.00%	0.00%	0.07%
Damarra	345	0	0.00%	0.00%	1.06%
Total	**12,601**	**0**	**0.00%**	**0.00%**	**0.03%**

Table 27. On board prevalence of scabby mouth in each category - Consignment twelve

	Total	Cases	Prevalence (%)	Confidence LL*	Confidence UL*
A Wether	2,021	0	0.00%	0.00%	0.18%
B Wether	9,387	0	0.00%	0.00%	0.04%
C Wether	1,081	2	0.00%	0.00%	0.67%
C Sp Wether	3,575	0	0.00%	0.00%	0.10%
B Y Wether	6,615	0	0.00%	0.00%	0.06%
Total	**22,679**	**0**	**0.01%**	**0.00%**	**0.03%**

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

6.3 Summary of results

The study monitored over 370,000 sheep on receival, at load out and on board. This was accomplished over a 12-month period. Six voyages were involved representing twelve consignments.

The consignments were split according to their sourcing and protocol requirements. Correspondingly this represented sheep subject to the non-Saudi protocol (sourced from the Eastern States), sheep subjected to the non-Saudi protocol (sourced from Western Australia) and sheep subjected to the Saudi protocol (all sourced from Western Australia). The non-Saudi sheep were not subjected to any vaccination protocol whereas the Saudi sheep were required to meet the double vaccination protocol. These divisions provided a fair representation from each group.

Each of these groups was further divided based on category (lambs, young wethers, adult wethers, ewes, rams and damarra). Again these divisions provided a fair representation from each group (see Table 28).

Table 28. The number of sheep in each group and category within the study

	Non-Saudi (ex E.S.)	**Non-Saudi (Ex W.A.)**	**Saudi (All W.A.)**
Lambs	13,344	34,497	19,604
Young Wethers	63,148	24,282	40,389
Adult Wethers	64,253	31,898	53,570
Ewes	0	7,219	1,028
Rams	680	3,436	11,083
Damarra	345	957	4,963
Total	**141,750**	**102,289**	**130,637**

* Numbers taken from load out figures.

The overall prevalence of scabby mouth at receival was **0.03%.** This represented 107 cases in a sample population of 389,666 sheep. The overall prevalence of scabby mouth at load out was **0.06%.** This represented 211 cases in a population of 374,676 sheep. The overall prevalence of scabby mouth on board (prior to discharge) was **0.15%.** This represented 566 cases in a similar population. The difference between these values was significant (Chi-square with P values of <0.0001 in each case). These results are summarised in Table 29.

Table 29. The overall prevalence of scabby mouth at receival, load out and on board (prior to discharge)

	Prevalence	Confidence LL*	Confidence UL*
Receival	**0.03%**^{a}	0.02%	0.03%
Load Out	**0.06%**^{b}	0.05%	0.06%
On board (prior to discharge)	**0.15%**^{c}	0.14%	0.16%

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate). Different letters indicate significant difference (P < 0.01).

The prevalence of scabby mouth on receival was very low in each of the three groups (**0.02%** in non-Saudi sheep sourced from the Eastern States, **0.02%** in non-Saudi sheep sourced from Western Australia and **0.04%** in the sheep subjected to the Saudi protocol (again sourced from Western Australia) (see Table 30). There was no significant difference between the non-Saudi groups of sheep. The difference between the Saudi and the non-Saudi sheep was significant (Chi-square with a P value of <0.0012 and <0.0087 respectively) even at this very low prevalence.

In the non-Saudi sheep (sourced from the Eastern States), this low initial prevalence of scabby mouth was maintained at load out (from **0.02%** to **0.01%)** and maintained throughout the voyage (**0.04%** at the point of discharge). This represented only 32, 20 and 55 cases respectively in a population of approximately 141,000 sheep. The difference between the on board prevalence and the prevalence at load out and receival was significant (Chi-square with a P value of <0.0001).

In the non-Saudi sheep (sourced from Western Australia), the low prevalence of scabby mouth was also maintained at the point of load out (from **0.02%** to **0.03%),** but lifted quite sharply on board (to **0.49%**). This difference was highly significant (Chi square value of 447 with a P value of <0.0001). This represented 20, 32 and 502 cases respectively in a population of approximately 102,000 sheep.

In contrast, the Saudi protocol (all sourced from Western Australia), showed a sharp lift in prevalence at the point of load out (from **0.04%** to **0.12%**) yet there was virtually no scabby mouth seen in these consignments prior to discharge at the voyage destination (**0.01%)**. This represented 55, 159, and only 9 cases respectively in a population of approximately 130,000 sheep. All of these differences were significant (Chi-square with a P value of <0.0001).

Table 30. Group prevalence of scabby mouth at receival, load out and on-board (prior to discharge)

	Prevalence	Confidence LL*	Confidence UL*
Non-Saudi (ex E.S.)			
Receival	**0.02%**	0.01%	0.03%
Load Out	**0.01%**	0.01%	0.02%
On board (prior to discharge)	**0.04%**	0.03%	0.05%
	Prevalence	Confidence LL*	Confidence UL*
Non-Saudi (ex WA)			
Receival	**0.02%**	0.01%	0.03%
Load Out	**0.03%**	0.02%	0.04%
On board (prior to discharge)	**0.49%**	0.45%	0.53%
	Prevalence	Confidence LL*	Confidence UL*
Saudi (all ex WA)			
Receival	**0.04%**	0.03%	0.05%
Load Out	**0.12%**	0.10%	0.14%
On board (prior to discharge)	**0.01%**	0.00%	0.01%

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

The prevalence of scabby mouth differed between the categories of sheep (see Table 31). This was more evident on board than at receival or load out. The prevalence of scabby mouth in the older wethers was consistently low throughout the study (**0.02%**, **0.05%** and **0.06%** at receival, load out and on board respectively). This represented only 34, 77 and 84 cases in a population of approximately 150,000 wethers. This was a consistent pattern in all consignments.

The overall highest level of scabby mouth was seen in lambs (**0.03%, 0.10%** and **0.33%** at receival, load out and on board respectively). This pattern was not consistent between the consignments and there were several consignments where the prevalence of scabby mouth in young wethers was higher (as compared to lambs). The overall prevalence of scabby mouth in young wethers was slightly lower (**0.03%**, **0.03%** and **0.17%** at receival, load out and on board respectively).

Note the significantly higher on board prevalence in both these categories (220 cases of scabby mouth in a population of 67,379 lambs (0.33%) and 212 cases of scabby mouth in a population of 127,783 young wethers (0.17%)). These results are summarized in Table 31.

There was no significant difference between these categories on receival but the differences at both load out and on board were significant (Chi-square with a P value of <0.0001).

The study also examined other categories (ewes, rams and damarra). The prevalence amongst these categories was inconsistent, as each comprises a range of age groups, often purchased in small groups, assembled and run together. Consequently their disease history is less clear. Each of these categories showed occasional high levels of scabby mouth in mobs within some consignments. The numbers involved were low and these categories have been left out of the comparison.

Table 31. Prevalence of scabby mouth in each category at receival, load out and on board (prior to discharge)

	Prevalence	Confidence LL*	Confidence UL*
Lambs			
Receival	**0.03%**	0.02%	0.04%
Load Out	**0.10%**	0.07%	0.12%
On board (prior to discharge)	**0.33%**	0.28%	0.37%
	Prevalence	Confidence LL*	Confidence UL*
Young Wethers			
Receival	**0.03%**	0.02%	0.04%
Load Out	**0.03%**	0.02%	0.04%
On-board (prior to discharge)	**0.17%**	0.14%	0.19%
	Prevalence	Confidence LL*	Confidence UL*
Wethers			
Receival	**0.02%**	0.01%	0.03%
Load Out	**0.05%**	0.04%	0.06%
On-board (prior to discharge)	**0.06%**	0.04%	0.07%

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

The study also compared cross bred lambs to merino lambs (see Table 32). Industry consultation had suggested that cross bred lambs might show a higher prevalence than merino lambs. While this was the case at load out (**0.18%** vs. **0.05%**), it was not the case on board (**0.10%** vs. **0.45%**). The prevalence was low in both groups at receival. These results were influenced by a high prevalence in individual consignments. These differences were significant (Chi-squared) but it is difficult to draw any conclusion since the trend was reversed.

Table 32. A comparison of prevalence between lambs at receival, load out and on board (prior to discharge)

	Prevalence	Confidence LL*	Confidence UL*
Cross Bred Lambs			
Receival	**0.01%**	0.00%	0.02%
Load Out	**0.18%**	0.12%	0.23%
On-board (prior to discharge)	**0.10%**	0.06%	0.14%
	Prevalence	Confidence LL*	Confidence UL*
Merino Lambs			
Receival	**0.04%**	0.03%	0.06%
Load Out	**0.05%**	0.03%	0.08%
On-board (prior to discharge)	**0.45%**	0.39%	0.52%

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

The voyages were undertaken over an 18-month period. There was no discernable seasonal pattern to the prevalence based on the findings of the study.

7 Discussion

The overall prevalence determined by the study was low, and much lower than that described in literature from 15-20 years earlier. Industry consultation suggests that the practice of vaccinating lambs at marking is responsible for this reduction but the same reduction is seen in the Eastern States where vaccination is not routinely practiced.

The most significant finding was the low prevalence in the non-Saudi sheep destined for the Middle East but sourced from the Eastern States. These sheep were not subjected to the Saudi protocol and were sourced from areas that do not routinely use vaccination as a control measure. Disease control in this case relies heavily on an exclusion strategy, and very few sheep would have received any vaccination at marking or any other time. The result demonstrates that an exclusion strategy can be effective; however it is probably more vulnerable in the face of a challenge from contaminated premises or infected sheep.

The lowest on board prevalence (prior to delivery) was demonstrated in the sheep destined for Saudi Arabia that had been subjected to the double vaccination protocol. The difference between this group and the non-Saudi sheep sourced from the Eastern States was significant (Chi square with a P value of <0.0001), however the prevalence in both cases was very low (0.01% versus 0.04% as shown in Table 33). If the cost of vaccination was insignificant and if the vaccination protocol did not impose a significant logistical impost on industry, then the double vaccination strategy would be favoured by this result. This is not the case, however, since the magnitude of the cost and logistical impost is high. This study evaluates the cost effectiveness of several disease management strategies later in this chapter.

The prevalence seen in the non-Saudi sheep sourced from Western Australia represents what might be expected in sheep exposed to contaminated premises and/or infected sheep. These sheep demonstrated a higher prevalence at both load out and on board prior to discharge.

Table 33. The group prevalence of scabby mouth at receival, load out and on board (prior to discharge)

	Prevalence	Confidence LL*	Confidence UL*
Non-Saudi (ex E.S.)			
Receival	**0.02%**	0.01%	0.03%
Load Out	**0.01%**	0.01%	0.02%
On board (prior to discharge)	**0.04%**	0.03%	0.05%
	Prevalence	Confidence LL*	Confidence UL*
Non-Saudi (ex WA)			
Receival	**0.02%**	0.01%	0.03%
Load Out	**0.03%**	0.02%	0.04%
On board (prior to discharge)	**0.49%**	0.45%	0.53%
	Prevalence	Confidence LL*	Confidence UL*
Saudi (all ex WA)			
Receival	**0.04%**	0.03%	0.05%
Load Out	**0.12%**	0.10%	0.14%
On board (prior to discharge)	**0.01%**	0.00%	0.01%

* Confidence levels computed by the exact binomial method. (Ross, T.D. (2003) Accurate confidence intervals for binomial proportion and Poisson rate).

Given the known incubation period of the disease, it is most likely that these sheep were exposed to the disease in the assembly facility. If this were the case, there are three possibilities: 1) a failure of the inspection procedure, 2) the presence of disease in carryover sheep or 3) that the sheep were exposed to environmental contamination of the disease in the assembly facility itself. The incidence pattern, showing a sharp rise in prevalence on board, suggests that the third possibility is the most likely and the sheep were exposed to the disease in the assembly facility.

