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Endemic diseases scoping project

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Abstract

This project was conducted to scope a potential survey of Australian red meat livestock. Several steps were taken to scope the survey including literature reviews, a workshop of endemic disease experts, epidemiological assessment and development/scoping of a suitable research project.

The MLA ‘survey’ should be a multi-phase research project. Phases include:

<u>Phase 1</u>: Determination of a priority list of diseases using questionnaire and reviews

<u>Phase 2</u>: Review priority disease list to decide which priority diseases need further investigation

<u>Phase 3</u>: Investigate poorly understood diseases using abattoir and field surveys

<u>Phase 4</u>: Conduct economic analysis using whole farm models

The estimated resources required to complete a research project depend mostly upon the field survey design. It is impossible to select an appropriate field survey design at this stage as too many uncertainties exist. This uncertainty can only be resolved after phases 1 and 2 have been completed. Despite this, several design options are presented as examples. It is estimated that to meet all MLA proposed TOR would require a research budget of tens of millions of dollars. A more cost effective option with several constraints, uncertainties and risks, running over 3 years, will produce some valuable information on endemic diseases in red meat livestock. As the project cannot be scoped fully before the project is begun, a staged approach with stop go points will be required to manage project risks. It may be worthwhile reducing the scope of the proposed research by reducing the number of species to be surveyed, the diseases to be surveyed or the information collected for each disease (e.g. risk factors).

Abbreviations

AAHL	Australian Animal Health Laboratory
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
ACV	Australian Cattle Veterinarians (SIG of the AVA)
AHA	Animal Health Australia
AMIC	Australian Meat Industry Council
ASV	Australian Sheep Veterinarians (SIG of the AVA)
AUS	Australia
AusVet	AusVet Animal Health Services
AVA	Australian Veterinary Association
BEF	Bovine Ephemeral Fever
BJD	Bovine Johnes Disease
BOSSS	Bovine Syndromic Surveillance System
BRD	Bovine Respiratory Disease
CC	Cattle Council
CLA	Caseous Lymphadenitis
DPI	Department of Primary Industries
EDM	Equilibrium Displacement Model
ELISA	Enzyme Linked Immunosorbent Assay
EOI	Expression of Interest
GICA	Goat Industry Council of Australia
GIT	Gastrointestinal
JCU	James Cook University
LHPA	Livestock Health and Pest Authority
MLA	Meat and Livestock Australia
NAHIS	National Animal Health Information System
NAMP	National Arbovirus Monitoring Program
NLIS	National Livestock Identification Scheme
NSHMP	National Sheep Health Monitoring Project
NSW	New South Wales
NT	Northern Territory
OH&S	Occupational Health and Safety
OJD	Ovine Johnes Disease
PCR	Polymerase Chain Reaction
PIC	Property Identification Code
R&D	Research and Development
SA	South Australia
SCAHLS	Sub-Committee on Animal Health Laboratory Standards
Se	Sensitivity
SIG	Special Interest Group (of AVA)
SMC	Sheep Meat Council
Sp	Specificity
TOR	Terms of Reference
UNE	University of New England
Vic	Victoria
WA	Western Australia

Executive summary

Introduction

Endemic disease influences the profitability of Australian red meat livestock producers. Limited R&D funding should be directed to the most important and economically damaging diseases.

MLA is considering research to determine the prevalence, risk factors, mitigation and cost of disease in Australian livestock. Subsequently **AusVet was commissioned to conduct a scoping project for a potential survey of red meat livestock**. This report presents the scoping project results.

Several steps were taken to scope the survey including literature reviews, a workshop of endemic disease experts, epidemiological assessment and development/scoping of a suitable research project.

The public version of this report has financial figures redacted to facilitate tendering.

Results of literature reviews and workshop

Literature review conclusions

- Previous work on endemic disease was good but limited by budget and is dated.
- Existing data should be carefully harvested and evaluated to reduce the need for further data collection.
- If new data collection is required, the most suitable study design would be a series of observational cross sectional surveys utilising single or multistage sampling with the best collection tools being first questionnaires and then biological specimen collection.
- Livestock populations are extensively distributed with more than 74,000 cattle premises, 44,000 sheep premises and 3,300 goat premises. These should be stratified by the production zones outlined in previous studies to allow regionalised conclusions.
- Economic research to investigate the cost of diseases has generally been simplistic (only assessing direct farm costs) and relatively inexpensive, for example assessing the economics of disease with partial budgets on simulated farms.

The workshop provided valuable information to assist the scoping study and improved an existing concept of the ‘survey’. Workshop discussion points are presented.

Some workshop participants noted additional areas of research that could be useful:

a) social research to investigate reasons for poor mitigation uptake.
b) More holistic economic research.

c) Ongoing endemic disease data collection, for example to benchmark progress. These are outside our TOR but may be beneficial to livestock production if additional funds can be garnered.

Research project design recommendations

The **MLA 'survey' should be a multi-phase research project**. Phases include:

Phase 1: Determination of a priority list of diseases (resources: two consultants and a marketing research company)

- A telephone survey of producers, processors and an internet survey of rural veterinarians.
- Systematic examination of existing data, published and grey literature (e.g. industry or government reports).
- Compilation of a priority disease list.

Phase 2: The objectives are to decide which priority diseases need further investigation/research and to compile data for synopsis and further economic analysis. Use a systematic literature review and data assessment of the priority diseases.

Phase 3: Objective is to determine patterns, distribution, prevalence or epidemiology of priority diseases where diseases are poorly understood. Use abattoir and field surveys.

The estimated resources required to complete phase 3 depend mostly upon the final field survey design (the field survey is also the greatest contributor to overall budget). A large number of study designs could be developed depending on the final composition of the priority disease list and by varying survey parameters (e.g. required precision and the number of laboratory tests required). For example, an optimal field survey design to meet all specifications in MLA TOR may cost tens of millions of dollars. However, a more moderately priced field survey that could provide good quality information is possible. Such a field survey design was chosen to allow scoping of the project. This design saves money by minimising sample size (with 10% cf. 5% precision) and by stratifying the national sample across production regions (cf. replicated zonal surveys).

- Abattoir survey (resources: multiple meat inspectors, a meat inspection vet and an epidemiologist): use inexpensive NSHMP data for sheep and consider designing an abattoir survey for cattle and goats (which doesn't currently exist). Implementing an abattoir survey for goats and cattle will be challenging and success will depend on industry support.
- Field survey (resources: multiple field vets, epidemiologist, endemic disease vet, laboratory): Stratified (zone), two stage, cross sectional survey using a

questionnaire and biological specimen collection (arbitrarily 5 diseases) for each of the three species. The field survey assumes 5 laboratory tests will be conducted on each sampled animal. Cooperation by producers to collect samples will be critical.

Phase 4: Economic analysis and synopsis (resources: an economist and epidemiologist required)

- Existing and new research results are compiled to assist economic analysis and synopsis of disease epidemiology and mitigation for final reporting
- Economic analysis consists of whole farm models of representative farms for estimation of impact at farm gate with aggregation up to zone and national levels. A similar approach can be taken for processor costs. This analysis is simple for budgetary reasons and collaboration with other interested parties may allow more extensive economic analyses, for example with equilibrium displacement models which account for surpluses and economic welfare.

Terms of reference, budget and time frame

Draft terms of reference are provided for all the phases of the proposed research project including estimated budget, time to complete, desired skills of researchers and some possible contributors. However, after phase 2, TOR are necessarily generic as confirmation of a priority disease list and knowledge of existing disease information for priority diseases would be required to scope a final project. Despite this, sensible assumptions are used to allow scoping of an achievable research project.

The greatest cost is associated with field surveillance, particularly laboratory analysis of field collected samples.

It is estimated that the project would take 3 years to complete, provided several steps are pursued concurrently and 2-3 consultants and many field vets and meat inspectors were available. This time frame allows two weeks between most steps. However, more than 6 months is allowed between the completion of phase 2 and field work. This is an essential stop/go time point and would also require project management such as issue and acceptance of EOI's.

Constraints, uncertainties and assumptions

A cost effective design has been outlined. Steps to achieve cost effectiveness and resulting risks are discussed below.

Spending is minimised by:

- Reducing field surveillance by utilising assumed existing and appropriate literature and data as much as possible before collecting new data.

- Relying on assumed achievable abattoir surveillance in the first instance to collect new data.
- Field surveillance first relies on a questionnaire tool and assumes this will suffice for many priority diseases. Biological specimens for limited laboratory analysis (5 diseases for each livestock species) are collected after this.
- Sample sizes are calculated with 10% confidence intervals, rather than 5%.
- Generic risk factor data are collected thereby reducing expense to assess risk factors. It is assumed such data are adequate for assessment of associations between most priority disease and hypothesised causes.

The research **project design has some constraints or potential risks. These should be managed with appropriate project design (see risk management below).** Risks include:

- Existing data and literature on priority diseases could be deficient. This could mean that greater field data collection is required which could increase costs.
- Abattoir surveillance may not be possible in cattle or goats which would lead to greater reliance on more expensive field surveillance.
- Bias may develop to some extent through reliance on questionnaires, due to the modest sample size of farms across the nation and through collection of generic risk factor information.
- Laboratory analysis of 5 diseases has been budgeted. The addition of extra tests will result in a more expensive project. Alternatively, fewer lab tests may be required for some species thereby substantially reducing the budget.
- Laboratory analysis is assumed to occur with relatively inexpensive serological tests that are assumed to be quite accurate. If tests are less accurate then greater sample sizes will be required and if more expensive tests are required (e.g. PCR or syndromic investigations such as abortions) budgets will also be more expensive.
- Later phases of the project cannot be scoped accurately until the priority disease list is determined and examined (i.e. after phase 1 and 2).

Risk management

A **staged approach to project implementation** should occur with the relatively inexpensive phases 1 and 2 completed before a MLA stop/go decision point is reached. A final field survey design and budget can then be completed and a decision to complete the project can occur. This will ensure MLA funds are disbursed responsibly by mitigating the uncertainty inherent in scoping and planning the project in advance. This will also ensure useful outcomes (for example a valid list of priority diseases and which of these diseases require future research) even if further field work is subsequently considered too expensive.

It may be worthwhile considering **inducements** to encourage farmer or abattoir participation (for example payment of an hourly rate for labour to complete questionnaire surveys or muster animals for biological specimen collection). This has not been budgeted.

Conclusions:

In order to **meet every MLA TOR a very expensive research project** would be required.

Therefore **a cost effective survey of endemic disease in red meat livestock** is proposed. This project will provide very valuable information and can satisfy most of MLA specified TOR. Such a project is expected to extend over 3 years.

Large projects such as the research project proposed include **inherent uncertainties** and hence a **staged approach** is recommended for risk management.

Following the initial two phases of the project whereby an extensive priority disease list is reviewed, a further assessment of the budget and field survey design will be required

It may be prudent to reduce the scope, for example by excluding one or more species from consideration, reducing the size of the priority disease list or reducing the number of laboratory tests required. It is recommended that at least the disease list be re-considered after phase 1 and 2 when more information is available.

It is recommended that MLA interactively explore assumptions and uncertainties using epidemiological knowledge and do some financial modelling before implementing the initial phases of the research project.

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1. Background and introduction

Meat and Livestock Australia contracted Sackett et al. (2006) to estimate the productivity costs of the major endemic diseases of sheep and cattle in Australia. This study provided absolute costs and a relative ranking of the major endemic diseases of livestock in Australia using a standardised methodology. The results have in part assisted MLA and other organisations to direct research and development money for endemic disease in the livestock sector. However, the study has some limitations as a document that can guide current decision making. MLA is therefore considering a national survey to determine the endemic diseases of livestock that are most economically damaging on farm. AusVet Animal Health Services was commissioned by MLA to scope and design such a study.

MLA indicated that a future survey should be regionally relevant, should consider 20-40 priority diseases for each species (sheep, cattle and goats), should utilise existing data and research where possible but should also collect field data. The objective of such a survey should be to determine priority diseases and for these diseases prevalence, risk factors, mitigation steps and the economic cost at the farm level and processor level. This project's TOR was to design such a survey along with the scope and required resources. The project's TOR are included as Appendix 1.

In designing a survey for these objectives there are several pieces of information to be considered and various means of acquiring the information. In this project, knowledge of epidemiological study design, Australian livestock and veterinary populations, economic methods and existing data was assessed with several literature reviews. Prior research of Sackett et al. (2006) and recent endemic disease emergences were assessed to assist consideration of endemic disease. Several epidemiologists used their knowledge of epidemiology, surveillance and Australian livestock production and the preceding literature review steps to develop a tentative research project that can meet MLA objectives. Twenty one endemic disease experts and representatives of interested bodies provided additional information and feedback on the tentative plan at a one-day workshop in Sydney.

This report documents the process and also the proposed research plan that was developed during this process.

2. Issues of importance to project design

Literature reviews and background papers on several issues were written and circulated to provide essential information for the workshop and project generally. These are summarised below and provided as appendices.

2.1 Endemic diseases of importance

The document aimed to provide context for workshop participants on the report by Sackett et al. (2006). It also provided an additional listing of newly emerged diseases or diseases where the knowledge base has expanded in recent years. The important diseases were then categorised to aid decision making at the workshop. The purpose was not to prescribe a list of economically important diseases (as this will occur in the proposed MLA research project), but to stimulate discussion and thought as to appropriate means of surveying and assessing the economic impact of such diseases in any future MLA survey. See Appendix 2.

2.2 Epidemiological study designs: advantages and disadvantages

A very useful means of surveying livestock may be screening of existing data such as existing databases of both abattoir data and research projects. This would allow rapid and relatively inexpensive collection of data.

If field data are required, then an observational study is required as this allows estimation of disease frequency and risk factors. Two observational study designs provide disease frequency and risk factor data, cohort or a cross sectional study designs. On balance a cross sectional study would be best as MLA has indicated they require a study of short duration (1-2 years) (Johann Schröder, Pers. Comm., Feb 2013). If risk factors were not to be considered (so as to save money and because much data on risk factors already exist for many diseases), a simple survey could be conducted. However, if a cross sectional study is pursued it must be accepted that data may be temporally limited in nature as a cross sectional design takes a ‘snapshot’, although questionnaires and serological assessment need not limit an assessment of disease status or risk factor exposure to the immediate sampling period. The most appropriate sampling strategy will likely comprise some stratification to ensure the geographic representativeness of the sample. Additionally, difficulty obtaining a complete sampling frame for all animals in each livestock class will mean that multistage sampling is required. See Appendix 3.

2.3 Population: Abundance and distribution of red meat livestock and rural veterinarians

Adequate survey design depends upon knowledge of the distribution and abundance of the populations being surveyed. Critically, knowledge of approximate population abundance is required to calculate appropriate sample sizes and to interpret survey results. Examination of livestock census data reveals numbers of premises and population sizes of livestock nationally and by production zone, significant hierarchical structuring of the population, regional variability and divergent distributions between species. This indicates regionally tailored approaches are required, that some zones can remain un-sampled for some livestock species (as minimal populations exist), that some form of multilevel sampling is indicated in most regions and that some regions are much more important to national production than others. There were sufficient numbers of rural veterinarians in most zones indicating that internet or telephone surveys of veterinarians may be a realistic means of data collection in most zones. See Appendix 4 (Livestock) and Appendix 5 (Veterinarians).

2.4 Economic analyses: tools and possibilities

Economic analyses are critical to decision making in animal health. There are many instances nationally and internationally where simple financial analyses allow the direct economic costs of a disease to be considered at farm and even at national level. These include partial budgeting at a simulated or observed farm level and extrapolation to aggregations of farms (e.g. national). Such analyses are somewhat limited (but cheaper than more holistic approaches) as they do not consider indirect and supply chain consequences that would present a fuller picture. An expanded TOR (to include market equilibrium effects) may be less biased but will be more expensive. See Appendix 6.

3. Information from workshop

A one day workshop was held at near Sydney Airport on the 9th of April, 2013. The workshop’s primary objective was to gather information, ideas and to identify issues to assist scoping the endemic disease research project. The day was structured into workshop sessions, each session covering several related topics of relevance to scoping the project. Each of the subheadings below represents a defined topic that was discussed and presents the main points from each topic.

It is important to note that points presented are the considered view of workshop participants but were often limited by a lack of objective evidence. Despite this they are presented to assist development of research project design. Additionally, each of the points of view are not necessarily accurate but are presented in their entirety. A more complete record of discussions for each topic is presented in Appendix 7. Workshop attendees are listed in Appendix 8.

3.1 Population

Objective: The primary objective of this workshop session was to gather information on sampling frames so that representative sampling of populations could be conducted.

Conclusions:

- Livestock populations are dynamic and rapidly change thus leading to different endemic disease problems over time. This may lead to biases if a project occurs at a point in time as some scenarios will not be represented in sampling. An example was provided that if the grain price collapses, then feeding of sheep in a feedlot situation increases thus leading to a different endemic disease picture. The time of sampling may not coincide with this period of grain collapse and hence under-estimate certain diseases in sheep. It is possible that a questionnaire tool to collect data may resolve this problem because producer memories, although not perfect, are longer than the current circumstances.
- PICs are the premium sampling frame but are not routinely accessible due to privacy constraints (i.e. not accessible to those outside government or for certain purposes even in government). Access may be gained by involving government departments/LHPA in research but funds may be required as no capacity for this research is available in departmental budgets. Another alternative to accessing this is for questionnaires inviting participation to be sent out by state departments.
- ABS agricultural census sampling frames have been used for research (e.g. ABARES). ABARES has access to this sampling frame and possesses a survey group with experience using it. To access this through ABARES would require ABARES involvement as a paid part of the process. Some significant bias may result from using this as a sampling frame as it will miss all hobby farms which are an insignificant part of the population individually but cumulatively comprise a (significant?) proportion of production in Australia.
- MLA levy database may be a relatively comprehensive sampling frame and consultants working on MLA behalf for research are likely to receive permission to use this data base for surveillance of endemic disease.
- Several other sampling frames were mentioned but all have inherent biases. These include private research company phone lists, client lists such as Mackinnon projects client lists of sheep producers in Victoria or veterinary practice lists, pregnancy diagnosis lay operators, LHPA lists in NSW (possibly a less biased sampling frame) and stock and station agents. Farmer associations were seen to be too unrepresentative.
- Vets would be best accessed through the email lists of the SIG at AVA. There are 300 sheep vets represented on the ASV mailing list and 1100 vets on the ACV list (i.e. approximately 30% of the size of the population of all rural vets). Board registration lists may be useful if privacy constraints are not an issue.
- Production zone areas should be refined (this view was not strongly supported).