The incident pattern in the Saudi sheep, whereby the prevalence at load out was significantly higher than that which was demonstrated at receival, would also suggest that the use of the live virus is responsible for introducing the disease into the assembly facility and contaminating the environment. This has implication for sheep destined for all Middle East markets.

As stated the prevalence of scabby mouth at receival was very low in all the sheep. This was maintained throughout load out and on board in the non-Saudi consignments sourced from the Eastern States. In Western Australia, the non-Saudi consignments demonstrated a slight increase in prevalence at load out followed by a sharp lift on board prior to arrival.

The extent to which these sheep may have been previously vaccinated (or exposed) in the non-Saudi consignments is, however, unclear. Vendor declarations indicated that the sheep in these consignments reflected the vaccine usage and management practises describe in industry consultation. Unfortunately, ear tag information collected as part of the inspection method showed high levels of ‘no match’ to vendors information. This precluded the inclusion of a single vaccination strategy in the comparison. It would be possible for this comparison to be made within normal commercial operations, but these sheep would need to be separated on receival and kept separate throughout the export process. This represents an area for further study.

Comparison of the strategies requires consideration of both risk and cost. The double vaccination strategy could be considered as the lowest risk strategy for sheep destined for Saudi Arabia, but it is recognised that the practice of vaccinating sheep at least 5 days prior to deliver to the assembly facility may be contributing to the risk of a high scabby mouth prevalence in sheep destined for other markets. Furthermore the same practice is thought to be contributing to the contamination of the facilities and therefore affecting the risk of exposure of sheep to the scabby mouth virus. There are also concerns that if sheep destined for Saudi Arabia are sourced from the Eastern States, this may increase the same risk of exposure in the facilities in the Eastern States.

The cost of vaccination itself can be relatively easily determined, although the logistical cost associated with vaccination close to the time of delivery is more difficult to ascertain. The cost of the failure of a disease prevention strategy can be determined although this is slightly more difficult. The most difficult aspect is to determine the likelihood or risk of failure associated with the disease prevention strategy.

This projects aim was to determine prevalence of scabby mouth in live export sheep and provide an assessment of existing disease management strategies. The associated literature review and industry consultation provide the basis to re-assess the effectiveness of these disease management strategies and better define the probabilities of outcomes within these strategies. These can be quantifies in dollar terms.

Cost benefit analysis indicates the economics by comparing the expected return, with or without the proposed investment. Accordingly the analysis looks at a ‘with versus without’ scenarios based on associated cash flows going forward.

There are three disease management strategies. These are:

1. No vaccination (low cost, high risk option).
2. One vaccination (preferably at marking), (medium cost, medium risk option).
3. The current protocol involving two vaccinations (high cost, low risk option).

The study has shown that although the first option (no vaccination) is considered the highest risk, it has been shown to be an effective disease prevention strategy. This applies to consignments sourced from the Eastern States where different conditions prevail to those in the Western Australia. In the Eastern States the focus is on excluding the disease from the export process. It is made easier by an all in all out policy with very little carryover of sheep between consignments. The assembly facilities involved do not utilise sheds. 'Saudi' sheep are currently not sourced from the Eastern States.

Although the double vaccination strategy is probably the least risky, much of its value is lost to the likelihood of introducing the disease into the assembly facility as a consequence of vaccinating sheep prior to them being delivered. Contamination of the feedlot environment is making it much more likely that sheep are exposed to the disease. This has implications for sheep in both Saudi and non-Saudi consignments.

There is no evidence to suggest that two vaccinations are better than one in regards to immunity. It has been shown that vaccinated sheep can be relatively easily re-infected although the disease is less severe and the animal recovers more quickly. There may be a 'time since vaccination effect' since immunity may wane over time, however, this has not been established in the scientific literature.

It is possible that the second option, a single vaccination administered at marking or well prior (at least 21 days) to delivery to the assembly facility is equally as effective as the double vaccination strategy, with the added benefit of reducing (or eliminating) the environmental contamination of the feedlot. This strategy also reduces the risk that recently vaccinated sheep become a source of active infection and removes the current irrational requirement that sheep must show signs of active infection in the axilla region (a 'take') but not show signs of active infection on the mouth or lips at the point of loading.

Most, if not all Middle East countries involved in trade with Australia, have memorandums of understanding (MOUs) that ensure that stock from Australia will be discharged into quarantine facilities even if they show evidence of disease, including scabby mouth. This requirement reduces the risk of outright rejection.

The history of events, as described in the study, suggests that Saudi Arabia, as a destination, is inherently more risky than other destinations within the Middle East. Recently, however, other countries (most notably U.A.E.) have expressed concerns about the presence of scabby mouth on board. As a general rule the Gulf countries represent a lower risk profile. Jordan has a similar (low) risk profile.

Administering the second vaccination (5 days prior to delivery to the assembly facility) is logistically very difficult and requires extra handling and re-mustering. As a consequence there is a risk of non-compliance. This risk should be considered when evaluating the disease prevention strategies.

The Saudi market has historically set the price for sheep in Western Australia. It has consistently been prepared to pay the highest price and has historically underpinned the market. The trade to the Gulf and other non-Saudi markets has often been close behind and differs only by the margin of additional costs associated with compliance to the Saudi protocol.

The value of these markets to regional Australia has been well documented. Clarke (2007) estimated the value of value the sheep trade from Western Australia (direct output) to be in the order of $330M AUD per year and the impact of trade cessation to be $939M AUD (as a net present value discounted over 10 years) [89]. Most of the implied benefit flows to the regions as a gross regional product. Clarke's assessment does not include the Eastern States. It is acknowledged that the impact of trade cessation in the East would be considerably less due to a far better next best price. Clarke's figures were supported by previous work conducted by Hassall and Associates in 2006 [90].

It is difficult to assess the risk of a trade being closed. The existence of MOU's in the countries involved makes this even more difficult. Cessation of the trade is likely to be a consequence of public reaction to any consequences of a vessel being rejected, rather than the rejection itself. It is hoped that the strength of the MOUs would ensure that vessel rejection was a remote possibility. A more likely scenario might be that sheep are discharged and held in quarantine facilities for an unspecified period.

The cost of vessel rejection is well documented. The rejection of the MV Cormo Express cost the industry $11.2M AUD. This cost was recouped as a levy on livestock exports from 2005-2008. The overall cost was probably higher if the 'cost to the brand' of livestock exports were considered. The Cormo incident represents a lingering sore that is used repeatedly as ammunition by those opposed to the trade. Nevertheless, the $11.2M AUD figure is robust and has been used in the cost benefit modelling.

The Saudi MOU requires that there be a quarantine facility made available to quarantine animals that are rejected for reasons of disease. The cost of being quarantined is significant and includes an agistment cost, the cost of feed and the cost of additional transport. It also includes the cost of any discount to the product involved in regards to the association of being diseased. The cost of quarantine has been calculated at $11.20 AUD per head. This assumes a time frame of 20 days. The actual time frame that might be incurred is difficult to predict.

The analysis includes both actual and opportunity costs. The actual cost of complying with the disease status required by the Saudi market is high whilst the opportunity costs of not complying are also high. The cost benefit analysis is used to determine which course of action is most economic. The costs considered by the analysis therefore include:

1. the direct operating costs involved in the preparation of the sheep for this market; and
2. the opportunity cost of failure.

For the purposes of the project, the cost of failure has been quantified by multiplying the cost of an event (such as the loss of the trade and/or vessel rejection costs) by the likelihood that it may occur. The costs of the scabby mouth disease prevention strategies are outlined in Table 34. Most values are from the perspective of the exporter although it is noted that some benefits and costs will often flow on to livestock producers and/or the nation as a whole.

The cost of undertaking a scabby mouth vaccination is $1.57 AUD per head. This does not include any mustering or handling cost. For on-farm vaccination, the cost of mustering and handling is assumed to be part of normal operating costs. But where a specific vaccination is required (i.e. 5 days prior to delivery), the cost of mustering and handling has been added. This is estimated at $1.37 AUD per head. Accordingly the cost of the on farm vaccination (as a cost to the producer) over 800,000 sheep is $1.26M AUD.

The same cost is applied to the second vaccination prior to delivery, plus the additional cost of handling and mustering. This is calculated at $1.10M per year. The overall cost of each strategy within the live export sheep trade to Saudi Arabia is therefore nil, $1.26M AUD and $3.62M AUD for each of the three strategies described (see Table 34). The operational cost of administering the second vaccination is therefore calculated as $2.26 AUD inferring a potential saving of over $2M AUD per year. This applies simply to the trade to Saudi Arabia, (if historic levels of sheep exports are restored).

Table 34. The assumptions used to quantify the cost of scabby mouth disease prevention strategies

Operating Costs	Strategy 1 (no vaccination)	Strategy 2 (single vaccination)	Strategy 3 (two vaccinations)
Number of sheep exported to Saudi Arabia each year	800,000 per year	800,000 per year	800,000 per year
No vaccination	nil	nil	nil
A single vaccination at marking or at least 21 days prior to delivery to the assembly facility	nil	1.26M AUD per year	1.26M AUD per year
The current strategy involving a pre-export vaccination			1.26M AUD per year
On farm costs relating to handling and re-mustering costs.		Assumed part of normal operating costs	1.10M AUD per year
Total Costs	**nil**	**$1.26M AUD**	**$3.62M AUD**

As mentioned, the cost of failure has been quantified by multiplying the cost of an event (such as the loss of the trade and/or vessel rejection costs) by the likelihood that it may occur. The cost of the outright loss of trade to the Middle East has been taken directly from the study by Clarke (2007) and is included in Table 35 as a reminder that the industry is under constant scrutiny and worst-case eventualities remain a possibility. It has not been included in the cost benefit analysis.

The likelihood of the outright rejection of a single shipment is also low, given the agreements with the Saudi Arabian authorities. Accordingly the cost, ($11.2M AUD) is also excluded from the cost benefit analysis but included in table 35 as a reminder.

The cost of rejection (in 2011) therefore relates to the quarantine of an individual shipment. It is assumed that a shipment consists of 70,000 head of sheep. Whether this would lead to more costly consequences is a matter of conjecture at this stage. All costs have been calculated in AUD equivalents. The cost of quarantining a shipment includes transport at 36c per head (both in and out of quarantine facility) to total $50,000. The demurrage for the vessel is calculated at $30,000 per day (for 3 days) to total $90,000. Agistment is calculated at 7c per day for an estimated 20 days to total $98,000. By far the highest cost would be feed which is calculated at 39c per head over the same period to total $546,000. The total cost is therefore calculated at $784,000 per shipment (see Table 35).

As discussed earlier, the quarantine premises in Saudi Arabia have yet to be used. However, the use of these facilities is considered the most likely consequence of a failure in current (or future) protocols. The cost benefit hinges on the assigned likelihood that any of the strategies might result in the quarantine of a shipment. It has been assumed that the current (double vaccination) strategy has a 10% likelihood of one shipment per year being quarantined. The single vaccination strategy has been assigned a slightly higher likelihood of 20%. It was assumed that the no vaccination strategy would suffer four shipment quarantines per year. This outcome would most likely result in widespread disruption to the trade but such a possibility has not been analysed at this stage. The three risk profiles are outlined in Table 36.