3.2 Endemic diseases

Objective: review the list of diseases in Sackett et al. (2006) to determine whether attendees would suggest changes.

Conclusions:

- **Generally, the list of Sackett et al. (2006) is good** and contains most of the diseases of importance (although goats are absent).
- **Some syndromes are extra-ordinarily damaging** but it is often difficult to diagnose a specific disease (e.g. perinatal mortality in adult sheep).
- **Under-nutrition and starvation are exceedingly important** as they are predisposing risk factors for many diseases. They should be within the definition of disease for this project.
- **Goat diseases** that are important include:
    - Physiological abortion
    - Internal parasites (e.g. *Haemonchus contortus* especially but also parasites that cause scours and liver fluke)
    - Q fever from zoonotic point of view- even in dairy goats, still getting disease even though milkers are vaccinated
    - There is a broad collection of inherited defects (especially teeth, udder and leg malformations/conformation) in goats due to importation and genetic bottlenecks, and also because individuals imported may not be adapted to the Australian environment
    - Footrot is significant as strains that are benign in sheep are generally virulent in goats
    - CLA is an issue as the sheep vaccine is not effective and infection leads to discharging abscesses
    - BJD/OJD
    - Plant poisonings
    - Clostridial diseases
    - In wild harvested goats development of disease between harvest and slaughter/export is significant. This includes transport injury (e.g. suffocations), stress induced disease such as salmonellosis. Movement of feral goats to wetter areas is a big risk factor for disease. Generally though, rangeland goats have a very low prevalence of disease before harvest and transport occurs.
- **Sheep diseases** that should considered to be added to the list of Sackett et al. (2006) or relisted as higher priority diseases include:
    - Pleurisy/pneumonia
    - Foot rot and abscesses in some regional locations
    - *Haemonchus contortus* is a critical issue in some regions
    - OJD should be a priority disease as there are such social impacts and because there are a lot of hidden control costs

  - Trace element deficiencies are becoming more common in some regions (e.g. Victoria) with intensification.
  - Mastitis is an emerging problem
  - Bacterial enteritis
  - Liver fluke
  - Grass seeds
  - Sheep measles (*Taenia ovis*)
  - Cheesy gland (caseous lymphadenititis)
  - Clostridial diseases
  - Grass tetany (hypomagnasaemia)
  - Hydatids
  - Hypocalcaemia
  - Ovine brucellosis
  - Photosensitization
  - Pregnancy toxaemia
  - Sarcocystosis
  - Scabby mouth
  - Selenium deficiency (trace element deficiency)
  - Sheep measles
- **Southern beef diseases** that should be considered to be added to the list of Sackett et al. (2006) or placed as higher priority diseases include:
  - Trace element deficiency
  - Theileriosis
  - Calf scours
  - Bovine respiratory disease complex
  - BJD (hidden impacts)
  - Buffalo fly
  - Anthrax
  - Annual and perennial ryegrass toxicity
  - Bovine ephemeral fever
  - BJD
  - Weaner ill thrift
  - Hydatids
  - Pestivirus
  - vibriosis
  - Leptospirosis
- **Northern beef diseases** that should be considered to be added to the list of Sackett et al. (2006) or placed as higher priority diseases include:
  - Plant poisonings (e.g. *Pimelea* poisoning)
  - BJD (especially as there is a huge trade impact currently)
  - Bluetongue (trade)
  - Pestivirus
  - Phosphorus deficiency
  - Trichomoniasis

    - Campylobacteriosis
    - Pink eye
    - Q-fever
    - Perinatal mortality
- **Feedlot beef diseases** that should be considered to be added to the list of Sackett et al. (2006) or placed as higher priority diseases include:
    - Lameness
    - Acidosis
    - Arthritis

3.3 Economic costs of disease

- **Data:** Need to identify occurrence at herd and individual level, losses and availability and expense of mitigation (should be good data on mitigation). Collect data during questionnaire survey. Other data collection methods including benchmarking good v. poor farms so that you can assess what can easily be changed.
- **Partial budgeting** would be the key tool to look at production impacts of diseases. Then can aggregate this up regionally and nationally.
- **Broader impacts** of some diseases such as BJD and Theileriosis should be studied with more holistic methods. If you don't look beyond the farm gate you won't be able to prioritise disease accurately. Need to look at social impact (e.g. stigma). Look at interaction between disease, resources, costs and prevalence.
- **Regional focus**: ensure studies are regionally focussed.

3.4 Existing data sources that could be useful

Objective: Identify existing data sources that may provide data or collaboration opportunities to address MLA's research question

Conclusion:

General points

- **Data do exist** but much of it is poor quality, and hence we will need to design some data collection. This can be expensive or very expensive if looking at syndromes. However, existing data should be the first choice if they are suitable.
- **Massive number of historical data sources** (e.g. trace elements research at state departments). However, need a considerable effort (resources) to access and make this available (although this will be cheaper than re-collecting field data).

- **Generally many diseases are well understood.** Instead of conducting more research on endemic disease, budget should be targeted to reasons that uptake of known mitigation steps is poor.

Lists of potential data sources

- MLA cash cow (78 northern breeding herds followed for several years and examined serology (pestivirus, BEF, *Neospora* and *Leptospira*), faecal phosphorus and risk factors).
- Feedlot BRD project (B.FLT.0225)
- Northern cattle mortalities project
- JCU goat health project with MLA.
- NAHIS (e.g. NAMP)
- University studies (especially as students make this very inexpensive)
- Serology banks (e.g. bovine at AAHL)
- Lots of case data
    - DPI or private lab accessions
    - Knackery surveillance
    - Saleyard surveillance
    - Syndrome reports are reported to SCAHLS (http://www.scahls.org.au/guidelines/reporting_of_syndromes)
    - Farmer sources (e.g. apps)
    - Flock and herd website of LHPA (http://www.flockandherd.net.au/index.html)
- NSHMP
- Public health arbovirus data
- MLA project on Theileriosis
- Economic data sources include ABARES, lifetime ewe, better beef and market indicators
- Beef up forums in northern Australia- deliver questionnaires at those

3.5 Contributors to proposed MLA survey

Objective: determine whether participants would wish to contribute to future research

Conclusions:

- **Very broad range of potential contributors. Many of the workshop participants are potential contributors and can be approached for further involvement.**
- MacKinnon group interested and have an on-farm project (cross sectional autopsies) that may be able to be to contribute to a rapid and inexpensive survey - John Larson
- University of Sydney- Peter Windsor
- LHPAs

- SIG of AVA- ACV, ASV would contribute. Sometimes private vets have good historical data in practice databases, but generally paying them to complete a task would be the best method.
- State DPIs, NSW DPI was reported as unlikely to contribute due to cuts, farm services at Vic DPI would contribute but would require payment, Tasmania likely contribute
- Perhaps jurisdictional reference groups
- Livestock Biosecurity Network
- Tasmanian Institute of Agriculture

3.6 Expense of collecting data

Objective: cost certain parameters for later use in scope calculations

Conclusions:

- Vets and vet consultants cost (hourly and /km fees)
- Some herd and flock consultants (daily fee)
- DPI and LHPA staff (hourly fee)
- PhD students are very good value
- Laboratory testing: serology (ELISA), antibody capture ELISA and PCR. Bulk testing will considerably lessen expense (for example if +1000 samples, can then utilise robotics which may reduce expense).
- If using laboratory methods to diagnose syndromes (e.g. abortion) then the price can be very expensive.

3.7 Survey design feedback

Objective: Seek attendee feedback on draft plan presented at workshop

Conclusions:

- Some specific comments on concept diagram were made. See appendices for specific comments but some important comments are made here.
    - Step 1 needs to account for recall bias, perhaps collect score data and be phrased very carefully (e.g. what are the problems around the district, syndromes etc.). Each farmer may only recall 4-5 diseases and not 20-40. Need to validate with other data to ensure accurate and unbiased. May need regional lists. Lists should be based on risk (likelihood and consequence)
    - Link box 5 and 8 (or 9 and 10)
    - Should be an ongoing research component to update results
    - Should be a phase to the research where the reasons for poor uptake of known mitigation steps is investigated (include at step 5), perhaps social research.

- General comments
    - Overall seems a sensible research plan subject to some tweaking
    - One group questioned need for initial questionnaire survey
    - Subclinical disease may be hard to diagnose with questionnaires
    - The economic modelling should be conducted predominantly with ‘partial budget modelling’ but there may be opportunity to increase scope by including other funding sources (example processors to fund an expansion of research)
    - Ongoing data collection seen as important (e.g. another step on the concept diagram)
    - Must be regionally focused
    - One group stated that prevalence from cross sectional studies not ideal as it only reflects current conditions. Hence need incidence data

Need to provide feedback to producers.

4. Recommended research project

4.1 Objective of survey

The primary objective is to determine the prevalence and economic costs of endemic diseases of red meat livestock in Australia, allowing for regional variation. A secondary objective is that risk factors should be determined with subsequent identification of intervention strategies. Separate assessments for sheep, beef cattle and goats are required.

4.1.1 Refinements of objectives specified in TOR

Refinement of open ended disease objective

Following discussions with MLA the open ended disease objective has been refined to a priority list of diseases, possibly 20-40 diseases for each species (Johann Schröder Pers. Comm., February 2013). This refinement is important; otherwise the scope of the survey is without bounds.

Opportunities for refinement of economic objective

Direct farm productivity costs and processing costs of disease are the focus of the economic part of the survey. That is, the financial effect of disease on the efficiency and quality of physical resource transformation at the farm and abattoir level (i.e. disease impact on mortalities, lost production, treatment and prevention cost (labour, drugs), trimming and downgrading).

However, it is important to note this approach will likely result in an incomplete assessment of the economic impact of disease on farm profitability. For example, disease at a larger scale has impacts on livestock commodity supply which affects the price commanded by farmers for their products and hence indirectly affects individual farm profitably. A more holistic economic assessment of disease impacts on farm profitability would need to consider this disease impact on supply (and other issues). For practical reasons of budget, the economic assessment will only assess direct costs on farm and at processing plants. However, there may be scope for other interested parties to partially fund a more holistic economic assessment, such as other groups within MLA. This would be a benefit to livestock producers but may not be justifiable from the animal health and biosecurity group within MLA.

Refinement of risk factor objective

Risk factors and resulting mitigation strategies are well understood for many endemic diseases of livestock, although implementation of mitigation strategies may be poor. Therefore conducting repeated and costly research to determine risk factors for those diseases is unwarranted. Instead investigation of risk factors should be reserved for those diseases that are newly emerged or poorly understood. Thus, a basic survey to collect prevalence and economic data is required for some diseases that are already well understood, whereas an observational study that also collects information on risk factors needs to be conducted for other poorly understood or recently emerged diseases (e.g. Theileriosis). However, this makes planning and scoping the project more difficult. That is, collection of risk factor data is more expensive than simple prevalence data. Without an *a priori* understanding of the diseases of economic importance to red meat producers it cannot be estimated how many diseases will require either collection of prevalence data or collection of full risk factor data.

A middle ground that allows relatively inexpensive collection of risk factor data is to collect comprehensive but generic risk factor data at every sampled farm. This will allow risk factor data to be collected for many diseases that are poorly understood in one series of questions. This will allow surety to project scoping and prevent the need for specific collection of risk factor data for every disease whose epidemiology is poorly understood. Individual risk factor data collection for many diseases would be very time consuming (and expensive) and reduce compliance by surveyed farmers. Some minimal disease specific risk factor data may need to be collected if a generic approach cannot meet objectives for every disease.

4.2 Population of interest for survey

The target population is red meat livestock of Australia, that is sheep, cattle and goats. The species need to be considered separately when designing the survey.

Importance of knowledge of population of interest

The population distribution and abundance of sheep, meat cattle and goats are outlined in the relevant discussion paper (see appendix 4). That discussion paper subdivides the meat cattle and sheep population into production zones and summarises population sizes. Provided it is realised that population estimates are downwardly biased (by ABS methodology) these zonal population estimates can be used to help design a future survey of livestock. For example, the population information can be used to:

1. Select appropriate sample sizes to design sampling

If the objective of a survey is to collect biological data from individual animals on farm, the number of premises and the mean number of animals on each farm is essential information to design a survey (e.g. to correct calculated sample sizes using finite population corrections).

2. Allow regionalisation of sampling

The combination of census data and beef and sheep regions allow regionalisation of sheep and cattle surveys (for example sampling stratified by region) and hence production of regional surveys. A similar approach may be possible to assess goat populations using an alternative regional subdivision such as state or territory, since production zones have not been established for goats.

3. Determine which areas have minimal population density or abundance and hence which areas do not require sampling

Some areas have minimal species populations. For example across the entire northern high rainfall sheep zone there are only 69 sheep farms in an area of 1.8 million km^2 with a density of less than 0.1 sheep km^{-2} . This indicates that this area can have little impact on the economic output of the sheep industry and is not a priority for sampling. This can present opportunities for savings in a national survey as this area is remote and relatively expensive to survey.

If the survey is to actually be based on a questionnaire of graziers and not biological sample collection then this data would still be useful as graziers are associated with farms. That is, the same information on farm populations within production zones could be used to select a sample size of graziers (although a second stage in sampling would not be possible). However, if the questionnaire data collection tool was focused on veterinarians estimates of veterinarian populations and distributions would be required. Such summaries have been generated using board registrations and could be repeated again. For example in 2006 there were approximately 7510 veterinarians registered in Australia (Heath, 2008). This data was assessed and there were from 0 (e.g. Barclay) to 1811 rural veterinarians in beef and sheep production zones.

Sampling of subpopulations

During survey design it is important to consider which subpopulations can be accessed for sampling and what samples collected from these subpopulations can indicate about the overall population (i.e. are subpopulations representative of the target population and hence are valid inferences possible to the target population). The TOR discusses many data sources representing distinct subpopulations, but one particularly important subpopulation is abattoir populations. These data are important because they can be collected relatively inexpensively and a large range of diagnostic specimens and pathological observations can be collected from slaughtered animals. However, significant issues exist (see below for further discussion).

4.3 Survey design

A multistep research project is proposed to provide the necessary data for an assessment of endemic diseases of livestock in Australia (see Figure 1 which outlines these steps). The project should be repeated separately for each of the three species of interest (sheep, cattle and goats). Additionally, most of the program (steps 4-9) should be repeated separately for each disease for each species (after a priority list is generated with steps 1-3).

The first three steps include a pilot telephone and internet questionnaire survey, review of relevant existing data and brief literature survey to determine a priority disease list (step 1, 2 and 3). An extensive literature review of each disease on the priority list is then required (step 4) to determine whether there is enough published data to describe the diseases impact on Australian livestock and if further research is required. Further research may involve field surveys on farm and can rely on biological specimen collection (if the accuracy of diagnosis on clinical signs is poor) or questionnaire surveys of vets and producers (step 5). Alternatively, abattoir surveys will be less expensive for diseases that do not bias presentation for slaughter and for diseases which are practically surveyed in abattoirs or cause direct financial costs to abattoirs (step 6). Disease data can then be compiled and analysed (step 7) for use in economic analysis using whole farm enterprise models and methods accounting for processing costs (step 8) and reported (step 9).

Additional beneficial research includes social research to investigate why diseases of significance that are well understood are not being effectively controlled and a more holistic economic analysis. Investigation of these areas is outside the scope of the project as specified in this projects TOR but would be off benefit to the livestock industries. Each of the 9 steps required to design an endemic disease survey are discussed below in greater detail. A GANTT chart is presented as Figure 2.

Figure 1: A concept diagram of the proposed MLA endemic diseases research project. The red boxes and solid black lines are considered core parts of the research project. The grey and dashed lines are useful parts of a research project, but outside the scope of this research project's TOR.

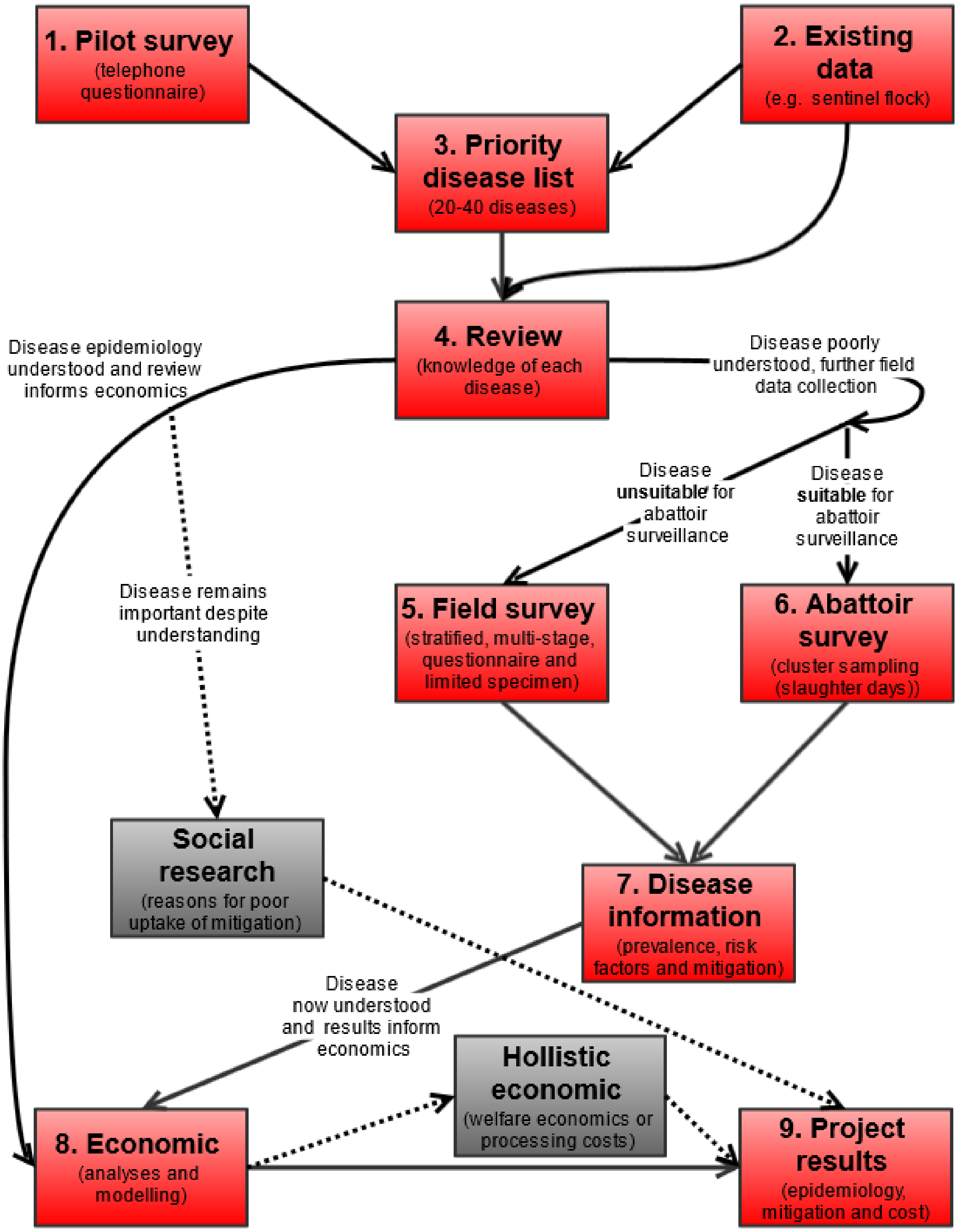
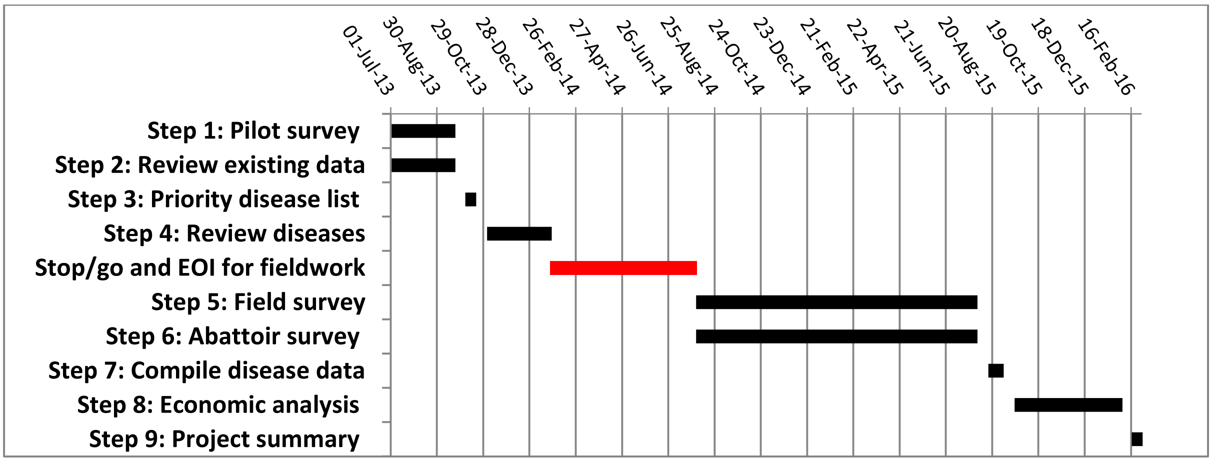


Figure 2: A GANTT chart of the proposed research project.

This chart includes time for consultants to complete research tasks, 2 weeks time between most steps but more than 6 months for MLA stop go decision making and project management between completing phase 2 (a reviewed priority list) and abattoir and field survey work. Black bars represent research steps, whereas the red bar represents MLA management time.



4.3.1 Step 1: Pilot questionnaire survey

Recommendation

Generate a priority list of the 20-40 most economically damaging diseases of red meat livestock using a telephone questionnaire of producers and abattoir managers and an internet survey of rural veterinarians. Sampling frames should be the MLA levy database for producers, AMIC abattoir lists (if available) and the cattle and sheep SIG of the AVA. Questionnaires should be designed by veterinary epidemiologists. A commercial telephone research company should conduct the telephone survey and the internet survey should be conducted using free internet software. A stratified (by zone) national random survey is required with sample sizes dictated by saturation concepts from social research.

Discussion and rationale for pilot questionnaire surveys

The objective of the pilot study is to help to generate a priority list of the most economically damaging diseases of red meat livestock (in conjunction with step 2-existing data). This list is required to narrow the scope of the project from an open ended research project to 20-40 diseases. This will ensure that a practical and structured/representative survey can occur later. An open ended question would be impractical (prohibitively expensive) for structured field data collection as there are many hundreds of diseases that could be examined and many hundreds of diagnostic tests that could be pursued. It is proposed that a questionnaire survey of veterinarians, processors and livestock producers occur. The method proposed to sample producers and processors is with a telephone questionnaire. The method proposed to sample veterinarians is with internet surveys targeting the cattle and sheep SIGS of the AVA (potentially with an additional telephone questionnaire of veterinarians if response rate to the internet survey is poor).

The questionnaire would generally be considered to be qualitative or perhaps a simple quantitative study (as it could also be argued to be descriptive). Questions should be open. The key question to be answered is: What are the main diseases of economic concern in the respondent's area (by species)? A ranking should be sought for this list. Additional information such as why each of the most important diseases are economically damaging could be sought if this does not extend the questionnaire too much. Location data of respondents should be collected as well as information on the type of veterinarian interviewed or the type of enterprise of the livestock producer or processor. This could be applied across the country using a commercial company for producers and free internet survey software such as *Survey Monkey*[1] for veterinarians.

The best sampling design is debatable. Undoubtedly stratified sampling (on geographic area such as production zone) is required to ensure that a geographically representative sample is collected[2]. Within zones, sampling could be random or some authors believe that qualitative research should be based on purposive sampling, for example targeted to the most knowledgeable individuals to ensure that information is maximised (Jette et al., 2003). Purposive sampling implies knowledge of all the individuals to be sampled and is unlikely to be available for a large and diverse national population of producers and veterinarians. Hence a stratified random sample would ensure that sampling within regions is representative and this is the method proposed here.

Sampling frames for veterinarians may comprise lists of registered veterinarians (assuming this data can be released), list of veterinarians constructed from advertising such as yellow pages (this would require labour or access to market research companies), professional groups (e.g. AVA special interest groups) and government veterinary registries. A good sampling frame of livestock producers is the MLA shareholder database. Initial discussions with the MLA company secretary indicate that it is likely that the database could be used for sampling (Johann Schroder pers. comm. April 2013). Additional producer sampling frames may comprise existing data bases held by commercial companies, PIC data (the premium sampling frame although this is unlikely to be publically available) or ABS databases (again this may not be publically available but could be accessible by contracting ABARES). Commercial market research companies already hold existing databases

[1] http://www.surveymonkey.com

[2] One workshop group suggested that the 12 beef and similar sheep production zones was too many and that zones could be aggregated up to just a few very large regions. This recommendation was not adopted here because detailed stratified sampling will ensure that all regions are sampled thus meeting MLA TOR. Additionally, no additional samples would be required and travel would be no issue as a telephone and internet survey is recommended. Hence there are few disadvantages to stratifying on production zones except that confidence intervals of estimated parameters may be wider as only a few samples may be collected in some less populous zones zone. With respect to field sampling (see below), MLA has specified they want a regional approach to the project so stratification on production zones was pursued in the field sampling as well.

of both vets and producers. A list of processors may be sought from AMIC. In practical terms market research companies, contracting ABARES or MLA lists will be most practical means to access producers and AVA SIG email lists most practical for veterinarians.

Sample sizes for qualitative research should be sufficient to achieve “saturation”, whereby enough samples are collected that further samples do not contribute additional information. Saturation is poorly defined but empirical reviews of a large number of qualitative theses that claimed saturation revealed that the mean sample size was 31. However many sample sizes were obviously arbitrary, rather than based on concepts of saturation (Mason, 2010). In contrast a review of the published literature suggested a range of 5 to less than 50 samples is enough to achieve saturation (Mason, 2010). Subsequently, the ‘correct’ sample size may be based on saturation concepts and financial costs for each region.

The national survey can be begun with a test survey in only one or two production zones for each species using an arbitrary sample size of 15 primary producers. After this, results can be examined for saturation and a subjective decision made as to whether and when (i.e. after how many samples was information sufficient) saturation has occurred in each zone and whether sample size is adequate. Sampling using an appropriate sample size can then be extended to other production zones. Alternative approaches to estimate sample size that may be useful include simulation.

A scoping conversation about telephone questionnaires was held with a research company. This company specialise in four areas, one being animal health research. They own a pre-existing database of veterinary clinics in Australia. The company suggested that this would be an almost complete list of veterinary clinics as it is harvested from client databases, yellow pages and other sources over a number of years. They also possess a livestock producer database across much of the country, with information on premises size and species. They generally conduct surveys of about 200 veterinarians in metropolitan regions and 40-100 veterinarians in rural areas. They have conducted surveys of up to 500 livestock producers. Surveys such as these can be stratified by region.

However, for veterinarians[3], it appears to be more feasible to conduct a valid internet survey of special interest groups of the AVA (sheep veterinarians and cattle veterinarians). Such internet surveys would be inexpensive if the email lists of such groups could be targeted and free software (e.g. Survey Monkey) was used. There are approximately 300-400 sheep veterinarians and 1100 cattle veterinarians in each of the special interest groups indicating that a sizeable portion of all rural veterinarians are members of such organisation. For example, if is assumed that the figures of Heath (2008) are correct, this would mean that approximately one third of veterinarians registered in rural regions may be members of the cattle veterinarians

[3] Some biases would likely develop if such an approach was used on producers as some producers would not use the internet and non-representative industry groups would be required to reach respondents

group. In principle discussions where held with the executive officer of the groups and it was indicated that a future internet survey would likely be approved by the executive of the SIGs, who would charge a fee to send an email to each SIG to solicit survey responses.

4.3.2 Step 2: Existing data

Recommendation

Further develop a priority list of the 20-40 most economically damaging diseases of red meat livestock using existing data and published literature. Locate, examine, describe and analyse relevant existing databases. Conduct a systematic literature review to identify key endemic diseases of Australian red meat livestock.

Discussion and rationale for existing data

The objective of this step is to further assist development of a priority list of diseases. A secondary objective is to validate the questionnaires of vets, producers and processors. Essentially the methodology to be pursued is to review and examine existing databases and published literature to identify priority diseases.

Several useful sources of data exist that can be examined to develop priority list of disease, including the NSHMP, Victorian Sentinel Flock Monitoring Project, several MLA projects (Cash Cow, JCU goat project, Theileriosis), pre-export testing databases and existing published and grey literature. These data sources should be examined thoroughly. This will reduce the number of diseases where field surveillance is required later. That is, desk based review of pre-existing data is much cheaper than field surveillance and a careful, systematic and well-resourced examination of existing data will markedly reduce the overall expense of a project by narrowing the scope of subsequent field research. Hence it is recommended that this phase of the research is well resourced, although resources required are only a small fraction of overall project expenses.

The National Sheep Health Monitoring Project (NSHMP) may be a particularly useful data source, but may require considerable analysis. This project has collected a range of data since 2007 on trade sensitive or important endemic disease in a number of abattoirs across Australia. These diseases include: Caseous lymphadentits, sheep measles, liver fluke, bladder worm, grass seeds, hydatids, dog bites, sarcocysts, cancer, pleurisy/pneumonia, knotty gut (*Oesophagostomum*) and lungworm. The occurrence of some diseases such as sheep measles, liverfluke and hydatids are unlikely to affect presentation at abattoirs and hence are likely to result in unbiased inferences. A range of animal ages (or simply all data in the data base) should be assessed to identify any age biases, but data collected is predominantly of sheep (cf. lambs). Surveillance occurs across a number of abattoirs across the country (approximately 20) but assessment of the representativeness of sampled abattoirs should occur.

The exact methodology required to extract optimal and relevant data and information on priority diseases will depend on the structure of the relevant data bases, the form of data and the accessibility of the data. Hence resources required to extract data can only be approximately estimated.

4.3.3 Step 3: Priority disease list

Recommendation

Aggregate, consolidate and reconcile findings from step 1 and 2 to report a final priority disease list.

Discussion and rationale

The priority list of 20-40 diseases can be developed from the pilot survey (step 1) and existing data (step 2) above. As the sampling that occurs will be stratified by production zone, priority lists for each production region and nationally will be available. This step will require that existing data and pilot survey be aggregated, consolidated and reconciled. Considerable expert judgement will be required to juggle potential biases that have developed in each step. This can then be the basis of further structured surveillance and economic assessments (steps 4-9).

4.3.4 Step 4: Literature Review

Recommendation

Determine the level of understanding (prevalence, distribution, risk factors, mitigation, economic data and bias in abattoir presentation) of each disease on the priority list using a systematic literature review approach. Make recommendations for each disease whether further research is required and if further research is required whether data collection is appropriate in an abattoir or using a field surveys.

Discussion and rationale

A thorough systematic literature review of each of the diseases on the priority list is critical to determine the current understanding of the disease. This should include an assessment of the prevalence (or other measures of disease frequency), distribution, risk factors, likely level of bias in presentation to abattoirs, possible financial impact in abattoirs and economic impact (or available economic data to base further economic assessments) of the disease. These will indicate two possible paths;

1. The disease does not require further epidemiological investigation (disease progresses to step 8) or that disease does not require further epidemiological investigation or economic investigation (disease progresses to step 9).
2. The disease is poorly understood (either uncertain of distribution, prevalence and pattern of infection or uncertain of risk factors, mitigation steps or

processing costs) and requires further epidemiological and economic investigation in the MLA field survey (step 5 or 6).

4.3.5 Step 5: Field Survey

Recommendation

If a disease on the priority list is poorly understood and not suitable to abattoir surveillance then conduct a national, stratified (by production zone), cross sectional survey of producers using a questionnaire. If disease cannot be diagnosed or prevalence determined by questionnaire, sample livestock on farms for further diagnostic testing.

Several survey designs are offered in Table 1 for consideration but the stratified by zone, 10% precision, questionnaire and biological specimen collection option is recommended as it is cost effective.

Discussion and rationale for field survey

If the pilot survey, existing data and a literature review reveals that a disease on the priority list is poorly understood (either uncertain of distribution, prevalence and pattern of infection or uncertain of risk factors and mitigation steps), then further data should be collected. If the disease is unsuitable for abattoir sampling (e.g. the disease biases presentation of animals at an abattoir or is impractical- see step 6 below) then field surveys must occur to generate information. A field survey could utilise a number of data collection tools, such as questionnaire (including further telephone delivery, but this time a quantitative study) or biological specimen collection or both. Considerable efficiencies are possible by examining multiple diseases concurrently in a single survey, and in some instances a single farm visit yielding information on multiple species (e.g. cattle and sheep).

It is assumed that a simple prevalence estimate at national level is not required (i.e. a cheaper multistage/cluster based sampling approach could be pursued). Instead, it is assumed that an idea of prevalence at several levels such as individual, farm, regional and national level is required as this will enable best inferences on economic costs. However, the information required may vary for individual diseases. For example, the required knowledge for a disease with a trade impact may simply be farm level prevalence with no further information on prevalence at individual level required. However, if a disease has an individual animal production impact and is not highly infectious an understanding of individual, farm, regional and national prevalence may be required to accurately determine the economic impact of the disease.

A suitable field survey design may comprise:

1. **A random sample of herds with data collection using a quantitative questionnaire**

Such a survey would question individual farmers on the presence or absence of several diseases of interest and additionally collect generic risk factor data. Limited specific risk factor data could also be collected for some key diseases. A survey could be a single national sample stratified to production zone (or could be replicated in each production zone if resources were extensive). This would be a simple one stage survey and would give an indication of prevalence of disease across the national population of farms. A diagnosis at farm level would rely on questionnaire responses.

The key advantages of such a design are simplicity and low costs. It would be suitable where the current understanding of disease distribution and prevalence across the nation is uncertain. This design may not provide information on prevalence on farm (i.e. the number of infected animals per farm as subclinical cases may not be detected). Hence if this data was not available in the published literature further on farm sampling of infected animals would be required to answer this question (i.e. second stage sampling).

Disadvantages of this design include that some farmers do not know whether or not some diseases occur on their farms as they are unable to detect or accurately diagnose some diseases and the fact that generic risk factor data is predominantly collected, which may not be suitable for understanding the 'cause' of some diseases. Additionally, data on the farm prevalence of disease may be absent, thereby precluding a full assessment of the financial implications of disease at the farm level if other data sources cannot provide this data. However, many of these disadvantages could be mitigated with further data collection (see point 2 'Second stage sampling' below).

Sample sizes can be established with regard to the expected prevalence of infected farms and normal considerations such as required confidence and precision. The aim of sampling is to estimate the prevalence of infected farms. See case studies below (Table 1 and Appendix 9).

2. **Second stage sampling (limited biological specimen collection from individuals within selected herds)**

A field survey where biological specimens are collected to diagnose disease will necessarily be more complex than a questionnaire based data collection. This is because farms, then individual animals on farms will need to be sampled. Thus a sample will need to be a collected with multi-stage techniques. Following selection of farm(er)s for questionnaire administration (above), second stage sampling of individual animals on those farms would occur. A suitable diagnostic test would be required to assist examination of animals and this would usually be a laboratory test.