Table 35. The assumptions used to quantify the cost of failure of scabby mouth disease prevention strategies for sheep destined to Saudi Arabia

The Cost of a Failure	Strategy 1 (no vaccination)	Strategy 2 (single vaccination)	Strategy 3 (two vaccinations)
Outright loss of live export trade to the Middle East	As per study (Clarke, 2007) $939M AUD	As per study (Clarke, 2007) $939M AUD	As per study (Clarke, 2007) $939M AUD
Outright rejection and associated costs as incurred by the “Cormo” incident (not included in current CBA)	As per actual levy $11.2M AUD	As per actual levy $11.2M AUD	As per actual levy $11.2M AUD
Quarantine of shipment with associated costs incurred under the current agreement with the Kingdom of Saudi Arabia	$784,000 AUD per shipment	$784,000 AUD per shipment	$784,000 AUD per shipment

Table 36. The assumptions used to quantify the likelihood of failure of scabby mouth disease prevention strategies for sheep destined to Saudi Arabia

Likelihood of Failure	Strategy 1 (no vaccination)	Strategy 2 (single vaccination)	Strategy 3 (two vaccinations)
Outright loss of live export trade to the Middle East (not included in current CBA)	Low	Low	Low
Outright rejection (as incurred by the “Cormo” incident (not included in current CBA)	Low	Low	Low
Quarantine of shipment with associated costs incurred under the current agreement with the Kingdom of Saudi Arabia	100% chance of four shipments per year	20% chance of one shipment per year	10% chance of one shipment per year

The cost of failure has been quantified by multiplying the cost of the event by the likelihood that it may occur. This calculation is shown outlined in Table 37.

Table 37. The assumed cost of failure of scabby mouth disease prevention strategies for sheep destined to Saudi Arabia

Assumed Cost of Failure	Strategy 1 (no vaccination)	Strategy 2 (single vaccination)	Strategy 3 (two vaccinations)
Outright loss of trade	Not included in CBA	Not included in CBA	Not included in CBA
Vessel rejection costs	Not included in CBA	Not included in CBA	Not included in CBA
Quarantine and associated costs	$3.14M AUD	$156,800 AUD	$78,400 AUD
Total Assumed Cost	**$3.14M AUD**	**$156,800 AUD**	**$78,400 AUD**

From the calculations it can be seen that the current management strategy (Strategy 3) has the lowest risk of failure but incurs the highest operational cost. In contrast the ‘no vaccination’ strategy (Strategy 1) has the lowest operating cost but has the highest risk of failure. The single vaccination strategy (Strategy 2) reflects both lower operating costs and little change to the potential of failure. Consequently, it is the most favoured option. These calculations are summarized in the following table (see Table 38).

Table 38. The total cost of scabby mouth disease prevention strategies for sheep destined to Saudi Arabia

Total Costs	Strategy 1 (no vaccination)	Strategy 2 (single vaccination)	Strategy 3 (two vaccinations)
Operating costs	nil	1.26M AUD	3.62M AUD
Cost of failure	3.14M AUD	156,800 AUD	$78,400 AUD
Total costs (per year)	**3,140,000 AUD**	**1,416,800 AUD**	**3,541,600 AUD**

The preceding table quantifies the cost of the three disease prevention strategies. Note that the analysis suggests that the adoption of a single vaccination strategy could offer a significant saving to the industry. Even where the cost of failure is factored in, there is a potential saving of over $2M AUD per year. This applies strictly to the trade to Saudi Arabia (if historic levels of sheep exports are restored).

This analysis comes with many caveats and qualifications. The results are highly sensitive to risk and therefore reflect the risk factor allocated to each strategy. The risk assessment notes that the prevalence of scabby mouth has subsided since the current protocol was implemented. Scabby mouth prevalence was low in unvaccinated sheep as well as sheep subjected to the Saudi protocol. It reflects the recent science that has better defined the immunosuppressive capabilities of the virus. It also notes the agreement with the Saudi Arabian authorities which should ensure any sheep with unacceptable levels of scabby mouth are taken to a quarantine facility rather than being rejected. It is acknowledged, however, that this agreement has not been tested since it was put in place.

The number of sheep exported to the Middle East has declined markedly in early 2011. To some extent this reflects high sheep prices (tied to lack of availability) but other factors are also involved. It is anticipated that export activity will return to historical levels by the middle of next year. Accordingly, the sheep numbers used for the cost benefit analysis reflect historic export levels.

Scabby mouth is not cited as a problem when delivering sheep to the Persian Gulf, (as opposed to the Saudi Market that discharges in Jeddah). Although disease incidents occur, there is anecdotally a greater tolerance exhibited by the veterinary authorities at the point of discharge. Sheep destined for the Persian Gulf do not require any protocol aimed specifically at scabby mouth and the sheep have generally had either no vaccination or a single vaccination at marking. There are significantly more sheep involved in the non-Saudi trade, (an estimated 2 million based on historic levels). As mentioned previously, the Saudi vaccination program has implications for both the Saudi and non-Saudi trade. Further calculations are therefore required to assess the overall impact of the Saudi vaccination protocol on the live sheep export industry.

The likelihood of a consignment being rejected in the Persian Gulf region is different to a consignment destined for Saudi Arabia. Thus a different risk profile is required. The likelihood of a vessel being rejected (under the current vaccination strategy) has been assessed at 20% in any one year. This translates into a relatively low cost of failure, implying significant savings in adopting a no vaccination program.

The likelihood of a vessel being rejected under the single vaccination strategy has been assessed as a 10% any one year and 5% with the double vaccination strategy. This implies an extremely low failure cost but additional costs are incurred. The associated calculations are summarized in the following tables (see Table 39 and 40). Note that the costs involved are strongly influenced by the greater number of sheep involved in the trade. operating cost per hd * 2 million sheep and........ cost of failure being likelihood * cost of shipment quarantine

Table 39. The assumptions used to quantify the likelihood of failure of scabby mouth disease prevention strategies for sheep destined for the Persian Gulf

Likelihood of Failure	Strategy 1 (no vaccination)	Strategy 2 (single vaccination)	Strategy 3 (two vaccinations)
Outright loss of live export trade to the Middle East (not included in current CBA)	Very low	Very low	Very low
Outright rejection (as incurred by the "Cormo" incident (not included in current CBA)	Low	Low	Low
Quarantine of a shipment with under the current agreements with Gulf countries	(say 20% chance of one shipment per year)	(say 10% chance of one shipment per year)	(say 5% chance of one shipment per year)

Table 40. The total cost of failure of scabby mouth disease prevention strategies for sheep destined for the Persian Gulf.

Total Costs	Strategy 1 (no vaccination)	Strategy 2 (single vaccination)	Strategy 3 (two vaccinations)
Operating costs	nil	$3.14M	$9.02M
Cost of failure	$156,800	$78,400	$39,200
Total costs (per year)	**$156,800**	**$3,218,400**	**$9,059,200**

Note – Operating costs equal to operating cost per head multiplied by 2 million sheep and cost of failure being likelihood multiplied by cost of shipment quarantine. Operating cost for double vaccination strategy includes two vaccination costs plus re-mustering/handling cost.

Note that if any markets within the Gulf become more stringent in regards to scabby mouth, this assessment would need to be reviewed. Clearly it is in the industry's interest to avoid the need to vaccinate sheep destined for the Persian Gulf unless the vaccination gives rise to benefits at other stages of the supply chain.

Discussion about scabby mouth generally centres on trade with Saudi Arabia but it can be seen that the trade to the Persian Gulf has a considerable stake in the outcome of scabby mouth disease prevention strategies. It is possible that further tightening in sheep supplies will force exporters to source Saudi consignments from the Eastern States. In this event, contamination of the assembly facilities by live vaccines would lead to a need for a more stringent protocol. It may also mean an end to the very low prevalence levels observed in sheep sourced from the Eastern States (as determined by this study).

The benefits of modifying the current protocol to a single vaccination strategy are therefore twofold. The first benefit applies to the Saudi trade that should (based on the findings of the study), be able to achieve similar (if not better) disease prevention at a much lower cost. The second benefit applies to the non-Saudi trade whereby the need to adopt a more stringent strategy is avoided by not allowing the existing Eastern States facilities to become contaminated in the same way as they are in the West. If both these figures are factored into an income stream (with an appropriate discount rate) there is a significant financial incentive to re-evaluate the current disease prevention strategy. The financial incentive is best depicted in the form of a cash flow over a specified time period (see Table 41).

Table 41. The overall industry benefit of adopting a single vaccination protocol for sheep destined for Saudi Arabia

	Year 1	Year 2	Year 3	Year 4	Year 5
Benefit to Saudi trade	$2.28M AUD	$2.05M AUD	$1.85M AUD	$1.67M AUD	$1.50M AUD
Benefit to Persian Gulf trade	$3.06M AUD	$2.78M AUD	$2.52M AUD	$2.29M AUD	$2.09M AUD
Total	$5.34M AUD	$4.83M AUD	$4.37M AUD	$3.96M AUD	$3.59M AUD
NPV	**22.09M AUD**				

*NPV calculated using a 10% annual discount rate.

The findings of this study suggest that the current disease prevention strategy is contributing to problems with scabby mouth without adding greatly to its prevention. It represents a high cost strategy without a significant animal health benefit. Each strategy comes with certain provisos and should always be cognisant of the potentially high cost of vessel rejection and/or the loss of trade. Assessment of risk and the likelihood of these events should be ongoing and reflect contemporary circumstances.

A considered disease prevention strategy should reflect the likelihood that sheep will be exposed to or challenged by the disease. It should also reflect the susceptibility of the sheep and their immune status. It is pertinent to note that there has been a trend toward supplying younger sheep. As the age of sheep being exported to Saudi Arabia drops, the time between marking and delivery to the assembly facility is shortened. Lambs born early in the year may have been marked and vaccinated by May. If these lambs are delivered later in the same year, the period between vaccination and delivery is short (5-7 months). There is no scientific justification to re-vaccinate these sheep. The same principle applies to the next age group of sheep meaning that older wethers are less likely to develop clinical signs of the disease.

The results of this part of the study, combined with the findings of the literature review and industry consultation provide sufficient grounds to suggest that the current vaccination protocol for sheep destined for Saudi Arabia be re-evaluated.

8 Summary

The major points stemming from the prevalence data can be summarized as follows:

- The prevalence of scabby mouth was determined at three distinct points within the live export supply chain (in keeping with the terms of reference of the project).
- The results enabled comparisons to be made between consignments, between different classes of sheep and between sheep sourced from the Eastern States versus sheep sourced from Western Australia.
- The results also compared disease prevalence between sheep that had been prepared with different protocols (Saudi versus non-Saudi).
- Pilot voyages were undertaken to evaluate inspection procedures and test data management systems. The pilot voyages determined that as far as possible, inspection procedures on receival should be 'piggy backed' on top of existing industry procedures and consignment size should be restricted to no more than 35,000 to 40,000 sheep (unless additional resources are engaged).
- It was determined that where possible, existing inspection procedures should be subjected to a double check to enable data to be validated independently by the research team members and only single tiered vessel should be utilized for the study (to allow proper scrutiny of sheep on board).
- A scoring system was developed to rank the severity of lesions.
- A disease mapping approach that inspected sheep in the pens prior to arrival was considered best suited to determining disease prevalence on board livestock vessels. This involved an initial inspection to establish the presence or absence of disease, followed by a more detailed inspection to determine prevalence. Mob size was determined by pen size and pen configuration.
- A census approach (population survey) was utilised to determine prevalence within the study, although provision was made for a sample approach where required. The sample approach and sample size required is described in the appendix.
- The overall prevalence determined by the study was low, and much lower than that described in literature relating to 15-20 years earlier.
- The lowest on board prevalence (prior to delivery) was demonstrated in the sheep destined for Saudi Arabia that had been subjected to the double vaccination protocol (0.01%), however, the study also showed a low prevalence amongst non-Saudi sheep sourced from the Eastern States (0.04%), where vaccination is not commonly practiced. Although this difference was statistically significant, the absolute difference was very low. This indicated that 'excluding' the disease from the supply chain is an effective strategy.
- It was not possible within the scope of the project to include a single vaccination strategy in the comparison since the study was strictly observational. Including a single vaccination strategy would have required intervention.
- The higher prevalence seen in the non-Saudi sheep sourced from Western Australia (0.49%) and the incidence pattern demonstrated in all the groups of sheep suggest that the use of a 'living' vaccine is responsible for contaminating the assembly facilities and subsequently infecting sheep included into the live export supply chain.
- The highest prevalence on board prior to discharge was seen in lambs (0.33%) followed by young wethers (0.17%). The prevalence amongst the adult wethers was low (0.06%).
- Cost benefit analysis indicates a potential saving of $2M AUD per annum between a single and double vaccination strategy (when considering only the trade to Saudi Arabia).
- If the practice of using a 'living' vaccine results in a requirement to vaccinate sheep into the Persian Gulf trade (particularly if sheep for Saudi Arabia are sourced from the Eastern States) the additional cost would be in the order of $3M AUD per annum.
- The NPV of the combined cost/savings of adopting a single vaccination strategy is $22.24M AUD.

9 Success in achieving objectives

The project was successful in achieving all the objectives outlined in the terms of reference. A comprehensive literature review was completed. This included an overview of the previous work conducted by industry researchers. Industry consultation included a review of vaccine sales and a nationwide survey conducted by MLA relating to sheep health and welfare. Consultation with other relevant sources was also undertaken.

Inspection and data collection systems were developed as well as a simple scoring system to grade the severity of scabby mouth lesions. The prevalence of scabby mouth was determined at three distinct points along the live export supply chain (receival, load out and on board livestock vessels prior to arrival). Six voyages were monitored involving over 370,000 sheep. Twelve discrete consignments were monitored representing sheep sourced from both Western Australia and the Eastern States. They also represented sheep destined for Saudi Arabia. This enabled a comparison between and within shipments.

The prevalence of scabby mouth sourced from Western Australia was compared to the prevalence of scabby mouth in sheep sourced from the Eastern States (at receival, load out and on board prior to arrival). Sheep destined for Saudi Arabia were compared to sheep destined for other Middle East markets (Bahrain, Kuwait, Doha and U.A.E). It was not possible to monitor a voyage to Oman. The prevalence of scabby mouth in each category of sheep was compared. The project was run over twelve months to determine if any seasonal pattern was observed. Conclusions were drawn from the findings of the literature search, the industry consultation and the prevalence results. These provided the basis for conclusions and recommendations.

10 Conclusions

There are strong grounds, based on the findings of this study, to re-evaluate the current Saudi protocol in regards to both its efficacy and its effects on sheep consignments to other destinations. This conclusion is based on the findings of PART A, the literature review, extensive industry consultation and PART B, the incidence pattern determined by the study. It also acknowledges the case presented in the cost benefit analysis.

The immune-suppressive capabilities of the virus are acknowledged. The way in which this allows the virus to become established in an animal that would otherwise be considered immune is also noted. The inability of natural infection or vaccination to prevent re-infection is a factor in the following recommendations, although it is noted that the lesions are "*less severe and recover more quickly*".

There is evidence to suggest that the use of the 'live' vaccine and a shorter time prior to the delivery of sheep to the assembly facility could be responsible for introducing the virus into the facilities and infecting sheep destined for other markets (i.e. non-Saudi destinations)

This study showed that the prevalence of scabby mouth in non-Saudi sheep sourced from the Eastern States, where vaccination is not routinely practiced, was significantly lower than the prevalence of scabby mouth in sheep sourced from Western Australia, where vaccination is more commonplace.

The ideal time (from an industry point of view), to vaccinate sheep with the current live vaccine would be 21 days prior to delivery. It is acknowledged that this provides a logistical challenge with the current purchasing arrangements. A single vaccination protocol that involves vaccinating sheep close to the time of delivery would compound the existing problem of infecting the premises and lead to a greater risk of infecting non-Saudi shipments and/or sheep that have not been effectively vaccinated or naturally exposed to the virus.

The development of an effective “sterile” vaccination (preferably virulent field strain and delivered either subcutaneously or intramuscularly) would have immediate application to any industry protocol.

11 Recommendations

It is suggested that a single vaccination protocol be considered in place of the current double vaccination protocol required by Saudi Arabia. It is suggested that the industry re-evaluate the practice of vaccinating sheep (with the current live vaccine) close to the time of delivery to the assembly facility. It is recommended that the disease prevention strategy embrace both the principles of exclusion as well as the principles of immunity.

In regards to exclusion, any changes to the existing protocol should be conditional upon there being stringent inspection procedures in the assembly facilities at the point of delivery to assembly facilities. These inspection procedures should be aimed at providing strong feedback to dissuade producers from delivering infected sheep. It is suggested that the inspectors be independent with the sole responsibility of rejecting sheep that are unfit for export. Any mobs that show visible signs of scabby mouth should be returned (or rejected and kept separate). Sheep sourced from traders (or sheep without a clear recent disease history) should receive special scrutiny. Sheep that are delivered to the assembly facility outside of the specified times (as early or late receivals) should be subjected to the same stringent inspection procedures as described above.

In regards to immunity, it is suggested that trial shipments should be monitored utilising a single vaccination protocol, preferably at marking. Sheep that have not been vaccinated at marking could be vaccinated at least 21 days prior to delivery to the assembly facility. The practical and logistical constraints are noted but, as mentioned, the practice of vaccinating sheep (with the current live vaccine) close to the time of delivery to assembly facility is not recommended. Recently vaccinated sheep should not, under any circumstances, be mixed with sheep that have not been recently vaccinated. This recognises the fact that recently vaccinated sheep have the capacity to infect sheep that have not been recently vaccinated (and/or not been vaccinated at all).

Documentation is required to meet the Saudi protocol and this poses logistical difficulties. The existing protocol requires that all sheep destined for Saudi Arabia be tagged with a numbered ‘Saudi’ tag. In terms of timing and logistics, it is unlikely that this task could be completed at any time other than just prior to delivery. A protocol that enabled an accredited person, most likely a vaccinator, to administer tags and check documentation prior to delivery could be developed to cater to a modified protocol. It would also provide the opportunity to verify the age of sheep in keeping with their age coded property tag. Again, the practical and logistical constraints are noted.

Disease prevention in sheep destined for other markets should, as they do now, rely on an exclusion policy to keep scabby mouth to acceptable levels. These markets have historically had a greater tolerance to the disease but low levels of scabby mouth in sheep delivered to UAE have been an issue recently. There is no requirement to vaccinate sheep that are delivered to these markets. The immune status of these sheep varies considerably.

Properties with no history of scabby mouth should only vaccinate against the disease if they wish to access the Saudi market. Producers who have commenced the practice of vaccinating at marking, should continue the practice, since the disease has probably been introduced to the property due to the use of the live virus.

If the industry were to refrain from vaccinating sheep just prior to delivery to the assembly facility, there may be an opportunity to empty the feedlot and disinfect the premises (particularly the sheds). The disinfection method is described under the heading of treatment and thorough cleaning should precede disinfection. This would have benefits for sheep destined for all markets.

It is recommended that the industry investigate the possibility of a 'sterile' vaccine that utilises an virulent field strain virus and is administered either subcutaneously or intramuscularly. Work undertaken by Mercante at the Institute of Zoological Experimentation in North Eastern Italy, has shown promise in this regard [82]. It is recommended that the industry follow up on this promising lead.

As a final word of caution, this study monitored twelve consignments on six voyages. None of the consignments demonstrated a disease epidemic of the type described in the literature. This would suggest that the disease prevention strategies already in place have been effective for those sheep involved in the study. It should be noted, however, that because the immunity gained from vaccination (and/or natural exposure) is not absolute and re-infection is possible, the supply chain may always be vulnerable to a disease outbreak.

12 Appendix

12.1 Sample size

The study utilised a two-stage inspection procedure. The initial inspection determined the presence or absence of disease, and a further inspection determined the overall prevalence. Most veterinarians are familiar with the concept of sample size, particularly when it comes to establishing the presence or absence of disease. Table 30 illustrates the sample size required according to the size of the mob. Note that it is first necessary to estimate the anticipated prevalence of the disease, which is sometimes difficult. The pilot voyages, industry consultation and anecdotal evidence suggested that a prevalence of one in a thousand is not uncommon and this was the anticipated prevalence used in this study.

To determine whether or not a disease is present in a population, the sample size is calculated by the following formula:

$$n = (1-(1-p_1)^{1/d1})(N-d/2) + 1$$

Where:
N is the population size
d is the minimum number of affected animals expected in the population
n is the required sample size
p is the probability of finding at least one case in the sample

This assumes that the sensitivity and specificity of the test is 100%. More complicated formulae are required to accommodate differing levels of sensitivity and specificity. Note that to detect the presence of disease at the very low end of the anticipated range (say 0.1%), a full census is required in all but the largest mobs (see Table 30).

The study was asked to determine the prevalence of scabby mouth in each category within the consignment. Categories may vary in size from a few hundred to several thousand. Sometimes a category may involve a very large mob of over 10,000 sheep.

In the on board situation, sheep are penned into small groups. Depending on pen design and management practices the numbers involved may vary from 30-40 sheep up to one thousand sheep. Where possible it is recommended that the pen be used as the defining mob size. This acknowledges that sheep are segregated throughout the live export process and that clustering will occur. It provides the basis for disease mapping (see disease maps in Appendix). If this were not logistically possible, then treating each category as the defining mob size would be acceptable. This study used pen size and a full census to detect the presence or absence of the disease in sheep in the pens.

Note again that the sample size nominated in the table is used only to determine the presence or absence of the disease. If the disease is found to be present, further calculations need to be applied. This requires a different formula and a larger sample size, again dependent on the anticipated prevalence.

Having established the presence of the disease (stage one) it is then necessary to determine the prevalence (stage two). This involves the same principles of sampling distribution including the choice of an acceptable confidence interval or width. For the sake of the study, the accepted confidence width has been deemed to be plus or minus 10% of the expected prevalence. Note that at a high prevalence the sample size required is still quite small, however at a low prevalence, a sample that is very close to the population size is required, even for the largest of populations.

Table 42. Sample size required for detecting disease

		Prevalence	(d/N)	
Population size (N)	2%	1%	0.5%	0.1%
10	10	10	10	10
30	30	30	30	30
50	48	50	50	50
70	62	70	70	70
90	73	87	90	90
120	86	111	120	120
160	97	136	157	160
200	105	155	190	200
300	117	189	260	300
400	124	211	311	400
500	129	225	349	500
600	132	235	379	597
700	134	243	402	691
800	136	249	421	782
900	137	254	437	868
1000	138	258	450	950
1200	140	264	471	1102
1400	141	269	487	1236
1600	142	272	499	1354
1800	143	275	509	1459
2000	143	277	517	1553
3000	145	284	542	1895
4000	146	268	556	2108
5000	147	290	564	2253
6000	147	291	569	2358
7000	147	292	573	2437
8000	147	293	576	2498
9000	148	294	579	2548
10000	148	294	581	2588

*This table has been taken from the text “Veterinary Epidemiology” 3rd edition (Michael Thrusfield) under the heading Surveys (Chapter 13) [38].

For a mob of 2,000 sheep, if the expected prevalence is high (say 2%), the sample size required to establish the presence of disease is only 143 (see table 30.). To make a valid estimation of prevalence the sample required is 1,404 sheep (see table 31.). In contrast, if the expected prevalence is low (say 0.1%, as in the case of many mobs within the study), the sample size required to detect the presence of disease is 1553 (see table 30.). To make a valid estimate of prevalence the sample size required is 1959 (see table 31.). Furthermore, the smaller the mob, the more likely it is that a total census is required. The above calculations explain why a population survey (or census) approach was chosen for the purposes of the study.