The first stage of farms (primary sampling unit) can be selected randomly with stratification by production zone (and will be conducted for a questionnaire survey). The next stage of individual animal samples could be systematically randomly sampled. Study design should be a cross sectional or simple survey (depending on the need to collect risk factor data).

There are two main reasons to proceed to individual animal sampling:

a. Estimate the prevalence of disease on farm.

If a producer indicates in a questionnaire survey that they have a disease/s on their farm but is unsure of how much disease is present (and no other data is available), further sampling is required to estimate on farm prevalence of disease. Such data would be critical to address the economic impact of disease in some instances (although not always as there is not always a clear relationship between prevalence and cost of disease). In this instance, a further second stage survey may be required to estimate prevalence. In such an example, a sample size would be established to estimate prevalence with a required precision on each farm. An estimated prevalence would be required and it is often set to 50% in the absence of further knowledge. This will maximise the required sample size, and ensure an adequate sample is collected.

b. Assess the disease status of the selected farm.

If it is unlikely that an accurate diagnosis of the presence of disease by a farmer could occur, a proof of freedom sample can be collected. Here a sample is collected to detect the presence (or otherwise of disease on a farm). An assumption is made that disease would exist at certain prevalence (design prevalence). A sample size is calculated to give appropriate confidence that if disease was present at higher than the design prevalence, infected individuals would be detected if that sample size was collected and tested. Usually design prevalence is set to a low level, to give surety to any conclusions. Thus a questionnaire survey for a disease presence or absence is not preformed (although a questionnaire for other diseases and risk factors may still be useful).

There is similarity in the two individual sampling approaches (a and b), as both collect a sample of individuals from selected farms to either estimate prevalence or test the hypothesis that disease is present or absent. The main difference is the sample size required to meet the differing objectives. In instances where both scenarios are important, in order to meet both objectives, the greater of the two sample sizes can be collected. This will enable estimation of both prevalence and demonstration of freedom from disease. In the instance of prevalence estimation, a sample of 87 is required to estimate prevalence (assuming a prevalence of 50%, and standard confidence and 10% precision). This concurrently results in testing for freedom from disease at a design prevalence of 3.5% (a relatively low number). If the disease is likely to be present at or above a prevalence of 3.5% then the prevalence estimation sample size would also be adequate to test for presence or absence of disease. However, if the disease is an important trade limiting disease with a very low prevalence such a sample may be inadequate to demonstrate freedom from that disease. In essence a disease by disease approach is required to calculate an appropriate sample size.

Other advantages of individual level data collection on farms include that good quality individual level risk factor data could be collected and an overall ‘headline’ number of the national prevalence of disease could be estimated.

Several possible options for field survey designs are outlined in Table 1. This table outlines two survey designs with a precision of 5% (scenarios 7 and 8), including one with a replicated sample by production zone. These are very expensive designs (-------- for all three species) and hence are not recommended. Other possible designs are offered and the preferred scenario is number 5. This preferred option is less expensive as it aims for a lower precision of 10% and stratifies a national sample. Further detail is provided in Appendix 9. A scenario where a simple overall headline prevalence estimate is the aim of a survey is presented in Appendix 10 using cost optimised cluster based approaches and results in much smaller sample sizes.

Summary of suggested field survey

Considerably different study designs are possible depending on the objective of the study. The objective will in part depend on the diseases that are included in the priority disease list, how many diseases are to be included, the characteristics of each disease and the livestock species being considered. Expenses will also vary depending upon the need or otherwise for laboratory diagnosis, the type of laboratory test that is applicable and the expense of each test.

Different survey designs will also affect expense, generally through different sample sizes. Table 1 presents several different generic field survey designs which range from a very precise and inordinately expensive survey to a cheap questionnaire design at the farmer level. These survey designs vary in 4 main ways:

1. Data collection tool. A questionnaire is much cheaper than biological specimen collection/laboratory analysis but in some instances less objective;

2. Stratified verse replicated sampling by the 12 production zones. Replicated sampling across every production zone will result in precise prevalence estimates at zone level but very large sample sizes (and expensive surveys) cf. stratification of sampling by production zones that will provide some information (somewhat imprecise) at zone level;

3. Precision varies from 5-10% across some survey designs. A sample sufficient to achieve a 5% precision will be much larger and more expensive but will result in greater confidence in estimates;

4. The number of laboratory tests conducted. In most scenarios where laboratory testing occurs, only one laboratory test is performed, but this is increased to an arbitrary 5 tests in the preferred option.

In short it is impossible to accurately scope the field survey (and hence the research project overall) until a priority disease list is populated and reviewed. Despite this, useful and suitably generic study designs are presented to assist estimation of costs and resources for the field survey component of the study. However, final pricing and resources can only be calculated after step 4 is complete and a final budget is calculated. Despite this, a cost effective compromise field survey that may be adequate has been designed. This is discussed more extensively below along with assumptions, imperfections and savings measures.

Table 1: Several study designs with objectives, resulting sample sizes and estimated costs (field and laboratory costs only) to sample a single livestock species. The preferred study design is bolded. Options are grouped in categories but essentially 4 parameters vary: precision, data collection tools, stratification verse replication of sample to allow regional estimates and the number of laboratory samples assessed.

Scenario	Objective	Data collection method	1st stage sample size	2nd stage sample size	Total samples	Cost of 1st stage sampling	Cost of 2nd stage sample	Total cost
Questionnaire survey of producers at 10% precision								
1. Questionnaire survey of farmers (replicated by zone), 10% precision[4]	Zone and national farm prevalence with farm risk factors (high zone precision). Bias by farmers possible.	Questionnaire	1 284 (107 x 12 zones)	NA	1 284	--------	NA	--------
2. Questionnaire survey of farmers (stratified by zone), 10% precision[5]	National farm prevalence with farm risk factors (and some zone prevalence information, low precision). Bias by farmers possible.	Questionnaire	107 (across 12 zones)	NA	107	--------	NA	--------
Biological specimen and questionnaire survey at 10% precision								
3. Two stage prevalence sampling (replicated by zone), 10% precision[6]	National farm and individual prevalence by zones. Less farmer bias.	Biological specimen and questionnaire	1 284 (107 x 12 zones)	86	110 424	--------	--------	--------
4. Two stage prevalence sampling (stratified by zone), 10% precision	National farm and individual prevalence. Some information on zone prevalence. Less farmer bias.	Biological specimen and questionnaire	107 (across 12 zones)	86	9 202	--------	--------	--------
5. Two stage prevalence sampling stratified by zone (Scenario 4) with 5 laboratory tests, 10% precision	**As above (4)**	**-**	**-**	**-**	**-**	**-**	--------	--------
6. As Scenario 4 but with 2 lab tests	As above (4)	-	-	-	-	-	--------	--------
7. As Scenario 4 but with 10 lab tests	As above (4)	-	-	-	-	-	--------	--------
'Precision surveys' with biological specimen collection and questionnaire survey								
8. Two stage prevalence sampling replicated by zone, 5% precision and 5 laboratory tests	National farm and individual prevalence by zones. This is the same as scenario 3 except 5% precision and 5 lab tests.	Biological specimen and questionnaire	5004 (417 x 12 zones)	220	1 100 880	--------	--------	--------
9. Two stage prevalence sampling stratified by zone, 5% precision and 5 laboratory tests	National farm and individual prevalence. Some information on zone prevalence. This is the same as scenario 5 except a 5% precision.	Biological specimen and questionnaire	417	220	91 740	--------	--------	--------

[4]Replicated survey across beef production zones: Estimated prevalence= 0.5, α=0.05, precision=0.1, sensitivity of diagnosis=0.99, specificity of diagnosis= 0.97, population size= 30 (Barkley) to 17 323 (Temperate South-east Coast and Tablelands (TSEC&T)).
[5]Stratified (proportional) across production zones: Other parameters as for scenario 1.
[6]Same parameters as first stage stratified sampling, except finite population size of 462 (average cattle herd size) results in a sample size of 86 in second stage. Note that a sample of 86 designed to estimate a prevalence also tests freedom at approximately 3.5% design prevalence.

The suggested generic and recommended field survey design is a stratified (by production zone), two stage, cross sectional survey with 10% precision. Data will be collected using a questionnaire and for an arbitrary 5 diseases using laboratory assessment of biological specimens. This design will allow an assessment of prevalence at individual, farm and national level, with some idea of prevalence at production zone level (albeit with low precision at zone level). Some bias in estimated prevalence at farm and national level may develop for some low prevalence diseases requiring laboratory testing, as the sample size selected at farm level (87) is only sufficient to demonstrate proof of freedom from disease at farm level using a design prevalence of 3.5%. That is, farms with prevalence recorded as zero may actually be very low prevalence farms and this would not be detected with specified sample sizes. The importance of this potential bias would depend on the individual disease. For example a disease of importance to trade that is present at a very low prevalence could still have a marked economic impact at the farm level but may not be detected in this field survey design. However, if the diseases economic impact was limited to those due to production impacts then under-detection of very low prevalence farms would have little impact on overall study findings.

The survey will aim to collect disease data, generic risk factor data and economic data on several diseases concurrently via questionnaires. The exact number of diseases able to be surveyed by questionnaire cannot be determined until the priority disease list from step 4 is assessed for suitability of diagnosis by farmers. The outlined design also allows for the collection of samples for laboratory diagnosis for selected diseases (5) that cannot be accurately diagnosed by farmers using a questionnaire. The complete cost of such a survey is anticipated to be approximately -------- for each species with this estimated price including 1 hour questionnaire administration, two hours of sample collection for 87 individuals, laboratory serological assessment of 5 diseases, 30+ days of veterinary consultancy (for coordination, survey design and analysis). Additional laboratory assessment would marginally increase costs, assuming a quite accurate (sensitivity and specificity= 99 and 97% respectively) serological test. Additional sampling time of 1 hour on each farm would marginally increase the budget.

Some savings may be possible if government veterinary services are utilised that charge a lower fee per hour. However, most expenses are laboratory expenses and a cheaper hourly field rate produces minor savings.

It should be noted that the suggested approach calculates a national sample size of 107 farms and distributes this between the 12 beef or sheep regions. This will result in mean sample size of 9 farms per production zone and hence imprecise estimates of farm level prevalence on a zonal basis (±35% with specified assumptions in option 5) and hence lower precision in the estimated regional prevalence. This may produce strange estimates. For example there may be strong spatial clustering of disease in certain areas even within production zones. If only a mean of 9 farms is collected from each zone, then serious bias could exist in prevalence estimates if for example none of these clusters were sampled. (Other estimates should attain a precision of ±10%). In order to enhance confidence in estimates at zone level, the 107 sample size could be collected from each zone (i.e. replicated surveys outlined in Table 1, although this appears prohibitively expensive), or simply sample size could be increased, and as many samples as could be afforded selected in the first stage (for example by increasing precision required at national level to ±5%, which would result in a 417 herd sample). One means of finding money to increase the first stage sample size and increase confidence in regional prevalence estimates is to minimise the number of diseases examined with laboratory testing by using abattoir surveys (step 6), by examining all pre-existing data available in an exhaustive manner (step 4) or by minimising the number of diseases allowed on the priority disease list or species surveyed.

In general, this illustrates the fact that the money available to conduct a survey will affect the objectives, design and outcomes of a survey. An unlimited budget would enable a perfect survey that could be designed to answer any question with high levels of precision. Whilst we have presented survey designs that will give a high precision to derived estimates (scenario 7 and 8 in Table 1), we have designed this project and particularly this step to fit within a defined budget. This has meant that many compromises have been required. These include:

- lower precision of estimates than are usually standard (±10% cf ±5%),
- reliance on prevalence sample size calculations rather than freedom sample size calculations at a design prevalence of 1%, resulting in potential bias in farm prevalence if important diseases are present at a very low prevalence(very low prevalence farms may be misclassified as negative farms)
- aggregation of the sample size to national level (i.e. stratified national sample by production zones) instead of replicated surveys by zones,
- an assumption that 5 disease will be examined by biological specimen collection (whereas if a priority disease list of 20-40 is used per species then many more may be required depending on steps 1, 2, 3, 4 and 6)
- assumed a quite accurate serological test (Se = 99%, sp= 97%)
- reliance on less accurate serological diagnosis instead of more expensive PCR testing (however, this has an advantage of diagnosing the historical disease status of the animal, thereby extending the ‘time reach’ of the survey),
- reliance on a one hour questionnaire. One hour will limit the amount of data that can be collected but has several advantages such as capping questionnaire expenses and encouraging compliance (i.e. longer surveys will reduce response rates)
- assumed that some diseases can be accurately diagnosed by farmers and reported without bias in a questionnaire
- No inclusion of financial inducements to encourage farmer participation in a field survey (e.g. reimbursement for time spent mustering or in yard work).

4.3.6 Step 6: Abattoir surveillance

Recommendation

If a disease on the priority list is poorly understood and suitable for abattoir surveillance then conduct an abattoir survey to collect data.

Sheep abattoir data should be gathered in the first instance using existing data from the NSHMP. If new data is required gather this with existing NSHMP infrastructure/resources.

Cattle and goat abattoir surveillance would require purpose built systems and may be considerably more difficult, but may be financially cheaper than field surveys. Therefore consider designing and implementing cattle and goat abattoir surveys.

Discussion and rationale for Abattoir surveillance

If disease of interest does not affect presentation at an abattoir, slaughtered animals may represent an unbiased sample of large portions of Australian livestock populations. That is, it can be assumed that most livestock are presented for slaughter in Australia during their lifetime and that surveillance for some diseases can occur validly at abattoirs. Additionally, collection of data from processing plants is essential for assessment of processing costs of disease. Successful contemporary sampling of sheep (e.g. the NSHMP) and cattle (Anon., 2008) has occurred. Therefore, less expensive abattoir surveys may be useful to sample large proportions of the Australian livestock population for certain diseases. Alternatively, simply accessing existing data (for example from NSHMP) may be a very cheap means of conducting surveillance. However, there are a number of limitations associated with abattoir surveillance including socio-political issues. Some of these issues cannot be resolved with a consultancy such as this.

Bias

Abattoir sub-populations can still be biased compared with the target population (the general population of livestock in Australia) about which inferences are required.

1. The subpopulation presented to an abattoir is generally healthy and young or conversely old and at the end of their productive life (e.g. cull cows).

Age stratification during sampling may be required to ensure that all ages are sampled adequately.

2. Some diseases are not present in slaughtered animals.

For example, perinatal mortality in sheep may be a very large problem in a general population of sheep but would obviously remain undetected if abattoir data was relied upon to detect it (animals die before presentation at an abattoir). In general, data collected from an abattoir subpopulation can only be considered useful to infer about the status of the larger population if the disease in question is unlikely to influence the presentation of an animal for slaughter. This narrows the list of diseases that can be surveyed with abattoir sampling, although many diseases can still be surveyed validly. For example, *Taenia ovis* (sheep measles) or *Echinococcus granulosus* (echinococosis) in sheep is unlikely to affect presentation to an abattoir and hence may be a candidate for abattoir surveillance. However an abattoir survey is routinely useful to allow unbiased estimation of some diseases of financial importance to abattoirs, regardless of presentation bias (either disease is present in slaughtered animals or it isn't).

3. Some geographic subpopulations are not presented for slaughter.

For example those populations that are marketed through live export. In this instance these populations must be excluded from inferences based on abattoir surveys and additional separate sampling and study designs would be required. This essentially means that cattle populations in many areas of northern Australia would be under-represented in abattoir surveillance. Other examples include older cull cows in northern Australia that are not suitable for export and where abattoir slaughter in Australia is not economically viable.

Sampling practicalities

A further drawback of abattoir surveillance is that associated with practicalities of sampling in an abattoir setting. Some issues include:

1. OH&S considerations
2. Access to processing line

A meat inspector may not be able to be placed at every location in an abattoir processing line, thereby precluding the collection of some samples or examination of some organs. For example it can be difficult for a sampler to be located in the killing room where blood samples would most optimally be collected. However, it is frequently the case that an inspector can be placed at the offal tray.

3. Speed of the chain.

The chain can move very quickly and sometimes only a cursory examination of some parts of the carcass is possible, thereby precluding sensitive or specific examination of some tissues.

4. Sampling can damage product

Sampling of some organs (e.g. GIT) can contaminate or lower the value of the carcass (e.g. microbial contamination).

5. Size of cattle can preclude adequate examination of organs

It can be difficult to examine some organs on a rapidly moving processing chain, thereby precluding accurate diagnosis. Essentially this results in the option of abattoir surveillance being less feasible in some circumstances in cattle than sheep (larger organs in cattle can be difficult to manipulate and screen rapidly).

6. Poor acceptability of sampling from some abattoir owners

Some owners and managers of abattoirs resist access for a variety of social, economic and practical reasons.

7. The data that can be collected is limited

Risk factor data may be difficult to collect from abattoirs. Whilst abattoir sampling can allow collection of individual animal risk factors such as sex, age, breed and condition score, it can be difficult to collect risk factors on management, environmental or other life history information. Despite this, if an accurate trace back system existed then information could potentially be collected from the property of origin. For cattle, NLIS data records the PIC of origin, so subject to privacy considerations (maybe a significant issue), trace back and collection of further risk factor data could occur. Sheep are somewhat different as lines have a PIC code associated with them, but several lines can be mixed to form a single boxed line for slaughter. Hence it may only be possible to trace a sheep back to several possible lines/PIC codes and trace back for further risk factor data may be difficult or impossible. The NSHMP restricts surveillance to single lines from private vendors to ensure trace back is possible (e.g. generally do not survey mixed lines from saleyards).

Summary of issues

There are considerable biases possible in presentation of livestock to abattoirs. Additionally a variety of practical issues can reduce access to or accurate examination of carcasses. Subsequently the diseases most suitable to examination in abattoirs are those where rapid visual screening can result in an accurate diagnosis (e.g. liver fluke) and where the disease does not affect presentation of the animal to the abattoir. Additionally, in general terms sheep are more likely to be suitable for abattoir surveillance than cattle. For example, the NSHMP already collects a variety of disease data and could potentially provide cheap and accessible data. However, risk factor data beyond individual features of an animal may be difficult to collect.

Abattoir survey design

If designing a survey from a theoretical perspective, an appropriate survey design would be a cross sectional survey (if risk factors were required) or simple survey of the prevalence of disease. Sampling using cluster sampling (day = cluster) would be appropriate. Production region could be considered as a stratum or could be used to establish separate surveys in each zone to ensure each region was represented. Sample sizes could be calculated based on the standard considerations.

Sample sizes can be calculated at several possible levels, for example sampling a certain number of animals within lines of slaughtered stock each day, sampling a certain number of lines each day (together would represent two stage sampling design) or sampling a certain number of days of abattoir slaughtering. However, given that the physical task of examining carcasses or collecting samples maybe very rapid there seems little point in designing complex sampling strategies at the within or between slaughter line level. Instead, it would be sensible for an inspector to screen every carcass possible on a day they are sampling. For example, given the time taken to examine and record results from an examination of liver for liver fluke, perhaps every liver could be examined whilst an inspector is present on a day.

This indicates that sample size should be based on sampling a certain number of days in an abattoir slaughter schedule to ensure that the animals examined within and between lines are representative of all the lines killed at the abattoir. This will be very much dependant on the size of the abattoir and factors such as the size of livestock consignments they receive, but if a day is considered a cluster, then cluster based calculation approaches can be used. Despite this, and pragmatically, the budget will generally determine the number of days of sampling that can be conducted. Inspector cost/hour (or day or year) with travel and other expenses, and only visual inspections (with no diagnostic expenses) will determine the cost for one day of sampling at each abattoir. Multiple samples (days) may be required from each abattoir and the number of days sampled would depend on the available budget and statistical considerations.

However, there seems little point in re-collecting abattoir surveillance data for sheep, if data for diseases on the priority list (from step 1-4) are already collected by the NSHMP. An in principle discussion was held with AHA on accessing data from the NSHMP for use in an MLA endemic disease project. Access to aggregated (by state) data would likely be granted immediately to consultants for analysis if requested. If data were aggregated to a finer level (e.g. local government area) a simple within AHA approval process would be pursued. However, if data were required to PIC level, then state CVO approval and collaboration would be required. For example, PICs could be used by LHPA's in NSW for an opt-in survey of producers. Data would generally be provided free of charge by AHA. Hence, it seems eminently feasible to use existing data collected since 2007 for the 13 diseases surveyed by the NSHMP if these diseases match the diseases on the priority list following steps 1-4. The only expense for these diseases would then be data gathering, cleaning, analysis and reporting. NSHMP predominantly collects data on diseases in sheep, with limited data collection in lambs and goats.

Tentative discussions with AHA indicate that it would be possible to work with the NSHMP to collect additional data if diseases surveyed by NSHMP do not match MLA priority diseases. If surveillance suited existing procedures, then little expense would be incurred. However, if surveillance for the MLA priority disease required additional survey locations (e.g. away from the offal tray where inspectors of the NSHMP are currently stationed) then cost recovery would be required. This would be at the standard rate (outlined above). It would be important to realise that efforts would be required to gain processor agreement for extra surveillance. One means would be to demonstrate to processors economic benefit of extra surveillance, another would be to use abattoir staff for surveillance.

Regarding cattle and goats, similar design and calculations for expense may be required in planning abattoir surveillance. However, a more expensive effort would be required because training, recording and reporting systems would be required to be established as inspection is currently only focused on condemnations rather than on disease diagnosis, recording and reporting. Careful consideration of the current status of other abattoir surveillance projects and stakeholders would also be required even before access negotiations with abattoirs could begin. For example, a number of ad hoc projects that are not properly conducted could reduce industry compliance with planned more holistic projects in the future. In essence, the resources required pursuing abattoir surveillance in cattle and goats can be estimated, but industry politics, industry strategy and future research projects cannot be predicted year/s in advance. Thus, the decision to pursue abattoir surveillance for endemic disease investigation in this project will require subjective decision making, collaboration and negotiation by MLA (or other consultants) at the time this project would be required (e.g. 18 months in the future (Mid to late 2014). It is possible that if there is an industry strategy and broad agreement within the beef and/or goat industry for abattoir surveillance that an MLA abattoir surveillance project could act as a pilot study for ongoing and holistic abattoir surveillance.

4.3.7 Step 7: Disease information

Abattoir and field survey data are compiled to present a complete picture of all previously poorly understood diseases on the priority list. This information then informs the economic modelling (along with summarised and well understood diseases from the comprehensive literature review of the priority list). This is a relatively simple step and simply collates and synthesises research data.

4.3.8 Step 8: Economic modelling

Recommendation

Collect field data if required during questionnaire surveys and reviews. Generate several representative whole farm models and abattoirs to investigate the impact of disease using parameters from field data collection. Aggregate the results to national scale. Consider holistic economic modelling using existing equilibrium displacement models (EDM)

Discussion and rationale for economic modelling

Recommended steps to investigate.

1. Field data collection on direct economic costs at the farm level. Several sources of data may be useful, including veterinary and producer questionnaires, farm production records, representative farm case studies and health remedy sales.
2. Collect abattoir data on processing costs associated with disease and prevalence of disease.
3. Generate several representative whole farm and abattoir models to investigate the impact of disease using parameters from field data collection. This will allow farm level assessment of the impacts of disease.
4. Aggregate costs.
5. Extrapolate the results to national scale preferably with existing EDMs. Several EDM exist in Australia, a sheep and beef model from UNE and a lamb one from Victorian DPI. This would allow a holistic assessment of the economic costs of disease using existing platforms.

Alternatively, if a holistic assessment is judged as too expensive then aggregation of direct farm and processing costs nationally can be pursued (i.e. avoiding the EDM step), although it should be realised that biases will result and it is unclear how these biases will affect the validity of inferences. It will be necessary to identify an economist relatively early in the overall research project to design economic data collection on farm.

Other approaches have been pursued in the past, such as marginal farm analysis, but these have now largely been discredited.

4.3.9 Step 9: Final summary

All project steps are compiled to present final results. This could be completed by an external consultant familiar with the project or the MLA project manager. Extension material could be prepared at this stage.

5. Suggested TOR for MLA endemic disease research project

Various phases of the research project are outlined below. Each phase is a believed a sensible breakdown of work and generally comprises several related steps of the research project. The TOR are concise and should be read with the corresponding sections of the research program and GANTT chart above. Phases 1, 2 and 4 should be conducted as single consultancies, whereas phase 3 may require several consultancies. It would be useful if phases 1 and 2 were conducted by the same consultant to avoid complete duplication of literature reviews that occur in both steps (literature reviews have a different focus but can build on one another). Whilst many field survey options are possible (see Table 1 and discussion above) a cost effective and practical field survey has been selected in Phase 3 to allow scoping of the project as per TOR.

5.1 Phase 1: Priority disease list (steps 1, 2 and 3)

Objective: Generate a priority list of the most economically damaging endemic diseases of red meat livestock

Method:

1. Questionnaire surveys

Geographically representative questionnaire surveys of veterinarians, processors and livestock producers to determine which are the most economically damaging diseases of livestock. It is anticipated that qualitative telephone and internet surveys will be required.

2. Data review

Examine relevant existing data sources and published literature (systematic literature review) to identify the most economically damaging red meat livestock diseases.

Deliverables:

A valid list (20-40) of the most economically damaging endemic diseases of each red meat livestock (sheep, cattle and goats).

Required Resources:

This would necessarily be a veterinary (preferably veterinary epidemiological) lead project, with involvement of telephone marketing research companies (or ABARES), considerable data gathering/ cleaning/analysis and systematic literature reviews. The resources required for each step (including marginal totals are presented in Table 2 below and are detailed in worksheets ‘step 1_pilot questionnaire’, ‘Step 2_existing data’ and ‘Step 3_Priority list’ in the associated cost and resources worksheet. The existing literature and data phase is potentially 30% over resourced as it is uncertain what data sources will be suitable and exactly what analyses will be required.

Table 2: Costs (AUS$) and human resources to generate a priority disease list

Phase of priority disease list	Sheep only	Marginal increase to cattle	Marginal increase to goats	Total for each step	Days for consultancy
Pilot study	--------	--------	--------	--------	--------
Existing lit. and data	--------	--------	--------	--------	--------
Compilation	--------	--------	--------	--------	--------
Total for species	--------	--------	--------	--------	--------

*If a telephone survey of veterinarians was also conducted, this figure would increase by --------

**excludes days of work for telephone survey company, although the telephone survey expenses are included in the budget.

Skills to complete:

Knowledge of surveillance and epidemiological study design, data base management, data analysis, relationships and ability to work with data custodians, ability to conduct systematic literature reviews, knowledge of endemic disease in Australian red meat livestock.

Time to complete:

Approximately 4 months if steps run concurrently.

Possible Contributors:

There are two general types of consultants available for this phase:

1. Veterinary epidemiological consultants.
2. Endemic disease experts. Academics could find students to conduct literature reviews and analysis of existing data relatively inexpensively, although the disadvantage of such approaches are poor timeliness, less experienced consultants and possible interruptions to work flow associated with discontinued candidatures etc.

Generally it would be advisable to have a veterinary epidemiologist with endemic disease experience conduct this phase of the research as endemic disease experts may not have suitable knowledge of study design, data analysis etc. Conversely, a combined consultancy of endemic disease experts and epidemiologists/statisticians may be an alternative path to complete the phase.

5.2 Phase 2: Systematic review of priority disease list (step 4)

Objective:

Summarise the knowledge (epidemiology, distribution and prevalence, bias in presentation to abattoir, economic impact and economic data available) of each disease on the priority disease lists. Make recommendations as to further research required.

Method:

Systematic review of scientific and popular databases. Some efficiency can be gained by utilising existing knowledge from step 2 (above). However, this is a much more thorough review of each priority disease than step 2 which sought to simply decide which diseases were important.

Deliverables:

A documented systematic review of each disease on the priority list. The systematic review should enable a recommendation for each disease on whether further research is required. That is whether sufficient information is available to accurately assess the prevalence and distribution, risk factors, mitigation steps and economic impacts of the disease in Australia. A statement of the optimal means of surveying the disease should be made (i.e. field survey verse abattoir survey).

Required Resources:

Phase of priority disease list	Sheep only	Marginal increase to cattle	Marginal increase to goats	Days for consultancy
Literature review	--------	--------	--------	--------
Grand total: --------*				

*****This assumes that 20 diseases are reviewed. If 40 are reviewed the budget may double.

Skills to complete:

Knowledge of endemic disease in Australia, skills in conducting systematic literature reviews, epidemiology, economics, scientific writing and synopsis.

Time to complete:

2 months for two consultants.

Possible contributors:

There are a broad collection of suitable candidates for this phase of the research. Again academic staff with students could contribute cheaply, but any veterinary surgeons with experience in clinical practice (with epidemiological experience) and good academic writing skills may be suitable. A combined consultancy between a veterinary epidemiologist and endemic disease expert may be suitable. There may be benefits in using the same group as for Phase 1.

5.3 Phase 3: Field Survey (step 5) and abattoir survey (step 6)

This phase will need to be scoped in more detail after step 4 is completed and it is known with certainty which diseases are on the priority list and the number and characteristics of diseases requiring field surveillance. Additionally, the quality of the field survey is very much informed by budget (here we have assumed a middle ground survey of moderate quality as per the preferred option in Table 1). Generic TOR and a generic budget are thus presented for the field survey. Similarly, the availability of existing abattoir data (especially for sheep) will heavily influence both further abattoir surveys and the field surveillance required. The difficulty of establishing data collection in beef and goat abattoirs and ensuring cooperation of producers in sampling livestock on farm should not be under-estimated, especially if controversial diseases were being investigated (e.g. Ovine Johnes disease).

Step 5: Field surveys

Objective

Estimate the prevalence and risk factors of priority diseases at individual, farm and national level in red meat livestock. Regional prevalence estimates are also required but it is acknowledged that available budget will limit sample size and hence the confidence of estimates at the regional level. Collect basic economic data on the costs of these diseases on farm.

Method

A national, stratified (by production zone) two stage (sample farms then for some diseases individual animals) cross sectional survey utilising questionnaire surveillance where possible and biological specimen collection/laboratory diagnosis where necessary. The sampling frame should ideally be the MLA shareholder database.

It is recommended that a veterinary epidemiologist with endemic disease expertise (or a combined consultancy of endemic disease expert and veterinary epidemiological experience) be engaged to coordinate and design the survey, once the priority disease list is examined in step 4, and poorly understood diseases are identified. One or more veterinarians (private or state veterinary service) in each production region will be required to administer questionnaires and collect samples. A suitable laboratory/ies will be required to analyse biological specimens.

Deliverables

For MLA identified diseases, prevalence estimates at individual, farm and national level. Some understanding of prevalence at regional level (production zones). Identify risk factors and hence mitigation of identified diseases. A basic understanding of the economic cost of these diseases on farm.

Required resources and skills to complete

Table 3: Resources required to complete a generic survey (stratified, two stage prevalence sampling with questionnaire and 5 laboratory tests) and marginal increase to extend survey from sheep to cattle and goats. See scenario 5 in Table 1 for further detail on study design.

Expense item	Total cost ($)
Two stage prevalence sampling (stratified by zone) with 5 lab tests	--------
Veterinary consultancy	--------
Total (one species)	--------
Total (three species)*	--------

*Marginal increase simply a 100% multiplication factor

For budget purposes it is assumed that this will require 12 contract veterinarians (clinical, state veterinary or post graduate student) for sample collection in each production zone. It is anticipated that each will spend 5 days for each species (15 days) in each of 12 production zones (therefore 180 vet days). These veterinarians will require experience in large animal practice and ability to relate to primary producers, an ability to administer questionnaires and keep accurate records.

This step will also require a coordinating consultant to design the sampling (i.e. implement this necessarily generic plan, for example write questionnaires), coordinate sampling and laboratory work and to analyse results (including prevalence estimates, risk factor estimation and economic data compilation). A coordinator would require considerable epidemiological experience, knowledge of endemic disease, livestock production and a demonstrated ability to conduct large scale surveys. A consultant may need assistance from an endemic disease expert for each of the species of concern.

See worksheet titled ‘step 5_field survey’ in the costs and resources Excel spread sheet for further details and to re-estimate costs whilst changing various parameters.

It is important to note that the budget includes time charges ($/hour) for one hour’s questionnaire administration and 2 hours’ specimen collection on farm. This may be an under-estimate in some circumstances. However, doubling of times (e.g. 2 hours for questionnaire administration and 4 hours for specimen collection) will result in only relatively small marginal increases in the expense of each species survey.

Time to complete

This project could be conducted relatively quickly as concurrent data collection would occur with multiple vets conducting data collection at once. However, although only several hours may be required on each sampled farm and each vet will only sample a mean of 9 farms in each region, it may take a significant period of time to schedule sampling tasks. For example, mustering may only occur once or twice per year in some regions and sampling may need to occur during mustering. Hence 1 year has been allowed for this task to ensure time for sample collection, coordination by consultant veterinarians and analysis of results.

Possible contributors

Consultant veterinarians include the several epidemiologists mentioned earlier (submitting joint bids with endemic disease experts) and the veterinary faculties which would also have the resources (endemic disease experts, epidemiologists and students) to lead the project.

Field data collection should predominantly be private veterinarians and government field veterinarians (e.g. LHPA). To access these vets could entail advertising with SIG for EOI or calling veterinary clinics in relevant areas.

Step 6: Abattoir surveillance

Objective

For specified diseases of red meat livestock, determine the prevalence, costs (e.g. downgrade or trimming) and distribution using abattoir surveillance. Some risk factor analysis may be possible and assessment of risk factors should be an objective where possible. However, again it is impossible to scope this accurately until a priority disease list is developed and reviewed (steps 1-4), and the diseases of concern and their characteristics identified. Additionally, higher level decisions on whether beef and goat surveillance should occur may be required. This section represents a summary of a generic approach with estimated costs.

Method

1. Sheep

- Analyse existing data from the NSHMP

Access data from AHA for suitable diseases of sheep. Analyse data to estimate the prevalence and distribution of diseases. Consider a case control study to identify risk factors, this will require collaboration with state DPI to access PICS (e.g. with an opt in survey of producers).

Some goat data is available from the NSHMP, but is limited. This was collected at no extra expense to the NSHMP. This data should be examined and described.

- Collect new data for diseases not currently surveyed

This will entail additional abattoir surveillance for priority sheep diseases that are not surveyed by NSHMP. This will likely be relatively simple (assuming disease chosen is suitable and supported by industry) as existing inspectors can simply add this disease to their routine.

2. Goats and cattle

A critical first step would be high level engagement and agreement by stakeholders of the need for abattoir data reporting project in beef and potentially goats. Only after this could a beef and goat abattoir data collection program be instigated. This may be a significant amount of work for a consultant, for example with design, negotiation and communication activities. Assuming permission was achieved from meat processors, training of inspectors to diagnose, record and report diseases would be required. There would likely be additional contract costs for meat inspection staff employed by processors.

Deliverables

Analysis and reporting of NSHMP diseases that match MLA priority sheep diseases.

Data collected, analysed and reported for additional MLA priority sheep diseases that are suitable for collection in the NSHMP, but not currently collected.

Engagement and agreement on a national beef and goat abattoir data collection project. Data collected, analysed and reported for MLA priority cattle and goat diseases that are suitable for collection in abattoirs.

Required resources and skills to complete

The beef and goat portion will predominantly be a project requiring the ability to implement meat inspection in abattoirs (therefore someone experienced in liaising with meat processors and training meat inspectors), but will require additional epidemiological skills (e.g. design, data analysis and reporting), and endemic disease knowledge. It would be ideal if consultants with varied skills teamed up to submit joint consultancy applications. The sheep portion will be a lot simpler and predominantly require public policy liaison and statistical epidemiological skills. It is suggested therefore that this comprise two separate consultancies (sheep and goats/cattle).