Table 43. Sample size required for determining prevalence

	Prevalence (d/N)			
	2%	1%	0.5%	0.1%
	(1.8%-2.2%)	(0.9%-1.1%)	(0.45%-0.55%)	(.09%-0.11%)
Population size (N)				
10	10	10	10	10
30	30	30	30	30
50	49	50	50	50
70	69	70	70	70
90	88	89	90	90
120	117	119	119	120
160	155	157	159	160
200	192	196	198	200
300	282	291	295	300
400	369	384	392	398
500	452	475	487	497
600	532	564	582	596
700	609	652	675	695
800	684	738	768	793
900	756	822	860	892
1000	825	904	950	990
1200	956	1066	1129	1185
1400	1079	1220	1304	1380
1600	1194	1370	1476	1574
1800	1302	1513	1645	1767
2000	1404	1652	1811	1959
3000	1832	2280	2593	2909
4000	2162	2816	3308	3840
5000	2424	3277	3963	4752
6000	2637	3679	4566	5647
7000	2814	4032	5123	6524
8000	2963	4345	5639	7384
9000	3090	4624	6119	8228
10000	3200	4874	6565	9056

* with an accepted confidence width of +/- 10% of the expected prevalence and 95% confidence interval. Source J Leivaart (pers. comm) derived.

When utilizing the inspection technique we are investigating a binary response. In the case of this study, either the animal shows clinical signs of scabby mouth or it does not. From the binary response we are able to determine the proportion of the animals showing clinical signs of the disease. If the test (in this case the inspection procedure) is perfect, then repeated sampling, at the same point of time, will result in exactly the same prevalence. The number of cases is actually finite. If the test is not perfect, and/or the test is applied to only a representative sample of the population, then repeated sampling may lead to slightly different results.

Statistical analysis addresses this by determining a likely sampling distribution that reflects these factors. The use of sampling distribution is explained in Chapter 4 of the statistics text “Statistics for Veterinary and Animal Science” (Petrie and Watson) [39]. When the sample size is large, the sampling distribution is usually considered to be normal. Since this study utilises a census approach, the sample size is large and accordingly a normal distribution is assumed in the sampling distribution. The shape of the distribution is further influenced by the accuracy of the test. If the test is perfect (or near perfect) then repeated sampling leads to determinations with very little variation around the mean and minimal standard deviation. This produces a thinner, taller and more peaked distribution curve. If the test is not perfect (as assumed in this study), there may be a greater standard deviation with a wider, shorter and more extended distribution curve. In statistics, the accuracy of the test is considered in terms of its sensitivity and specificity.

The sensitivity of a test gives an indication of the ability of the test to correctly identify those animals with the disease. It is measured as the proportion of true positives that are identified as positive. Specificity provides an indication of the ability of the test to correctly identify those animals without the disease. It identifies how many cases are wrongly diagnosed as being positive.

A sample of any size will determine prevalence. The conventional way of establishing whether the prevalence determination is good (or not) is to apply a confidence level to the determined value and then describe the value in terms of the confidence width. Most analytical frameworks apply a 99%, 95% or 68% confidence level. This study has utilised a 95% confidence level. The confidence interval is defined by its upper and lower limits, the confidence width (or interval). This refers to the likelihood that the true value will fall within this range. If the confidence width (i.e. the difference between the upper and lower limit) is wide then the prevalence determination is a poor estimate. Conversely, if the confidence width is narrow then the prevalence determination is a good estimate.

12.2 Scoring system

As mentioned in the body of the report, Brightling (2001) had developed a scoring system that was used in the trial work leading up to implementation of the SLEP program in 2000 [10, 12-14]. It graded lesions according to size and was described in the handbook provided to veterinarians and stockmen travelling on vessels that included Saudi consignments [20].

This study adopted this scoring system, with some modification. The Brightling scale included lesions that could not be seen from one metre but this did not suit the purposes of this study. A simple grading system of mild, moderate and severe was preferred (see Table 45).

Table 44. The scabby mouth severity scoring system used previously (Brightling 2001).

	Description
Score 0	No evidence of scabby mouth.
Score 1	A lesion that cannot be seen from a distance of 1 metre.
Score 2	A lesion that can be seen from a distance of 1 metre but is less that the size of a 5 cent coin.
Score 3	A lesion that can be seen from a distance of 1 metre and is the size of a 5 cent coin or bigger.

N.B. This is the scoring system described in the current Stockman's handbook (Handbook for shipboard stockmen and veterinarians (sheep and goats) 4th edition November 2005.

This study involved only the detection of visual lesions. The attached figures provide a guide as to how the lesions were scored. It was noted from the outset that the scoring system reflects only the size of the lesions, and not the infectivity of the lesions, and/or the stage of development.

Rather than impose yet another scoring system, notes as to the stage and apparent infectivity were kept separate to augment the findings. The various stages of the disease are better described under the heading pathogenesis.

Table 45. Showing the scabby mouth severity scoring system used in this study

	Description
Score 0	No evidence of scabby mouth.
Score 1	Mild.
Score 2	Moderate.
Score 3	Severe.

N.B. This is the scoring system utilised in this study. It is acknowledged that small early lesions may not be detectable with the described inspection procedure. The individual capture and inspection of sheep was not practical under the terms of reference of the project.

Figure 11. Mild Scabby Mouth lesion – Severity Score 1

Figure 12. Moderate Scabby Mouth lesion – Severity Score 2

N.B. Severity score is not a score of infectivity. Healing lesions will often score higher in terms of severity, but may be shedding negligible levels of virus.

Figure 13. Severe Scabby Mouth Lesion – Severity Score 3

12.3 Disease Mapping

Disease Map - Voyage I

CARGO PLAN VOYAGE 109-L PORTLAND

Inspections 16th, 17th and 18th June 2010

PORTLAND Day 14, 15 & 16….ex Portland

Species	Heads	SM Cases	Prevalence
A Wethers	1680	0	0.00%
B Wethers	12845	13	0.10%
C.Wethers	790	0	0.00%
AYW	8807	0	0.00%
BYW	9844	4	0.04%
Hoggets	2240	1	0.04%
H RAMS	113	0	0.00%
P.Rams	92	0	0.00%
Y.Rams	107	3	2.80%
TOTAL	**36518**	**21**	**0.06%**

Scabby Mouth Prevalence

0	⬜	
0-0.5	🟧	1
0.5-1.0	🟨	2
1.0-1.5	🟧	3
1.5-2.0	🟧	4
2.0-2.5	🟧	5
2.5-5.0	🟫	6
>5.0	🟥	7

Mob boundary ☐

FREMANTLE

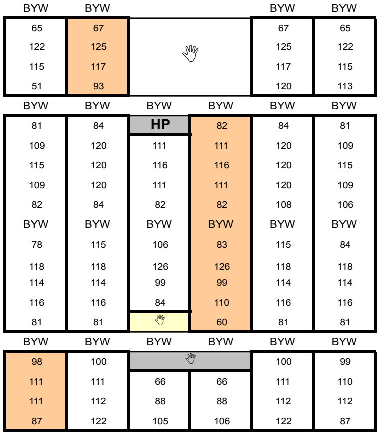
Species	Heads	SM Cases	Prevalence
A.Wethers	1302	5	0.38%
B.Wethers	2604	12	0.46%
Sp.C.Wethers	2873	6	0.21%
WT YW	6681	63	0.94%
A.Ewes	1929	6	0.31%
B-Ewes	1823	5	0.27%
A MWL	5155	40	0.78%
B MWL	2486	26	1.05%
A XBL	4945	25	0.51%
Rams Horned	182	0	0.00%
Ram Polled	207	0	0.00%
Ram Hoggets	765	3	0.39%
Ram Lambs	1498	7	0.47%
Dam Ram Lambs	315	2	0.63%
Dam Ewe Lambs	642	2	0.31%
Mixed Lambs	552	4	0.72%
Store Wethers	249	0	0.00%
Total	**34208**	**206**	**0.60%**

Total Sheep Loaded	**70726**	**227**	**0.32%**

Deck No.10

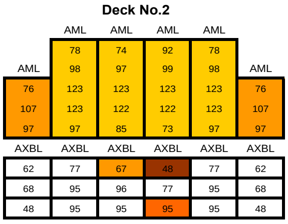
P-BW	P-BW	P-BW	P-BW	P-BW	P-BW
57	62	61	61	62	57
78	79	78	78	79	78
101	103	101	101	103	101
95	97	95	95	97	95
85	99	95	90	99	94
95	99	71	96	99	95
P-BW	P-BW	P-BW	P-BW	P-BW	P-BW
64	69	**HP**	66	69	64
95	99	102	96	99	95
90	99	92	92	99	90
67	69	68	68	89	86
P-BW	P-BW	P-BW	P-BW	P-BW	P-BW
66	95	90	69	95	70
98	97	104	104	97	98
95	94	82	82	95	95
96	96	69	92	96	96
67	67	0	54	67	67
P-BW	P-BW	P-BW	P-BW	P-BW	P-BW
82	82	✋		82	82
92	92	55	55	92	92
92	92	73	73	92	92
72	100	89	89	100	72

Deck No.11



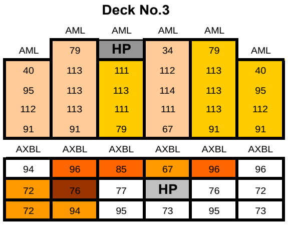
BYW	BYW			BYW	BYW
65	67	✋		67	65
122	125			125	122
115	117			117	115
51	93			120	113
BYW	BYW	BYW	BYW	BYW	BYW
81	84	**HP**	82	84	81
109	120	111	111	120	109
115	120	116	116	120	115
109	120	111	111	120	109
82	84	82	82	108	106
BYW	BYW	BYW	BYW	BYW	BYW
78	115	106	83	115	84
118	118	126	126	118	118
114	114	99	99	114	114
116	116	84	110	116	116
81	81	✋	60	81	81
BYW	BYW	BYW	BYW	BYW	BYW
98	100	✋		100	99
111	111	66	66	111	110
111	112	88	88	112	112
87	122	105	106	122	87

Disease Map - Voyage I (cont.)



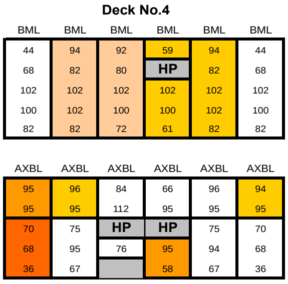
Deck No.2

	AML	AML	AML	AML	
	78	74	92	78	
AML	98	97	99	98	AML
76	123	123	123	123	76
107	123	122	122	123	107
97	97	85	73	97	97
AXBL	AXBL	AXBL	AXBL	AXBL	AXBL
62	77	67	48	77	62
68	95	96	77	95	68
48	95	95	95	95	48



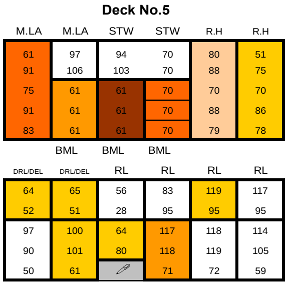
Deck No.3

	AML	AML	AML	AML	
AML	79	HP	34	79	AML
40	113	111	112	113	40
95	113	113	114	113	95
112	113	111	111	113	112
91	91	79	67	91	91
AXBL	AXBL	AXBL	AXBL	AXBL	AXBL
94	96	85	67	96	96
72	76	77	HP	76	72
72	94	95	73	95	73



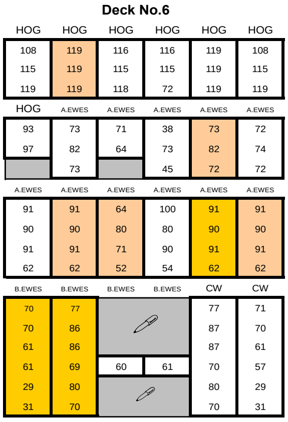
Deck No.4

BML	BML	BML	BML	BML	BML
44	94	92	59	94	44
68	82	80	HP	82	68
102	102	102	102	102	102
100	102	100	100	102	100
82	82	72	61	82	82
AXBL	AXBL	AXBL	AXBL	AXBL	AXBL
95	96	84	66	96	94
95	95	112	95	95	95
70	75	HP	HP	75	70
68	95	76	95	94	68
36	67		58	67	36