Table 4: The resources required to complete abattoir surveillance of sheep, beef and cattle.

Phase of priority disease list	Sheep only	Marginal increase to cattle	Marginal increase to goats	Total for each step	Days for consultancy/inspector
NSHMP data analysis	--------	NA	--------	--------	--------
Collect new NSHMP data	--------	NA	NA	--------	--------
New abattoir surveillance	NA	--------	--------	--------	--------
Total	--------	--------	--------	--------	--------

Time to complete

The actual time to physically complete tasks may be quite limited, for example 4-5 months to design and analyse data, and meat inspection time per abattoir of 10 days (replicated by 20 abattoirs for cattle and goat). Sheep data could be collected very quickly using existing data or existing systems for data on new diseases. However, what may take considerable time is negotiation to access new beef and goat abattoirs for surveillance and training of existing inspectors. This time period cannot be predicted but should be conservatively estimated at 6 months. Hence approximately a year should be allowed for this project.

(See below under possible contributors for other details to be considered). In short careful consideration should be given to whether this project has the imprimatur, political support and time to embark on a large beef (and goat) abattoir surveillance project.

Possible contributors

AHA has indicated interest in ongoing endemic disease surveillance for ‘benchmarking’ industry improvements. This overall project could serve as a starting point for ongoing surveillance. However, given AHA involvement, expertise and experience in sheep abattoir surveillance, AHA may be a valuable contributor to designing the cattle (and goat) abattoir surveillance. If AHA was interested in ongoing endemic disease surveillance they may also contribute funds to develop this abattoir surveillance and then potentially carry on the project after data was collected.

AMIC has indicated a willingness to be involved in future abattoir surveillance. A future comprehensive and ongoing cattle abattoir surveillance scheme with efficient feedback to producers and processors will provide mutual benefit. AMIC has a small project currently being planned with MLA (e.g. a surveillance project across 7 abattoirs, aiming to refine Australian Standards for meat inspection). This project may be operational by the 2013/2014 financial year and has processors from WA, SA, SE Qld and Victoria in sheep and cattle involved. Both AMIC and MLA have indicated a willingness to collaborate to save sampling effort and to avoid doubling projects. Data to be collected varies, but may include liver fluke, dog bites, CLA and *Taenia bovis*.

However, in general, AMIC are keen to be holistic about a program of abattoir surveillance rather than have a number of small schemes rolled out piecemeal that will reduce future processor compliance. There are a number of sensitivities mostly concerned with processor expenses, control of information and potential harm to processors associated with disease surveillance (e.g. differential selling by producers to processors without surveillance). In order to establish a comprehensive beef surveillance system several components are required:

- inspectors (currently present in abattoirs),
- up-skilling of inspectors (to go beyond detection and trimming of abnormal meat to actually diagnosing and recording observed abnormalities),
- stakeholder negotiation and engagement (AMIC, MLA, CC, SMC, AHA, potentially GICA)
- processors to see benefits and few risks (e.g. business rules about data)
- resources (should be present if can demonstrate advantages such as cost benefit analysis)
- a vision (i.e. that processors and producers cooperate to maximise benefit to all)

An MLA endemic diseases project could be a pilot study for future schemes but there are difficulties associated with implementing a beef surveillance system. The approach should be collaborative. It will be hard to conduct a similar scheme for goats as it is an emerging industry. There are only two major goat processing plants. Some sheep plants do process goats occasionally. Other sheep plants are able to but choose not to.

5.4 Phase 4: Economic analysis (step 7 and 8) and project summary (step 9)

Objective

Determine the on farm and abattoir costs of disease and aggregate this for production zones, the processing sector and nationally

Method

A possible method of estimating farm costs involves whole farm modelling with results aggregated to higher levels. Data from earlier research and literature reviews (e.g. farm and animal prevalence of disease) to inform analysis. It would be ideal if EDM models were then used to ensure a more holistic analysis of the economic impact of disease. Processing costs can be determined for abattoirs based on prevalence and marginal costs of infected animals with aggregation nationally.

Deliverables

An assessment of the economic impact of each priority disease on farm productivity.

An assessment of the economic impact of each priority disease to abattoirs.

Required resources and skills to complete

Two skill areas are required, veterinary/veterinary epidemiological to summarise parameters required for economic analysis, but most importantly, an economist with agricultural or biosecurity research experience.

It is estimated that 150 days may be required for economic modelling.

Time to complete

5 months

Possible contributors

Many economists could contribute.

6. Conclusions and discussion

It appears possible to conduct an adequate affordable national survey of endemic diseases in red meat livestock. Such a project would be a staged multistep research project and could be conducted over three years with good project management. Research steps include:

1. Phase 1: Development of a priority disease list with concurrent examination of existing data and literature and questionnaire surveys of producers and rural veterinarians.
2. Phase 2: Review of the priority disease list for the level of knowledge of each disease
3. Phase 3: Field and abattoir surveys of poorly understood diseases
4. Phase 4: Economic analysis and summation of the knowledge of each priority disease

However, a full scope of the project cannot be confirmed until after Phase 2 is complete. At this time, priority diseases, the level of existing knowledge for priority diseases and therefore the best means of investigating poorly understood diseases can be determined. In other words it is only part way through the research project that the scope and design of field and abattoir surveillance can be determined and an accurate costing developed for the entire research project. Fortunately, the first two phases of the project that are required to be completed before a final costing can be developed are relatively inexpensive to conduct. This mitigates risk to MLA by allowing early and relatively inexpensive projects to be instigated and later expensive phases to be instigated only when more information is available to accurately scope the project. Additionally, completion of the first two stages of the project will allow a desk based assessment of established endemic disease regardless of whether the rest of the project is completed. Small additional inputs (e.g. assessment of recently emerged diseases and economic modelling) would allow a similar but updated project to Sackett et al. (2006) to be produced, thereby producing an outcome of benefit to the livestock sector even without the project progressing further. That is the project could morph to a useful desk based assessment after phase 2 if the collection of field data was believed unviable.

Despite this, scoping for phase 1-2 and generic scoping for phase 2-4 are provided. Additionally, an interactive electronic workbook has been provided to assist MLA in investigating several scenarios/assumptions and therefore various cost estimates for these and later more uncertain phases. It would be prudent for MLA to explore this tool and various options before a project was instigated and again after phase 2 is completed (before final and expensive phases are implemented).

It is important to realise that some parts of the research project, especially the field surveillance is relatively expensive and small changes in design can lead to very large cost increases. In essence the research project is currently designed to reduce field surveillance in order to keep the budget to a realistic scale. Money is saved predominantly by utilising existing data where possible, by using abattoir surveillance to collect new data and by minimising sample sizes at all levels of sampling (national, farm, individual and the number of laboratory tests per individual). However, minimising sample sizes has several drawbacks. The precision of estimates at the national and zone level are relatively low. This may be important for national estimates. Additionally, limiting the number of laboratory tests potentially reduces the number of priority diseases that can be assessed if abattoir surveillance and existing data do not allow inexpensive assessment of many diseases. The complexity (mostly social) of establishing abattoir surveys for cattle as an alternative to field surveillance should not be underestimated. Likewise it may be difficult to garner cooperation for field surveillance as this is a significant workload for producers.

It may therefore be advisable to consider minimising the scale of the research project so that more resources can be available to ensure more precise and adequate research is done on the remaining project. This could be done in several ways, by reducing the number of red meat livestock species examined (e.g. by removing goats), by reducing the size of the priority disease list and by ensuring that abattoir data collection in cattle can be successful. However, possibly the two best means are to remove goats and to reduce the size of the priority disease list.

With respect to goats, the majority of meat goats are harvested goats. This means that few mitigation steps are possible to reduce disease in the majority of meat goats. Therefore enhanced understanding of diseases and economic impacts cannot improve meat goat production markedly as intervention is difficulty. Subsequently there seems less point in pursuing expensive disease research programs in goats compared with cattle and sheep, as mitigation is not generally possible. An obvious exception is the period of time between harvest and export or processing where disease mitigation may be beneficial. Hence a small and focused research project may be possible, for example pursuing only abattoir surveys at the two major goat abattoirs in Australia as these will allow estimation of the prevalence of diseases that have developed since harvest.

Justification for reducing the size of the priority disease list for each species can be given by considering the relatively fixed cost of laboratory diagnosis and declining benefits of understanding less and less significant diseases. In more detail, by far the most significant single cost item in the research projects budget is laboratory diagnosis of field collected biological specimens. However, each test for each disease costs on average the same amount. If the number of diseases on the priority list is reduced then the tests per animal is also reduced and therefore significant savings are certainly possible. Conversely, as one moves progressively down a priority disease list, diseases will become less and less economically important, despite the costs of diagnosing these diseases remaining high. Hence it seems sensible to reduce the priority disease list down from 20-40 diseases to some smaller number. However, culling the priority disease list is un-necessary in the early planning stages of the project, as it is only after phase 2 is complete that the diseases of importance and the best means of investigating the diseases can be determined. That is, it only then that field and abattoir surveillance can be firmly designed and the need for reducing the disease list determined.

Conversely, there may be scope to save significant monies if diseases can predominantly be diagnosed by visual abattoir inspection, because this will lessen the number of laboratory tests required. By examining the high priority disease list of Sackett et al. (2006) it is evident that many diseases in sheep and cattle could be diagnosed through abattoir inspection. Given that a functioning NSHMP could collect additional abattoir data relatively cheaply (or provide existing abattoir data) then it is quite feasible in sheep that the estimated 5 diseases for laboratory diagnosis in sheep may be excessive. However, a final assessment is only possible after phase 2 is completed and a priority disease list is populated.

Appendix 1: MLA terms of reference

Terms of REFERENCE

Scoping a livestock disease survey

Background:

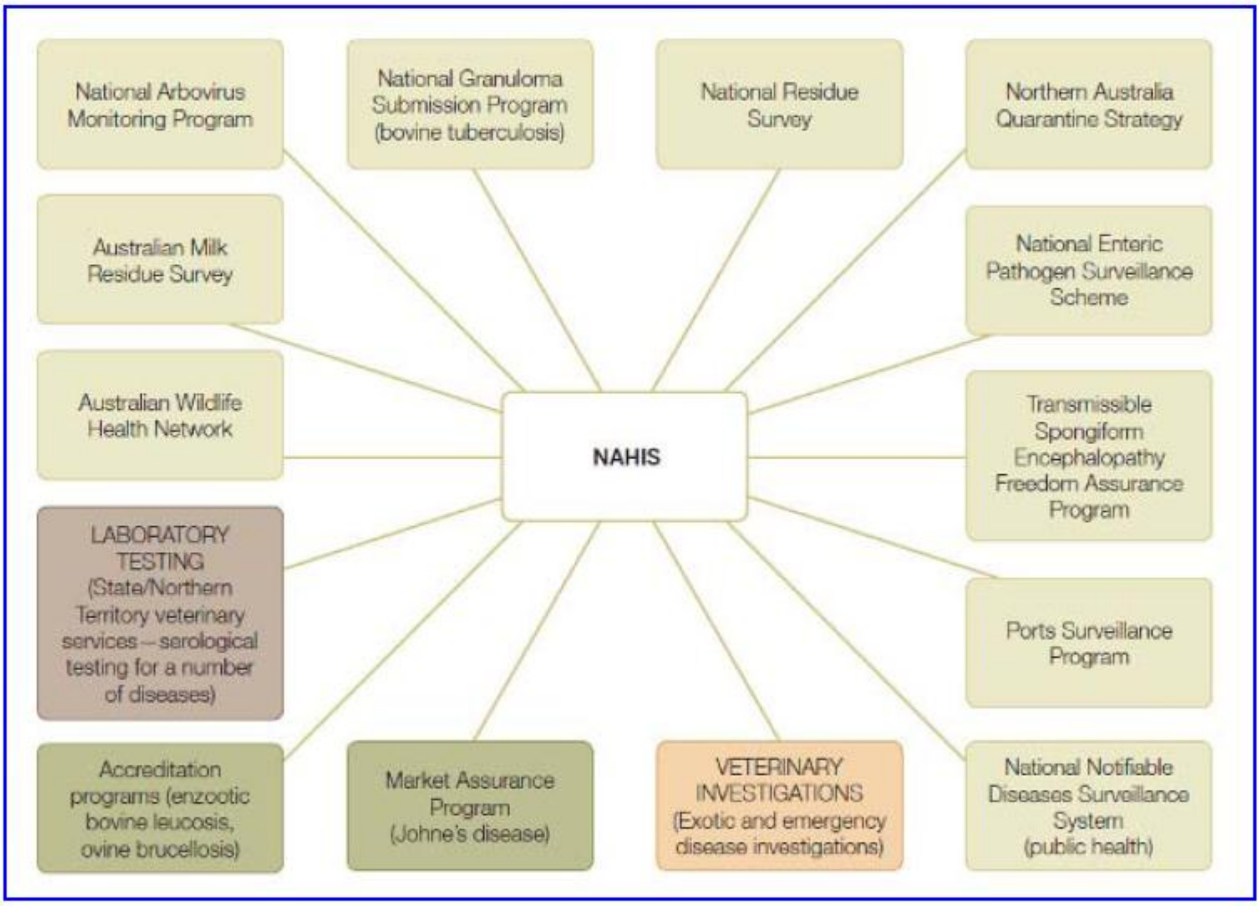
Since 2006, MLA has used the final report of project AHW.087 by Holmes, Sackett, et al., co-funded by MLA and AWI, with its estimates of the economic cost of endemic cattle and sheep diseases in Australia, to guide RD&E investments. However, it is recognised that this report has a number of shortcomings:

- It was a desk-top study, which relied on expert opinions and published literature.
- It excluded goats.
- It was unable to address problems perceived to be relatively localised in their impact.
- It was completed before newly emerged Bovine Theileriosis became a problem in NSW and Vic.

The AHW.087 final report is now more than 6 years old and there is a need for an up-to-date, objective assessment of the most important endemic diseases for the red meat industries.

MLA has recently received a number of requests and/or proposals in this area, using either abattoir and or on-farm surveys (more details are shown in Appendix 1):

- The preliminary abattoir survey data used for the AHA E-Surveillance report (March 2009) indicated that **arthritis** was a relatively important cause of condemnations, trimming and downgrading of sheep carcases. The on-farm risk factors and possible husbandry interventions seemed to be possible researchable topics. Arthritis was also flagged as an R&D priority by the Sheep Meat Council of Australia (SCA) in April 2012. In response to an invitation of expressions of interest, MLA received two proposals.
- A proposal to investigate the cost of **pneumonia and pleurisy** in lambs, starting with a baseline abattoir survey in NSW, VIC and TAS, followed by on-farm case studies and economic evaluation. This condition also featured prominently in the E-Surveillance report.
- A proposal to specifically investigate the role of ***Chlamydophila pecorum***, which causes polyarthritis in lambs and Sporadic Bovine Encephalitis in NSW.
- Vic DPI completed a Sentinel Flock project in June 2012, which recorded reproductive performance data, as well as causes of peri-natal/-parturient mortality, in 20 sheep flocks over 3 years. There is now a proposal to extend this with a **National Flock Health survey** over 5 years, monitoring morbidity/mortality and disease prevalence on 30 properties country-wide.
- In 2007, Animal Health Australia commenced a National Sheep Health Monitoring project (**NSHMP**) in abattoirs in six states. Twenty conditions which can cause on-farm loss or affect market access are being monitored. The project is planned to run for another year. Preliminary data from this project (and from the national OJD surveillance program and AQIS' Export Production and Condemnation Statistics database) were used to analyse the benefit-cost of instituting an E-surveillance system.
- The Red Meat Co-investment Committee (**RMCiC**) has recently released a report entitled Lamb Supply Chain and Animal Information RD&E Plan. One of its projects (1.4) aims to develop systems to collect animal health data and transfer these data to producers and animal health / biosecurity agencies.
- Livestock Data Link (**LDL**) is an early stage MLA project which aims to collect slaughter data from 8 Australian meat processing plants. One of its objectives is to identify animal health conditions which will be monitored.
- Animal Health Australia maintains a National Animal Health Information System (**NAHIS**), which collects, collates, manages and analyses data from a variety of sources, as shown in the following diagram:



Purpose:

MLA is now seeking expressions of interest from suitably qualified individuals and/or groups to scope a project to gather information on the prevalence and cost of endemic diseases which adversely affect the productivity of Australian red meat production (sheep, cattle and goats).

The project will achieve sufficient geographical coverage to be considered representative of the entire country and the diverse production systems, take into account conditions suspected of causing subclinical disease through to those causing clinical disease and death and consider production losses on-farm, as well those incurred in abattoirs through carcase trimming, downgrading and/or condemnation.

It is expected that the envisaged survey will be conducted in a collaborative effort involving universities, state government researchers and practising rural veterinarians and livestock consultants. Access will need to be gained to properties and their records through liaison with the producers, as well as meat inspectors in participating abattoirs.

Proposed survey project deliverables:

1. Information on the prevalence of sheep, cattle and goat diseases diagnosed in abattoirs and on their properties of origin.
2. Calculations of the economic cost of sheep, cattle and goat diseases diagnosed in abattoirs and on their properties of origin. Mortalities, lost production, treatment and prevention cost (labour, drugs).
3. On-farm risk/predisposing factors contributing to disease prevalence.
4. On-farm husbandry interventions to reduce/mitigate economic loss and their estimated cost.

Scoping study deliverables:

1. Definition of the scope of the proposed livestock disease survey:
   a. The optimum number of investigators.
   b. Their ideal geographic locations.
   c. Their expected resource requirements.
2. Linkages with existing work.
3. Proposed data gathering: methods; sample types, sizes and analyses (options and relative merits).
4. Estimated time required for completing the proposed livestock disease survey.
5. Estimated cost of completing the livestock disease survey for sheep only.
6. Estimated marginal cost increase of extending the survey to include goats, southern and northern beef, respectively.
7. Where possible, the names of candidate researchers who should be invited to contribute expressions of interest in the survey.

Timeframe:

MLA would expect this scoping study to be completed within 3 months from the date of contract execution.

Quotations

Researchers interested in performing this scoping study should submit their proposals to MLA by 17th December 2012 to Johann Schröder, either by email (jschroder@mla.com.au), or at:

Meat & Livestock Australia

Level 1

165 Walker Street

North Sydney NSW 2060.

Appendix 1:

	RECENT MLA FUNDING PROPOSALS				RELATED ACTIVITIES		
	ARTHRITIS	PLEURISY/ PNEUMONIA	CHLAMYDOPHILA	NATIONAL FLOCK HLTH SURVEY	NAT SHEEP HLTH MON PROJECT (NSHMP)	RMCiC	LIVESTOCK DATA LINK
ORIGIN	AHA E-Surveillance report. Project B.AHW.0123 SCA resolution	Vic DPI – E-Surveillance rep; abattoir survey	Central-W / Tablelands LHPA NSW	Vic DPI Sentinel Flock Project (SFP)	Animal Health Australia	Lamb Supply Chain and Animal Information RD&E Plan (proj 1.4)	MLA Industry Systems
TYPE	Abattoir/On-farm	Abattoir/On-farm	Laboratory/On-farm	On-farm	Abattoir	?	Abattoir
GEOG. COVERAGE	5 vet schools: Sydney, Melbourne, CSU, Adelaide, Murdoch	NSW, VIC, TAS	Central NSW	30 properties, 6 states	8 – 9 meatworks, 6 states	?	8 meatworks
	T B A	T B A	T B A	T B A	2007	T B A	2011

START							
DURATION	2 yrs; 3 yrs	3 yrs	1 yr	5 years	5 years	?	Open ended
COST	$242K; $370K	$520K (w AWI)	$126K	$3 100K ($620K p.a.)	???	?	?
PRO	Interest from researchers. SCA support	Interest from researchers. SCA support	Interest from researchers	SFP experience valuable.	Underway. Data for follow-up.	Broad stakeholder engagement	Underway. RFID technology
CONTRA	Narrow disease scope. Geographic coverage likely to be inadequate.	Narrow disease scope. Geographic bias.	Narrow disease scope. Geographic bias.	Inadequate national coverage. Jurisdictional collaboration still to be negotiated.	Monitoring only 20 conditions. Trace-back possibilities uncertain.	No concrete plan as yet. No assigned responsibilities yet.	Slaughter data only. No animal health component yet. Trace-back possibilities uncertain.

Appendix 2: Summary of Sackett et al. (2006) and recent diseases of importance

Background and introduction

Sackett et al. (2006) conducted a useful study to estimate the productivity costs of the major endemic diseases of sheep and cattle in Australia. This study provided absolute costs and a relative ranking of the major endemic diseases of livestock in Australia using a standardised methodology. The results have assisted MLA and other organisations to direct research and development money for endemic disease in the livestock sector.

However, the study has some limitations as a document that can guide current decision making. It is somewhat dated and the study methodology was necessarily limited by resources to a desk top review of expert knowledge and modelling. Some diseases could not be assessed as data was lacking (e.g. bovine pestivirus) and experts consulted may not have been able to assess the impact of endemic diseases in some specific regions. Since the report was written there have also been a number of emergences of important endemic diseases (e.g. Theileriosis) and an increased understanding of the importance of some endemic diseases (e.g. arthritis in sheep). A number of new data sources are being developed that will provide extra information on endemic diseases and MLA has received a number of applications for funding for endemic disease research. This indicates that a new study is required that is contemporary, that collects field data for example on prevalence, and that is regionally as well as nationally focused. Meat and Livestock Australia are considering a national survey to determine the most economically damaging endemic diseases of livestock. AusVet Animal Health Services has been commissioned by MLA to scope and design such a study.

This document aims to provide context for workshop participants on the report by Sackett et al. (2006). It also provides an additional listing of newly emerged diseases or diseases where the knowledge base has expanded. A categorisation of all the important diseases discussed is then made to aid decision making at the workshop. The purpose is not to prescribe a list of economically important diseases (as this will occur in the proposed MLA study), but instead to stimulate discussion and thought as to appropriate means of surveying and assessing the economic impact of such diseases in any future MLA survey.

Methodology of Sackett et al. (2006)

The study had three phases:

1. Workshop

The workshop aimed to identify all diseases and prioritise them economically. Specifically, participants listed all diseases in their sector. These were then prioritised to high, medium or low economic impact diseases. Prioritisation was based on the number of the flock/herd affected and the cost of the disease at herd/flock level if controlled or uncontrolled.

Participants also identified important factors to inform later economic modelling.

2. Literature review

Data on the economic impact of the diseases listed by participants was gathered with a literature review. This looked at prevalence/incidence of disease, mortality rate and the cost of disease.

3. Economic modelling

Spread-sheet models of simulated herds were developed to calculate the marginal cost of disease at the farm level for high economic impact diseases. Marginal cost means that the only factors that varied during modelling were those due to disease whilst all other factors were held constant. This was conducted for several sectors of the sheep industry and for northern, southern and feedlot cattle. Only disease effects on productivity at the farm level was assessed and all other disease impacts remained unassessed (e.g. market impacts, processing, trade, quarantine and regulation).

Results of Sackett et al. (2006)

Diseases of high economic importance to southern beef:

Bloat

Clostridial diseases

Gastrointestinal parasites

Grass tetany

Liver fluke

Pestivirus

Pinkeye

Reproductive wastage

Rotavirus

Under-nutrition/starvation

Diseases of high economic importance to northern beef:

Botulism

Bovine ephemeral fever

Buffalo fly

Nutritional deficiency

Reproductive wastage

Tick and tick fever

<u>Diseases of high economic importance to feedlot beef:</u>

Bovine respiratory disease complex

Heat stress

<u>Diseases of high economic importance to sheep:</u>

Abortion and stillbirth

Arthritis

Blowfly

Lice

Ovine Johne’s disease

Peri-natal mortality

Plant poisons

Post-weaning mortality

Scouring

Worms

Emergence of new diseases and additional information since Sackett et al. (2006)

Bovine theileriosis

Buffalo fly (northern NSW)

Sheep arthritis

Lamb pleurisy and pneumonia

Categorisation of diseases

It is possible to categorise these diseases into several broader categories for ease of consideration:

1. Parasites
Sheep (lice, worms, blowfly), cattle (gastrointestinal parasites, liver fluke, buffalo fly, tick)

2. Transmissible infectious diseases and vector borne disease
Sheep (Ovine Johnes disease), cattle (tick fever, bovine ephemeral fever, pinkeye, pestivirus, rotavirus, bovine respiratory disease complex, bovine theileriosis).

3. Infectious diseases
Sheep (arthritis- although some causes (e.g. Chlamydophila) are transmissible), cattle (clostridial diseases including botulism)

4. Nutritional
Sheep (plant poisoning), cattle (bloat, grass tetany, under nutrition/starvation, nutritional deficiency)

5. Other (e.g. non-specific signs)

Sheep (peri-natal mortality, post-weaning mortality, abortion and stillbirth), cattle (reproductive wastage, heat stress).

Many of the categories contain diseases that are well described with effective treatments (e.g. parasites). Research on risk factors for this category of diseases would be less rewarding as uptake of available management practices is the issue. For these categories, a simple survey may be more sensible. Other categories (e.g. peri-natal mortality) are complex multifactorial issues and further epidemiological investigation on risk factors may be useful.

Conclusions

The study by Sackett et al. (2006) was a well conducted and useful study. Despite this it has several limitations associated mostly with the resources expended on the study, the time since the study and that it focused only on the direct economic impact of disease on farm productivity. This last is particularly important, as there are a wide variety of economic effects of disease on livestock production that are not associated with direct on farm profitability effects. It may be important to consider these additional economic impacts in future research on the economic impacts of disease (depending upon available resources).

There are several categorisations of economically important diseases possible. Some broad categories include nutritional, transmissible infectious or vector borne diseases, non transmissible infectious diseases, parasitic diseases and a broad 'other' category.

A key finding is that many listings are not specific diagnosable diseases. Instead they are syndromes such as perinatal mortality, reproductive wastage or post weaning mortality. It would be virtually impossible to investigate such diseases with some survey methods such as a structured sero-survey as there are many infectious organisms possibly responsible and because such syndromes are frequently multi-factorial. (Indeed the diseases that can be examined by a simple sero-survey will frequently be quite limited). In these instances a more complex study design such as longitudinal study or a different data collection tool such as a questionnaire survey is required. Such approaches can still be costed and scoped, but cannot be completely designed *a priori*.

A further important finding is that some syndromes will be obvious in one study population and not another. For example, at the farm level, with appropriate methods certain syndromes (such as peri-natal mortality) will be very obvious. At other levels such as abattoir, such syndromes would not be detected easily. In reverse, liver fluke may be obvious at the abattoir level but not at the farm level. Thus care will be required to select appropriate study populations for sampling.

Appendix 3: Survey methods and tools

Introduction:

There are a wide variety of study types, sampling methods and data collection tools available to investigate animal health events. In order to choose the most appropriate method and tools these should be classified and the relative benefits and disadvantages understood. The following discussion briefly classifies and discusses these. Conclusions are presented as to appropriate categories that are consistent with MLA requirements and TOR.

Types and features of animal health study types:

Study type

There are two broad approaches to investigating animal health related events, experimental and observational approaches (Dohoo et al., 2009).

Observational studies are where an investigator simply observes a population for the disease or development of disease and concurrently whether they have been exposed to a putative risk factor. This allows the investigator to compare groups of animals with and without the risk factor for the presence of disease and thus infer whether a putative risk factor causes disease[7]. Observational studies are often quicker, cheaper and more easily implemented than experimental studies. However, caution is often indicated when inferring the cause of disease as the level of evidence offered is lower than in clinical trials.

There are several types of observational studies:

- Survey

A survey is a simple example of an observational study but unlike other observational study types does not measure risk factors. Specifically members or aggregates (e.g. herds) of the population of interest are counted and their characteristic of interest measured (Thrusfield, 2007). Surveys frequently measure prevalence of infection, sero-prevalence or clinical disease. They generally occur in a defined period of time and hence present a 'snap-shot' of the population of interest.

- Cross sectional study

These are similar to a survey but also collect data on risk factors[8]. The association between risk factors and prevalence of disease are generally quantified with an odds ratio. The great advantage of cross sectional surveys is the speed and simplicity of approach resulting in a relatively inexpensive observational study. A large

[7] Note that a case control is somewhat different but nonetheless an observational studies. Here controls are arbitrarily selected, compared with cases and the odds of exposures contrasted between cases and controls.
[8] It should be noted that the distinction between surveys and cross sectional surveys is sometimes blurred. For example Thrusfield (2007) distinguishes them but another leading text Dohoo et al. (2009) does not. In this project surveys and cross sectional studies are distinguished.

disadvantage is that the reliability of inferences based on observed associations are not as great as for several other study types and that a snapshot in time is presented. For example for inferences, an explanatory variable may be associated with disease but this could either be because the variable causes disease or because the risk factor prevents animals from dying due to the disease (and thus is more common in diseased individuals). In the latter case, the risk factor may be falsely identified as a risk factor.

- Case Control Studies

These studies compare the frequency of risk factors in cases relative to controls in order to quantify the association between the explanatory variable and being a case. Some key advantages are that the approach is excellent for rare diseases, can utilise existing or new data (i.e. can be retrospective or prospective), can utilise primary or secondary study bases (e.g. a listing of animals on farms or farms versus animals recorded in a database such as veterinary consultations or abattoir killing lists) and be relatively inexpensive. However, the approach can suffer from bias, for example it can be hard to select appropriate controls or if using existing data the data can be inappropriate or incorrect. Additionally, the use of such approaches makes it impossible to assess prevalence of disease (because the number of cases and controls are set arbitrarily and because a representative sample of the population is not attained).

- Cohort studies

Cohort studies follow a group of individuals for the development or otherwise of disease (or infection etc.), whilst also assessing the exposure. This allows a comparison of the incidence of disease in exposed to unexposed individuals and hence allows assessment of both the incidence of disease and risk factors for disease. Its primary advantage is that the rigour of inferences about causes of disease is greater than for other observational study types and that incidence data is collected. Key disadvantages are the expense of such studies is high as a group is followed longitudinally for many years. Additionally, sample sizes can be hard to maintain as drop-outs can develop with participants declining to remain in the study over long periods of time.

Experimental studies allow the investigator to allocate putative risk factors (either treatments or exposures) to groups of animals and follow these groups for development of the outcome of interest (e.g. disease9). This then allows the investigator to prove that a treatment or risk factor respectively prevents or causes disease. A typical example is a two armed controlled trial where a control group receives no treatment (control group) and a treatment group receives a treatment (such as a vaccine or exposure) and the two groups are compared for the development of disease. Differences in disease development between the groups

[9] The outcome of interest will be referred to as disease herein for simplicity, but it is acknowledge that the outcome of interest can be many and varied including infection, sero-prevalence, disease, production metrics etc.

then demonstrate the effect of the exposure or treatment on disease. These can be conducted in the laboratory or a more natural setting such as the field (controlled or clinical trial). Controlled trials are considered the gold standard for proving the cause of disease and for determining the efficacy of mitigations. In contrast, laboratory experiments are too far removed from reality to be very useful except for proof of concept. However controlled trails are very difficult, expensive and time consuming studies. Additionally, these studies are limited in scope and can only assess a few risk factors at a time and only those risk factors or treatments that can be manipulated by the investigator.

Other means of classifying animal health study types

Time period of study

Surveys and epidemiological studies can be structured to occur over different time periods. These include:

- ‘Snap-shot’ in time: Animals (or aggregates such as herds) are examined at a single contemporary time point (or a short period of time e.g. 1-2 years). Surveys can also be repeated several times to give several ‘snap-shots’ which can indicate changes in the prevalence of disease over time. These include surveys and cross sectional surveys.
- Retrospective: Existing data is followed back to see how disease developed over time. This especially includes case control studies.
- Prospective or longitudinal: By following animals for some time to observe the development of disease. These include cohort studies and clinical trials.

The broad aim of the study

Most observational studies seek to infer the cause of disease through measuring associations. Several can also estimate the frequency of disease. However a simple survey seeks only to measure the frequency of disease. A survey and observational studies that assess risk factors thus vary considerably in objectives with the scope of risk factor studies being much wider. Thus study design affects the expense of the study as collecting and analysing risk factor data considerably increases the expense of a study. For this reason, most observational studies and clinical trials are more expensive than simple surveys.

Data collection tools

Information about a health related event may be collected by interview, by collection of biological specimens or by screening of records or biological specimen banks (Cameron and Baldock, 1998a). Interview can be used to deliver questionnaires or conduct participatory epidemiology. Each means of collecting animal health data have relative advantages and disadvantages.

Questionnaires

A questionnaire is a data collection tool used in a wide variety of epidemiological settings (Dohoo et al., 2009). Questionnaires can be qualitative (exploratory and useful for generating hypothesis early in a research program) or quantitative (structured and useful for quantifying information about study subjects such as prevalence). They can be delivered by a variety of means including in person, by mail or phone and over the internet. MLA has used a specialist rural market research company (Kaliber) who have access to MLA member lists (and the companies own rural lists) to successfully conduct questionnaire surveys previously.

Advantages of questionnaire data collection include:

- Relatively inexpensive data collection. This is because interviewee knowledge is used which avoids the need for more expensive biological specimen collection and laboratory analysis. Additionally, questionnaires can be administered by phone, letter or internet which further lowers costs.
- The time frame of interest of the questionnaire is not fixed. That is, even though questionnaire studies often occur over a short period of time the time frame of interest can be set by the investigators. For example, the interviewee can be asked to answer the questionnaire with respect to their experience over many years. Questionnaires thus offer considerable advantages when investigating periodic diseases. For example arboviruses such as Akabane virus or bovine ephemeral fever may only cause occasional but extremely severe epidemics in certain regions of Australia that are bordering endemic areas as suitable environmental conditions occur. If biological specimens were relied upon (e.g. sero-prevalence) and epidemics were a considerable period of time apart a false conclusion could be made that the arboviruses are not important in the region of interest. However, an experienced interviewee would recall earlier severe epidemics and report this data.
- A further advantage is that multiple diseases can be assessed during a questionnaire survey. For example the question could be posed: “what are the 20 most financially damaging diseases of sheep in your district?” To achieve similar answers using biological measurement would entail testing of serum for many diseases and may never reach the correct conclusion depending on which diagnostic tests are applied.

Disadvantages of questionnaire surveys include:

- Difficulty validating responses compared with objective measurement
- Recall or experience and knowledge of some respondents may be poor (e.g. may not recognise a disease of interest)
- Low response rates can introduce bias (especially for mailed or internet questionnaires)
- Questionnaires can be complex and time consuming to construct correctly and require considerable subject matter knowledge

- Extensive expertise with database management and statistical computing is required

Participatory epidemiology (participatory and rapid rural appraisal techniques)

These techniques can be used to gather animal owner knowledge and experience on disease (Heath, 2008). It has been widely used in rural settings in developing countries. Where a population has high literacy rates (e.g. Australia), a questionnaire survey may be simpler and more repeatable.

Collection of biological specimens

Collection of biological specimens offers many advantages, especially the objective and repeatable nature of data collected with this technique. Additionally, other data (e.g. individual animal information) can be collected at the same time that biological specimens are collected facilitating risk factor analysis at the individual animal level.

Disadvantages include additional expense in collecting and analysing samples, inaccuracy in laboratory analysis (e.g. test performance (sensitivity and specificity) and reproducibility) and the fact that a priori decisions on what diseases are assessed is required.

Screening of records or biological specimen banks

A primary advantage is that such records already exist and therefore data collection can be rapid and inexpensive. Additionally, the time span of such collections is usually long. However, disadvantages include that the existing data may not be suitable for the task at hand (e.g. unsuitable data or specimen was collected), that the size of the sample is not sufficient (e.g. volume of serum) or that the population sampled was not the population of interest.