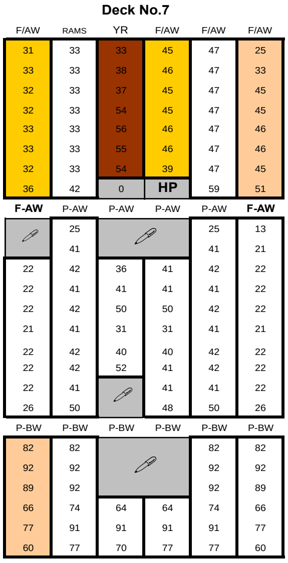
Deck No.5

M.LA	M.LA	STW	STW	R.H	R.H
61	97	94	70	80	51
91	106	103	70	88	75
75	61	61	70	70	70
91	61	61	70	88	86
83	61	61	70	79	78
	BML	BML	BML		
DRL/DEL	DRL/DEL	RL	RL	RL	RL
64	65	56	83	119	117
52	51	28	95	95	95
97	100	64	117	118	114
90	101	80	118	119	105
50	61	✎	71	72	59



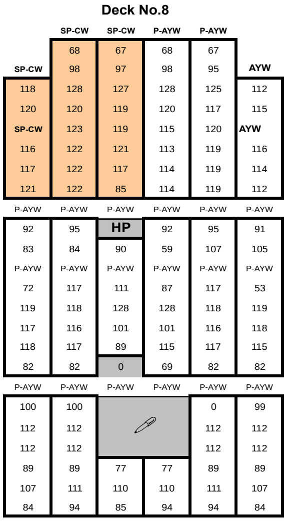
Deck No.6

HOG	HOG	HOG	HOG	HOG	HOG
108	119	116	116	119	108
115	119	115	115	119	115
119	119	118	72	119	119
HOG	A.EWES	A.EWES	A.EWES	A.EWES	A.EWES
93	73	71	38	73	72
97	82	64	73	82	74
	73		45	72	72
A.EWES	A.EWES	A.EWES	A.EWES	A.EWES	A.EWES
91	91	64	100	91	91
90	90	80	80	90	90
91	91	71	90	91	91
62	62	52	54	62	62
B.EWES	B.EWES	B.EWES	B.EWES	CW	CW
70	77	✎		77	71
70	86			87	70
61	86			87	61
61	69	60	61	70	57
29	80	✎		80	29
31	70			70	31



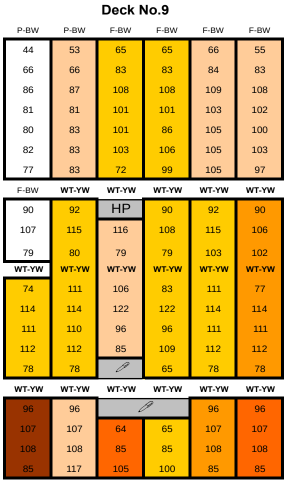
Deck No.7

F/AW	RAMS	YR	F/AW	F/AW	F/AW
31	33	33	45	47	25
33	33	38	46	47	33
32	33	37	45	47	45
32	33	54	45	47	45
33	33	56	46	47	46
33	33	55	46	47	46
32	33	54	39	47	45
36	42	0	HP	59	51
F-AW	P-AW	P-AW	P-AW	P-AW	**F-AW**
✎	25	✎		25	13
	41			41	21
22	42	36	41	42	22
22	41	41	41	41	22
22	42	50	50	42	22
21	41	31	31	41	21
22	42	40	40	42	22
22	42	52	41	42	22
22	41	✎	41	41	22
26	50		48	50	26
P-BW	P-BW	P-BW	P-BW	P-BW	P-BW
82	82	✎		82	82
92	92			92	92
89	92			92	89
66	74	64	64	74	66
77	91	91	91	91	77
60	77	70	77	77	60



Deck No.8

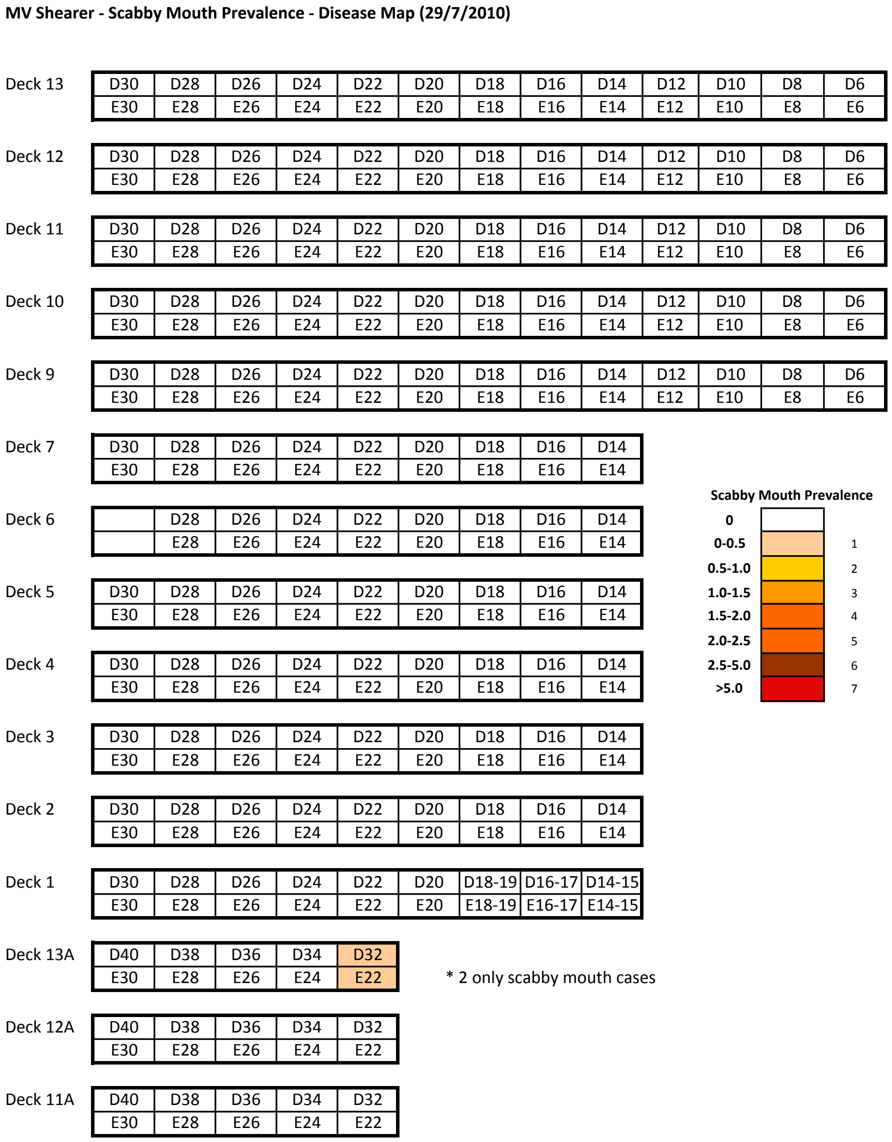
	SP-CW	**SP-CW**	**P-AYW**	**P-AYW**	
	68	67	68	67	
SP-CW	98	97	98	95	**AYW**
118	128	127	128	125	112
120	120	119	120	117	115
SP-CW	123	119	115	120	**AYW**
116	122	121	113	119	116
117	122	117	114	119	114
121	122	85	114	119	112
P-AYW	P-AYW	P-AYW	P-AYW	P-AYW	P-AYW
92	95	HP	92	95	91
83	84	90	59	107	105
P-AYW	P-AYW	P-AYW	P-AYW	P-AYW	P-AYW
72	117	111	87	117	53
119	118	128	128	118	119
117	116	101	101	116	118
118	117	89	115	117	115
82	82	0	69	82	82
P-AYW	P-AYW	P-AYW	P-AYW	P-AYW	P-AYW
100	100	✎		0	99
112	112			112	112
112	112			112	112
89	89	77	77	89	89
107	111	110	110	111	107
84	94	85	94	94	84



Deck No.9

P-BW	P-BW	F-BW	F-BW	F-BW	F-BW
44	53	65	65	66	55
66	66	83	83	84	83
86	87	108	108	109	108
81	81	101	101	103	102
80	83	101	86	105	100
82	83	103	106	105	103
77	83	72	99	105	97
F-BW	**WT-YW**	**WT-YW**	**WT-YW**	**WT-YW**	**WT-YW**
90	92	HP	90	92	90
107	115	116	108	115	106
79	80	79	79	103	102
WT-YW	**WT-YW**	**WT-YW**	**WT-YW**	**WT-YW**	**WT-YW**
74	111	106	83	111	77
114	114	122	122	114	114
111	110	96	96	111	111
112	112	85	109	112	112
78	78	✎	65	78	78
WT-YW	**WT-YW**	**WT-YW**	**WT-YW**	**WT-YW**	**WT-YW**
96	96	✎		96	96
107	107	64	65	107	107
108	108	85	85	108	108
85	117	105	100	85	85

Disease Map - Voyage II



MV Shearer - Scabby Mouth Prevalence - Disease Map (29/7/2010)

Deck 13	D30	D28	D26	D24	D22	D20	D18	D16	D14	D12	D10	D8	D6
	E30	E28	E26	E24	E22	E20	E18	E16	E14	E12	E10	E8	E6
Deck 12	D30	D28	D26	D24	D22	D20	D18	D16	D14	D12	D10	D8	D6
	E30	E28	E26	E24	E22	E20	E18	E16	E14	E12	E10	E8	E6
Deck 11	D30	D28	D26	D24	D22	D20	D18	D16	D14	D12	D10	D8	D6
	E30	E28	E26	E24	E22	E20	E18	E16	E14	E12	E10	E8	E6
Deck 10	D30	D28	D26	D24	D22	D20	D18	D16	D14	D12	D10	D8	D6
	E30	E28	E26	E24	E22	E20	E18	E16	E14	E12	E10	E8	E6
Deck 9	D30	D28	D26	D24	D22	D20	D18	D16	D14	D12	D10	D8	D6
	E30	E28	E26	E24	E22	E20	E18	E16	E14	E12	E10	E8	E6
Deck 7	D30	D28	D26	D24	D22	D20	D18	D16	D14				
	E30	E28	E26	E24	E22	E20	E18	E16	E14				
Deck 6		D28	D26	D24	D22	D20	D18	D16	D14				
		E28	E26	E24	E22	E20	E18	E16	E14				
Deck 5	D30	D28	D26	D24	D22	D20	D18	D16	D14				
	E30	E28	E26	E24	E22	E20	E18	E16	E14				
Deck 4	D30	D28	D26	D24	D22	D20	D18	D16	D14				
	E30	E28	E26	E24	E22	E20	E18	E16	E14				
Deck 3	D30	D28	D26	D24	D22	D20	D18	D16	D14				
	E30	E28	E26	E24	E22	E20	E18	E16	E14				
Deck 2	D30	D28	D26	D24	D22	D20	D18	D16	D14				
	E30	E28	E26	E24	E22	E20	E18	E16	E14				
Deck 1	D30	D28	D26	D24	D22	D20	D18-19	D16-17	D14-15				
	E30	E28	E26	E24	E22	E20	E18-19	E16-17	E14-15				
Deck 13A	D40	D38	D36	D34	D32								
	E30	E28	E26	E24	E22								
Deck 12A	D40	D38	D36	D34	D32								
	E30	E28	E26	E24	E22								
Deck 11A	D40	D38	D36	D34	D32								
	E30	E28	E26	E24	E22								

* 2 only scabby mouth cases

Scabby Mouth Prevalence

0	
0-0.5	1
0.5-1.0	2
1.0-1.5	3
1.5-2.0	4
2.0-2.5	5
2.5-5.0	6
>5.0	7

Disease Map – Voyage III

CARGO PLAN VOYAGE 113-L PORTLAND

Inspections 18th, 19th and 20th December 2010

Fremantle Day 12, 13 & 14….ex Fremantle

Species	Heads	SM Cases	Prevalence
A Wethers	5107	0	0.00%
B Wethers	6865	0	0.00%
C.Wethers	12456	30	0.24%
Store Wethers	428	0	0.00%
A Young Wethers	13690	89	0.65%
B Young Wethers	2873	32	1.11%
Trial Young Wethers	1034	0	0.00%
A Merino Lambs	4270	29	0.68%
B Merino Lambs	6994	89	1.27%
H D Lambs	340	0	0.00%
XB Lambs	7568	0	0.00%
Dorper Lambs	677	0	0.00%
Ram Hoggets	974	0	0.00%
Polled Rams	869	9	1.04%
Horned Rams	439	1	0.23%
A Ewes	1735	1	0.06%
B Ewes	1730	16	0.92%
TOTAL	**68049**	**296**	**0.43%**

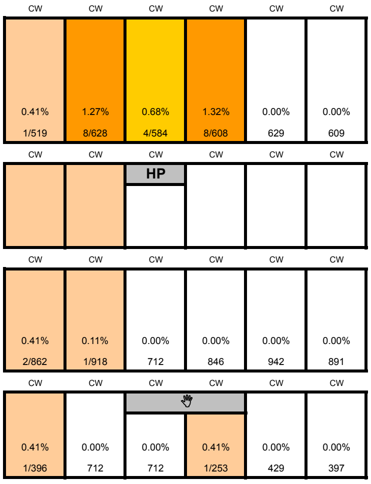
Total Sheep Loaded	**68049**	**296**	**0.43%**

Scabby Mouth Prevalence

0	⬜	
0-0.5	🟧	1
0.5-1.0	🟨	2
1.0-1.5	🟧	3
1.5-2.0	🟧	4
2.0-2.5	🟧	5
2.5-5.0	🟫	6
>5.0	🟥	7

Mob boundary ☐

Deck No.10



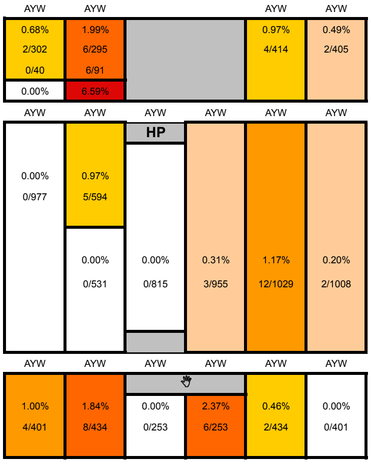
CW CW CW CW CW CW
0.41% 1/519 | 1.27% 8/628 | 0.68% 4/584 | 1.32% 8/608 | 0.00% 629 | 0.00% 609

CW CW CW CW CW CW
HP

CW CW CW CW CW CW
0.41% 2/862 | 0.11% 1/918 | 0.00% 712 | 0.00% 846 | 0.00% 942 | 0.00% 891

CW CW CW CW CW CW
0.41% 1/396 | 0.00% 712 | 0.00% 712 | 0.41% 1/253 | 0.00% 429 | 0.00% 397

Deck No.11



AYW AYW AYW AYW
0.68% 2/302 0/40 0.00% | 1.99% 6/295 6/91 6.59% | 0.97% 4/414 | 0.49% 2/405

AYW AYW AYW AYW AYW AYW
HP
0.00% 0/977 | 0.97% 5/594 | 0.00% 0/531 | 0.00% 0/815 | 0.31% 3/955 | 1.17% 12/1029 | 0.20% 2/1008

AYW AYW AYW AYW AYW AYW
1.00% 4/401 | 1.84% 8/434 | 0.00% 0/253 | 2.37% 6/253 | 0.46% 2/434 | 0.00% 0/401

Disease Map – Voyage III (cont.)

Deck No.2

	ML/A	ML/A	ML/A	ML/A	
	74	71	87	74	
ML/A	94	92	94	94	ML/A
72	117	117	117	117	73
102	117	116	116	117	102
92	92	80	70	92	92
XBL/A	XBL/A	XBL/A	XBL/A	XBL/Cne	XBL/Cne
75	93	81	59	95	29
83	115	116	95	117	29
58	115	116	89	116	59

Deck No.3

	ML/A	ML/A	ML/A	ML/A	
ML/A	82	HP	36	82	ML/A
41	117	115	115	117	41
99	117	118	118	117	99
116	117	115	115	117	116
94	94	82	70	94	94
ML/Cne	ML/Cne	ML/Cne	ML/Cne	ML/Cne	ML/Cne
113	116	102	81	115	115
86	91	92	HP	91	86
87	114	114	88	114	87

Deck No.4

ML/A	ML/A	ML/CN	ML/CN	ML/CN	BYW/CN
51	108	105	67	107	Enter
78	93	92	HP	93	64
117	117	117	117	117	117
115	117	114	114	117	115
94	94	82	70	94	94

ML/CN	ML/CN	ML/CN	ML/KO	ML/KO	ML/KO
115	115	102	80	115	114
115	114	135	115	114	115
84	91	HP	HP	91	84
81	114	91	115	114	82
44	80	69	69	80	43

Deck No.5

BYW/K	BYW/K	BYW/K	BYW/K	BYW/K	BYW/K
64	101	98	98	36	50
95	111	108	72	Enter	74
89	89	89	49	Enter	69
109	111	108	108	53	84
99	100	78	66	100	76

ML/KO	ML/KO	ML/KO	ML/KO	ML/KO	ML/KO
113	115	100	79	115	114
92	91	50	91	91	92
109	113	72	112	113	109
101	114	90	109	114	7
56	69	✋	32	114	7

Deck No.6

CW	CW	CW	BYW/Cne	BYW/Cne	BYW/Cne
97	107	104	106	109	98
104	107	55	105	109	105
107	107	62	66	109	108
BYW/A	BYW/A	BYW/A	BYW/A	BYW/A	BYW/A
84	86	84	45	86	77
87	97	75	86	97	86
	97		12	57	79
CYW/K	CYW/K	CYW/K	CYW/K	CYW/K	CYW/K
91	91	64	100	91	91
90	90	80	80	90	90
91	91	71	90	91	91
62	62	52	54	62	62
CYW/K	CYW/K	CYW/K	CYW/K	CYW/K	CYW/K
70	77	✋		77	71
70	86			87	70
61	86			87	61
61	69	60	61	70	57
29	80	✋		80	29
31	70			70	31

Deck No.7

AW/A	AW/A	AW/A	AW/A	AW/A	R
39	41	35	35	42	39
40	41	40	40	47	42
39	41	39	39	37	41
39	41	39	39	43	41
41	41	40	40	43	42
40	41	40	40	43	42
39	41	39	34	43	41
44	51	HP	HP	23	46
AW/K	AW/K	AW/K	AW/K	AW/K	AW/K
✋	25	✋		25	13
	41			41	21
22	42	36	41	42	22
22	41	41	41	41	22
22	42	50	50	42	22
21	41	31	31	41	21
22	42	40	40	42	22
22	42	52	41	42	22
22	41	✋	41	41	22
26	50		48	50	26
AW/A	AW/A	AW/A	AW/Cne	AW/Cne	AW/Cne
82	82	✋		82	82
92	92			92	92
89	92			92	89
66	74	64	64	74	66
77	91	91	91	91	77
60	77	70	77	77	60

Deck No.8

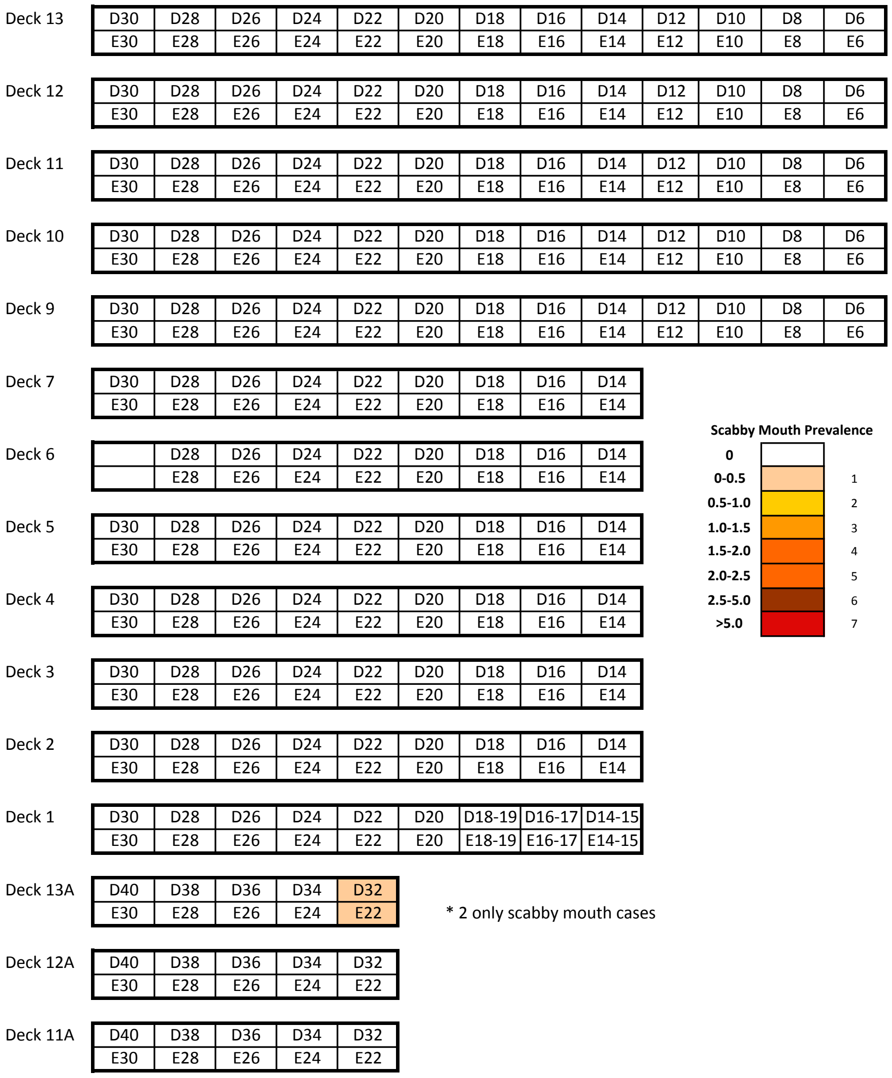
	AYW/A	AYW/A	AYW/A	AYW/A	
	60	59	60	60	
AYW/A	86	86	86	86	AYW/A
104	113	112	113	113	104
105	106	105	105	106	105
	108	105	101	108	
102	108	106	102	108	106
103	108	103	103	108	103
106	108	75	103	108	103
BYW/Cne	BYW/A	BYW/A	BYW/A	BYW/A	BYW/A
83	89	HP	86	89	86
75	78	84	55	100	98
67	108	103	80	108	49
110	109	118	118	109	110
108	107	93	93	107	108
109	108	82	106	108	109
76	76		63	76	76
BYW/Cne	BYW/Cne	BYW/Cne	BYW/Cne	BYW/Cne	BYW/Cne
90	90	✋		90	90
101	101			101	101
101	101			101	101
81	81	70	70	81	81
97	100	99	99	100	97
76	85	77	85	85	76

Deck No.9

CSpYW/C	CSpYW/C	CSpYW/C	CSpYW/C	CSpYW/C	BW/K
59	71	70	70	71	59
89	90	89	89	90	89
116	117	115	115	117	116
109	110	108	108	110	109
108	112	108	92	112	107
110	112	110	114	112	110
104	112	77	106	112	104
CSpYW/C	CSpYW/C	CSpYW/K	CSpYW/K	CSpYW/K	BW/K
90	92	HP	90	92	90
107	115	116	108	115	106
79	80	79	79	103	102
CSpYW/C	CSpYW/C	CSpYW/K	CSpYW/K	CSpYW/K	BW/K
74	111	106	83	111	77
114	114	122	122	114	114
111	110	96	96	111	111
112	112	85	109	112	112
78	78	✋	65	78	78
CSpYW/A	CSpYW/A	CSpYW/A	CSpYW/A	CSpYW/A	CSpYW/A
96	96	✋		96	96
98	98	58	59	98	98
98	98	78	78	98	98
77	106	96	91	77	77

Disease Map - Voyage IV

MV Shearer - Scabby Mouth Prevalence - Disease Map (29/7/2010)



Deck 13	D30	D28	D26	D24	D22	D20	D18	D16	D14	D12	D10	D8	D6
	E30	E28	E26	E24	E22	E20	E18	E16	E14	E12	E10	E8	E6
Deck 12	D30	D28	D26	D24	D22	D20	D18	D16	D14	D12	D10	D8	D6
	E30	E28	E26	E24	E22	E20	E18	E16	E14	E12	E10	E8	E6
Deck 11	D30	D28	D26	D24	D22	D20	D18	D16	D14	D12	D10	D8	D6
	E30	E28	E26	E24	E22	E20	E18	E16	E14	E12	E10	E8	E6
Deck 10	D30	D28	D26	D24	D22	D20	D18	D16	D14	D12	D10	D8	D6
	E30	E28	E26	E24	E22	E20	E18	E16	E14	E12	E10	E8	E6
Deck 9	D30	D28	D26	D24	D22	D20	D18	D16	D14	D12	D10	D8	D6
	E30	E28	E26	E24	E22	E20	E18	E16	E14	E12	E10	E8	E6
Deck 7	D30	D28	D26	D24	D22	D20	D18	D16	D14				
	E30	E28	E26	E24	E22	E20	E18	E16	E14				
Deck 6		D28	D26	D24	D22	D20	D18	D16	D14				
		E28	E26	E24	E22	E20	E18	E16	E14				
Deck 5	D30	D28	D26	D24	D22	D20	D18	D16	D14				
	E30	E28	E26	E24	E22	E20	E18	E16	E14				
Deck 4	D30	D28	D26	D24	D22	D20	D18	D16	D14				
	E30	E28	E26	E24	E22	E20	E18	E16	E14				
Deck 3	D30	D28	D26	D24	D22	D20	D18	D16	D14				
	E30	E28	E26	E24	E22	E20	E18	E16	E14				
Deck 2	D30	D28	D26	D24	D22	D20	D18	D16	D14				
	E30	E28	E26	E24	E22	E20	E18	E16	E14				
Deck 1	D30	D28	D26	D24	D22	D20	D18-19	D16-17	D14-15				
	E30	E28	E26	E24	E22	E20	E18-19	E16-17	E14-15				
Deck 13A	D40	D38	D36	D34	D32								
	E30	E28	E26	E24	E22								
Deck 12A	D40	D38	D36	D34	D32								
	E30	E28	E26	E24	E22								
Deck 11A	D40	D38	D36	D34	D32								
	E30	E28	E26	E24	E22								

* 2 only scabby mouth cases

Scabby Mouth Prevalence

0	⬜	
0-0.5	🟧	1
0.5-1.0	🟨	2
1.0-1.5	🟧	3
1.5-2.0	🟧	4
2.0-2.5	🟧	5
2.5-5.0	🟫	6
>5.0	🟥	7

Disease Map – Voyage V

CARGO PLAN VOYAGE 113-L PORTLAND

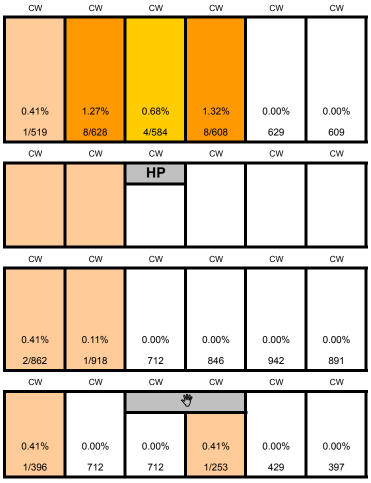
Inspections 18th, 19th and 20th December 2010

Fremantle Day 12, 13 & 14….ex Fremantle

Species	Heads	SM Cases	Prevalence
A Wethers	5107	0	0.00%
B Wethers	6865	0	0.00%
C.Wethers	12456	30	0.24%
Store Wethers	428	0	0.00%
A Young Wethers	13690	89	0.65%
B Young Wethers	2873	32	1.11%
Trial Young Wethers	1034	0	0.00%
A Merino Lambs	4270	29	0.68%
B Merino Lambs	6994	89	1.27%
H D Lambs	340	0	0.00%
XB Lambs	7568	0	0.00%
Dorper Lambs	677	0	0.00%
Ram Hoggets	974	0	0.00%
Polled Rams	869	9	1.04%
Horned Rams	439	1	0.23%
A Ewes	1735	1	0.06%
B Ewes	1730	16	0.92%
TOTAL	**68049**	**296**	**0.43%**

Total Sheep Loaded	**68049**	**296**	**0.43%**

Deck No.10

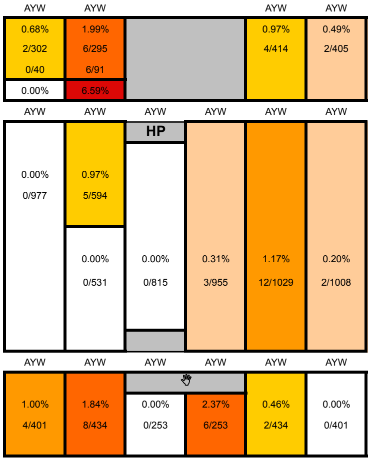


Scabby Mouth Prevalence

0	⬜	
0-0.5	🟧	1
0.5-1.0	🟨	2
1.0-1.5	🟧	3
1.5-2.0	🟧	4
2.0-2.5	🟧	5
2.5-5.0	🟫	6
>5.0	🟥	7

Mob boundary ☐

Deck No.11



Disease Map - Voyage V (cont.)

Disease Map – Voyage VI

CARGO PLAN VOYAGE 116-L PORTLAND

Fremantle

Species	Heads		
A Wethers	1522		
B Wethers	4046		
C.Sp. Wethers	3792		
Orange Tag Young Wethers	11040		
Merino Wether Lambs	11282		
Cross Bred Lambs (XBL)	2656		
Dor/Dam Lambs	1620		
Ram Lambs	1789		
Ewes	2758		
TOTAL	40505		

Scabby Mouth Prevalence

0	⬜	
0-0.5	🟧	1
0.5-1.0	🟨	2
1.0-1.5	🟧	3
1.5-2.5	🟧	4
2.5-5.0	🟫	5
>5.0	🟥	6

Mob boundary ⬜

Inspections 18th, 19th, 20th, 21st and 22nd May 2011

Adelaide

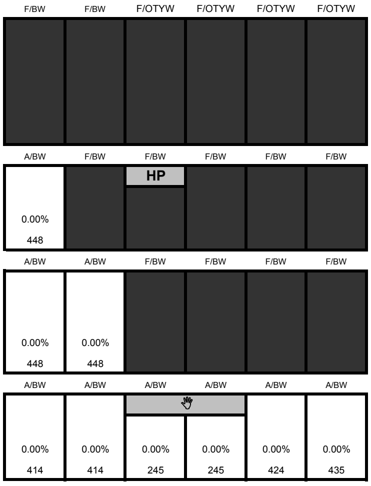
Species	Heads	Cases	Prevalence
A Wethers	483	0	0.00%
B Wethers	3296	0	0.00%
C Wethers	470	0	0.00%
C Sp Wether	2828	0	0.00%
B Young Wether (BYW)	5179	0	0.00%
Damarra	345	0	0.00%
TOTAL	12601	0	0.00%

Portland

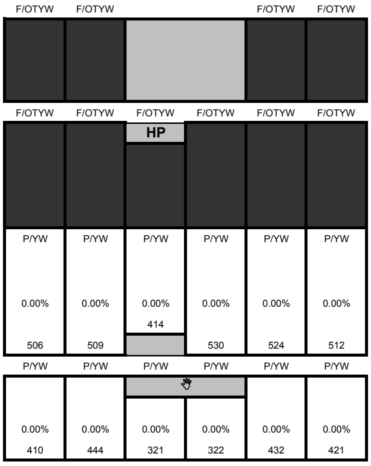
Species	Heads	Cases	Prevalence
A Wethers	2021	0	0.00%
B Wethers	9387	0	0.00%
C Wethers	1081	0	0.00%
C Sp Wether	3575	0	0.00%
B Young Wether (BYW)	6615	0	0.00%
TOTAL	22679	0	0.00%

Total Sheep Loaded	75785		

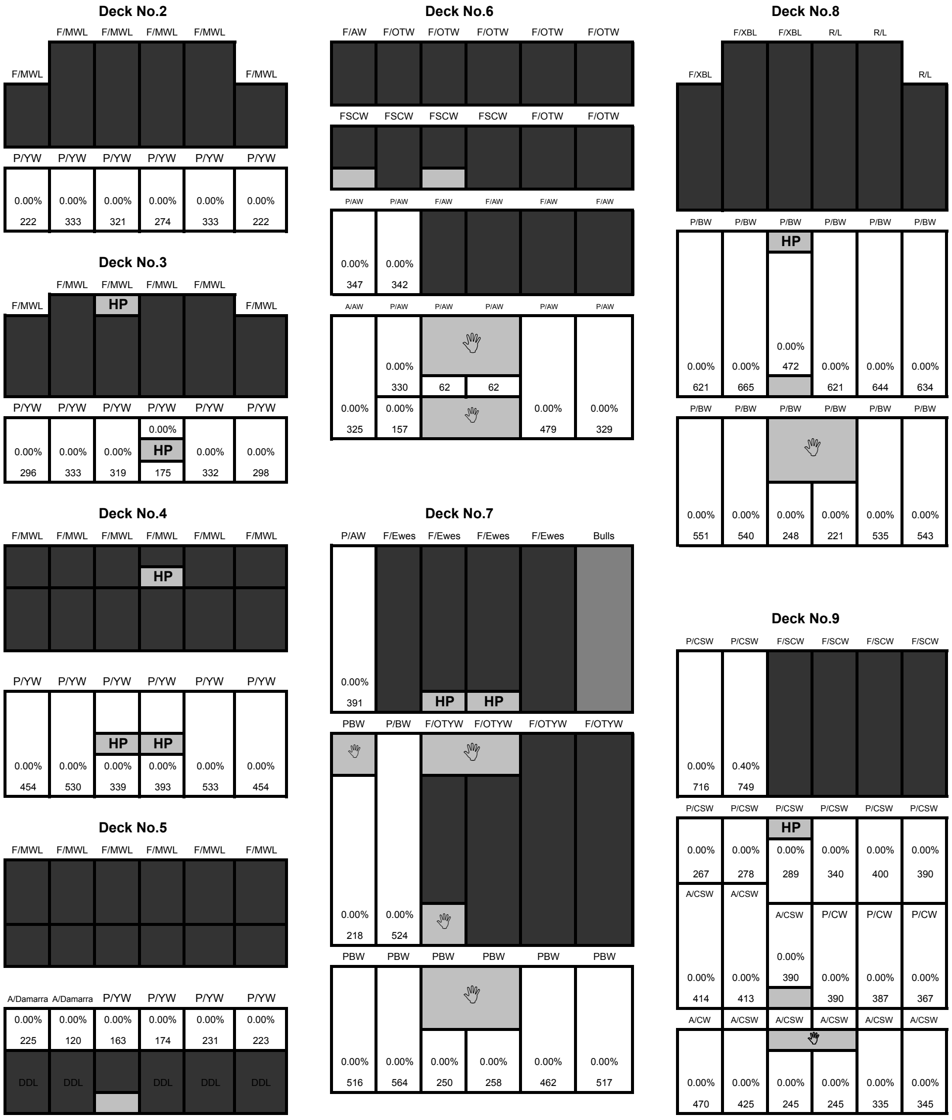
Deck No.10



Deck No.11



Disease Map – Voyage 6 (cont.)



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