Other tools

There are several other tools to collect animal health data, but generally these are applied to longer term surveillance efforts, whereby data is collected over significant periods of time with the aim of responding when adverse findings occur (such as detection of an emergency disease). These include passive surveillance, use of negative disease reporting, syndromic surveillance, sentinel herds and ongoing collection of data at abattoirs. These tools are less applicable to a single survey to assess the prevalence and distribution of endemic disease (although see screening of records above with reference to abattoir surveillance).

Sampling methods

Sampling approaches are divided in to non-probability and probability based approaches.

Non-probability approaches are approaches where sampling occurs without an explicit means of determining an individual's probability of selection (Dohoo et al., 2009).

For example a sample is selected using the judgement of the selector or using convenience as a criterion for selection. These types of sampling do not allow a population characteristic (e.g. disease) to be described adequately.

Probability sampling is where every individual has a known probability of selection. These methods generally involve the application of some form of randomisation to a sampling frame (Dohoo et al., 2009), but not necessarily in risk based surveillance. These methods are able to be used to describe a population characteristic such as disease.

Probability approaches include simple random samples, systematic random samples, stratified random samples, cluster sampling, multistage sampling, random geographic coordinate sampling (Cameron, 1999) and risk based sampling (Dohoo et al., 2009).

During simple random sampling every animal in a population has an equal chance of selection. Sampling is likely to occur across many premises across the country. Whilst simple random surveys are likely to result in results of greater precision for the same sample size, they are relatively expensive because more premises will need to be visited for sample collection. A major impediment of such an approach is that every animal must be listed in the sampling frame.

Systematic random sampling is where no explicit listing of animals occurs, but every member of the populations is presented sequentially. If the population size and required sample size is known then a sampling interval can be calculated and the first sample randomly selected within a sampling interval. A complete sample can be collected by randomly selecting the same numbered animal in every sampling interval.

During cluster and multistage sampling a sample of premises is first selected and then either a census or a sample is taken on the selected premises. Cluster and multistage sampling are much cheaper and practical because fewer premises have to be visited to collect a sufficient sample of individuals, although the precision of results will often be reduced. The sampling frame must contain all the premises, but not a complete listing of every animal.

Stratification of sampling is where a population can be divided into subpopulations based on mutually exclusive strata (Dohoo et al., 2009). Sampling can be proportional to the relative number of individuals within each stratum. This can be combined with other forms of probability sampling such as multistage, cluster or simple random sampling. A form of stratified random sampling is dividing the population into geographic strata such as the beef or sheep production zones.

Risk based sampling

Surveillance analysis and design has rapidly evolved in recent years (Cameron, 2012b). Cannon and Roe (1982) first made formal survey design accessible to veterinary medicine with tools to calculate sample sizes during representative surveys. These approaches were later adapted for test performance (Cameron and Baldock, 1998a; Cameron and Baldock, 1998b). However, in recent years a significant evolution occurred with the development of scenario tree modelling (STM) approaches that allowed analysis and assessment of non representative sampling approaches (Martin et al., 2007). Or more specifically, the analysis and design of risk based sampling where sampling is based solely on the probability of infection of a unit within the population (Cameron, 2012b). These approaches have three main uses: to detect emergent diseases, to substantiate freedom from disease and to detect cases and hence the prevalence of an endemic disease in a population (Willeberg et al., 2012).

Cameron (2012a) outlined the use of scenario tree modelling for case detection. In short representative surveys are generally used to measure the distribution and amount of disease (e.g. prevalence) (Cameron, 2010 2012a), but STM can be used for case detection to identify all cases for example in control or eradication programs. Thus representative surveys are the tool of choice for determining the distribution and amount of disease. Alternatively, STM has not yet been adapted to assess the prevalence of widespread endemic disease and has less application to the current MLA survey. However, STM may have some applications as it allows a complex surveillance system to be broken into constituent surveillance system components (e.g. active surveillance verse abattoir surveillance) and then to compare these constituent parts. For example the detection of cases verse occurrence of cases, the sensitivity and specificity of surveillance tools in each component and the coverage of each component in terms of the overall population can be assessed. This then allows the optimal combination of surveillance system components to be determined. However, a good understanding of the risk factors and true prevalence of disease in the population as well as the distribution of the population within each surveillance component is required.

The specific application to the current project may therefore be in assessing surveillance results following the pilot studies. That is, several survey approaches could be trialled in one or two areas of interest (e.g. questionnaire surveys of vets and producers), examination of existing abattoir data and recent research projects (Vic sheep flock project). The optimum combination of surveillance components could then be estimated with STM using one of the methods (e.g. Victorian sheep flock project) as the gold standard for both prevalence and calculation of relative risk between population strata. This would allow the most optimal survey design to be assessed for extension to a national survey.

Abattoir sampling

A great advantage of collecting surveillance data at an abattoir is that it is relatively inexpensive. However abattoir data has a number of limitations. Abattoir data is useful to identify diseases with distinctive gross pathology but can be inaccurate for other diseases or infections. Abattoir surveillance generally only samples a particular subset of animals, and hence can introduce bias if an understanding of a population characteristic is required. For example, abattoir populations generally include those animals that are relatively healthy (otherwise stock should not be declared healthy and transported for abattoir slaughter). Hence there may be a preponderance of healthy young animals (for example heavy export steers) or at the very least the slaughtered population may be similar and consistent for example a line of cull cows. Abattoir surveillance is most useful if the disease in question does not bias presentation of the animal at the abattoir. Additionally, there are a number of practical inhibitions on abattoir surveillance associated with OH&S, the physical practicality of abattoir surveillance and social and market pressures.

These features mean that abattoir data is essentially useless for some diseases or syndromes, for example conditions that occur on farm that never reach the abattoir. Some include pre-natal or post weaning mortality and reproductive wastage.

Further discussion will occur elsewhere in our study design document.

Study design given TOR

Table 5 is included to assist identification of appropriate study designs. It matches MLA desired requirements of such a study against the features of each study type to allow an assessment of the suitability of the several study designs. Additional summaries of sampling strategies and data collection tools are also provided.

Table 5: A summary of study type, sampling strategy and data collection tools for suitability against MLA requirements. Green rows represent suitable and red rows represent unsuitable.

	1. Assessment of study type					
	MLA specified feature of survey					
Study Type	**Time frame (1-2 years)**	**Number of diseases assessed (suggest 20-40 diseases)**	**Budget (--------[10])**	**Assessment of Risk factors**	**Assessment of prevalence and economic cost**	**Comments**
Survey	Suitable as rapid	Suitable as could have a broad scope. Care would be required in selecting suitable data collection method.	Suitable as the cheapest observational study	No	Yes	This study type appears very suitable to assess the prevalence and cost of endemic disease but not for assessment of risk factors
Cross sectional survey	Suitable as rapid	Suitable but as number of diseases increase it may become difficult to collect specific risk factor data for every disease as too broad	Suitable as the next cheapest observational study	Yes	Yes	This is similar to a survey but also collects data on risk factors. Care in inferences on cause of disease.
Case control study	Suitable as rapid and can use existing data	Suitable as can use existing data- depends on data quality	Suitable as relatively inexpensive, especially if retrospective	Yes	No, cannot assess prevalence as the investigator specifies cases and controls.	Not suitable as the design won't provide basic prevalence data.
Cohort study[11]	Not suitable as time consuming	Unsuitable as does not have a broad scope.	Unsuitable as likely to be very expensive if national and therefore exceed this budget.	Yes	Incidence (better than prevalence)	The time frame and budget of the project are too short/small.
Controlled trial (field)	Not suitable as time consuming	Not suitable as require focused study	Not suitable as very expensive	Suitable	Suitable	This trial design would be too expensive and time consuming if conducted nationally. It is best applied to a focused research question for example looking at an intervention or a risk factor.
	2. Sampling designs					

[10] Not proscriptive as yet to be determined. Provided so AusVet has a nominal figure to work with for planning purposes.

[11] Simple multiform longitudinal studies are also possible and subtly different from cohort studies in that farms are not selected on exposures for a certain disease. Here any farm is selected and followed for a time and can collect data on a number of diseases and exposures. These can have a broader scope and an example includes the Victorian DPI sentinel flock study.

Simple random	**Not suitable as no listing of all cattle, sheep or goats exist in a single sampling frame. Even if a sampling frame were present this method would entail a very expensive data collection as likely many more premises wold have to be visited that for other methods.**
Systematic random	**Marginally suitable. Most cattle may be progressively presented to sale or export yards (even older cull animals) but some biases would be present (e.g. especially older cattle in northern Australia). It would be practical to sample these in a timely fashion as they are presented to saleyards. However, there may be sensitivities to sampling some groups of cattle (e.g. export cattle).**
Multistage	**Suitable (most). A listing of all agricultural establishments exists in Australia (PIC codes) and hence a first stage sampling frame exists. Systematic or simple random sampling on premises could occur to sample each property.**
Cluster	**This is relatively unsuitable as it is unlikely a census could be carried out on each premises which is what would be required for this method.**
Stratification	**Suitable as this allows the survey to be divided across geographic strata to ensure every region is represented. Gives both an overall and region by region estimate of prevalence and risk factors.**
Risk based sampling	**Usually depends on excellent knowledge of the system being sampled (e.g. relative risks between strata, understanding of the coverage of each surveillance component, the sensitivity and specificity of surveillance component etc.) and the aim is generally to demonstrate freedom from disease for trade purposes. Hence is less applicable than representative surveys for this MLA project although there may be some benefit to using this method to analyse pilot studies to suggest the most applicable survey design.**
	3. Data collection tools
Data collection method	
Questionnaire design	**Suitable as can search for many diseases in the one questionnaire (broad scope), it is not time limited and is relatively inexpensive.**
Participatory epidemiology	**Less suitable for Australia with high literacy and good communications.**
Collection of biological specimens	**Suitable but scope limited to a certain number of diseases due to expense of laboratory testing for each disease of interest. Time frame of interest limited in some cases so may just present a snapshot in time.**
Screening of existing records or samples	**Could be suitable, for example if abattoir records are screened then prevalence could be ascertained, although a highly biased sample of animals (i.e. population presented to the abattoir is not representative of the general population). Risk factors could be examined with a case control approach.**

Conclusion

The TOR specifies that the study should collect prevalence and economic data as well as risk factor data. Following discussions with MLA the focus of the survey should be on the prevalence and economic impact of endemic diseases. Risk factors are a secondary focus, but nonetheless important (Johann Schroder pers.com. Feb 2013). Hence an observational study is required as this allows estimation of disease frequency and risk factors. Two observational study designs provide disease frequency and risk factor data, cohort or a cross sectional study designs. On balance a cross sectional study would be advantageous as MLA has indicated they require a study of short duration (1-2 years) (Johann Schroder, Pers. Comm., Feb 2013). If risk factors were not to be considered to save money and because much data on risk factors already exist for many diseases, a simple survey could be conducted. A meaningful cohort study would require a longer data collection time than the 1-2 years specified and cannot focus on many diseases at the same time (although a simple multi-farm longitudinal study could).

However, if a cross sectional study is pursued it must be accepted that data may be temporally limited in nature as a cross sectional design takes a 'snapshot'. This can lead to incorrect inferences from such a study if secular (long term trends) or cyclical (regular variability in data) changes in disease incidence can occur and the time period of the cross sectional study period does span a sufficient time period to detect these trends. For example, the regional impact of bovine ephemeral fever may be assessed as unimportant in northern NSW if sampling occurs in a dry year with no incursion of BEF. In contrast, a longer term cohort study that collects data over several years including wet years with BEF incursions may correctly conclude that BEF was a locally important disease.

Fortunately a cross sectional study may still overcome this temporal issue and allow correct inferences if tools to collect data are appropriately chosen. That is, some data collection tools utilised in a cross sectional study do not limit an assessment of disease status or risk factor exposure to the immediate sampling period. For example serological assessment of older cattle for an infectious agent can allow a lifetime or long term history of infection status of cattle to be ascertained, rather than an assessment of the current status of cattle if virological or PCR tools are used. Likewise, a questionnaire survey of vets or owners can allow many years of collective experience of interviewees to be collected, rather than just the current status of a district. However, in order to ensure the objectivity of the data collected, some form of biological specimen collection will also be required. A very useful means of surveying livestock may be screening of existing data such as existing databases of both abattoir data and research projects. This would allow rapid and relatively inexpensive collection of data.

The most appropriate sampling strategy will likely comprise some stratification to ensure the geographic representativeness of the sample. Additionally, difficulty obtaining a complete sampling frame for all animals in each livestock class will mean that multistage sampling is required.

Risk based sampling may have some utility in the early stages of the survey, for example during pilot studies. Here several survey methods can be used and each component assessed to assist in designing an optimal survey strategy. However, in general representative surveys have more utility in determining the prevalence and distribution of endemic disease.

Appendix 4: Population and distribution of red meat livestock in Australia

Introduction

A critical part of planning a national survey of red meat livestock diseases is knowledge of the distribution and abundance of livestock. This is important from a technical point of view to plan sample sizes and survey design, but also to ensure the geographical representatives of the survey as specified in the scoping study TOR.

The Australian Bureau of Statistics (ABA) conduct an agricultural census every 5 years, with the most recent in 2011 (http://www.abs.gov.au/agcensus2011). Included in the census are the number and types of agricultural premises and the number of livestock by category. These are collected to statistical area 2 (SA2) level in Australia, with SA2 regions containing approximately 10 000 people (range 3 000-25 000 people) and there being more than 2000 regions across Australia. The census examines agricultural businesses with an estimated value of agricultural operations or business activity statements of greater than $5000. These businesses are surveyed using an ABS maintained agricultural survey frame (ASF) which is based on Australian Tax Office administered Australian Business Numbers. The sampling frame subsequently lists many agricultural premises of interest in Australia. In the 2011 census, responses were received from 88% of all premises in the ASF. Possible omissions from the sampling frame are small producers or those who do have an ABN.

The large geographic scale and complexity of production practices within the sheep and meat cattle sectors indicate that categorisation of the sectors is required for comprehensive understanding and description. Work of this nature has occurred for the sheep and beef cattle sectors with production zoning of the sectors (AusVet, 2006; Hassells_&_Associates_Pty_Ltd, 2006). Each production zone captures commonalities in the production, marketing, climate and general nature of the livestock sectors in that region. Geographical information system (GIS) compatible shape files delineating these sheep and beef production zones are available. These zones present an opportunity to meaningfully regionalise the endemic diseases survey as specified in the TOR.

Some authors (Heath, 2008) have surveyed the distribution and number of Australian rural veterinarians. This data may provide a sampling frame or at least knowledge of sample sizes required if a survey of veterinarians was designed.

This paper describes both results of the ABS agricultural census for sheep, meat cattle and goats and the integration of census data and sheep and beef cattle production zones. These data and descriptions are considered useful information in designing an endemic diseases survey of red meat livestock across the country.

Appendix one describes the distribution of rural veterinarians across beef and sheep zones of Australia as sampling of veterinarians for their knowledge may be useful in the MLA study.

Method

Data source description

ABS data consisted of two files, a GIS file of all SA2 regions nationally and a spread sheet of agricultural commodities by SA2 region. The public versions of these data could not be comprehensively matched as there was no primary identification key available across the two files (this was due to extensive inconsistencies between place names in the two files and an absent SA2 code in the agricultural census data). Subsequently, the ABS conducted a paid consultancy ------) to provide agricultural census data in a spread sheet that included a SA2 code. This allowed joining of the two data sources so that geographical queries and visualisation could occur.

GIS files that document the geographic extent of beef and sheep zones were sourced from Dr Evan Sergeant (AusVet) and Dr Graeme Garner (DAFF).

Description of ABS data and integration with beef and sheep zones

Summary statistics of ABS sheep, goat and meat cattle industries were calculated. Choropleth maps of beef, sheep and goat population distributions to SA2 level were created in QGIS. Here ABS data was first joined to SA2 regions. Next the number of animals per SA2 region was divided by the area of the SA2 level to yield a density of animal per km2. Choropleth maps were created for sheep, goats and meat cattle using these densities.

Integration of ABS data and industry production zones was conducted within a QGIS using spatial queries. Specifically, the beef or sheep zones were used to identify intersects between the zones and SA2 regions. Manual queries were used to avoid double counting of SA2 regions as SA2 regions were often partly within more than one beef or sheep region. Thus each SA2 region was assigned to a beef or sheep region allowing summary beef and sheep statistics to be calculated for each zone.

Results

Results are presented using maps and tables as appropriate. Table 6 presents summary data on the national population of sheep, cattle and goats. Table 7 and 8 present data on the population of meat cattle and sheep in each production region. Figures 3 and 4 shows the location of beef and sheep production regions respectively. Figures 5-7 are choropleth maps of the density of meat cattle, sheep and goats.

Table 6: Summary statistics of meat cattle, sheep and goats nationally.

Sector	No. of livestock (x1 000 000)	No. of premises (x1000)	Mean livestock/premises
Meat cattle	25.94	73.48	462
Total sheep	73.07	43.80	2,561
Goats	0.54	0.33	163

Table 7: The population of meat cattle by beef production region.

Beef region	Number of beef farms	Number of cattle	Average farm size (cattle/farm)	Density (cattle/area of zone in km^2)	Area of cattle region (km^2)
Arid Zone	1,595	2,833,241	1,776	0.70	4,069,052
Barkley Tableland	30	858,465	28,875	2.83	303,295
Central Qld and North-west NSW	12,448	6,270,282	504	11.57	541,992
Far North	288	1,379,185	4,785	1.90	725,020
Lower North	1,263	3,480,925	2,757	4.76	731,621
Mediterranean	10,482	1,900,464	181	7.13	266,544
New England	2,119	663,807	313	22.73	29,198
South-west WA	4,278	898,238	210	2.67	336,733
Tasmania	2,603	466,583	179	6.86	68,018
Temperate Slopes and Plains	10,077	1,780,060	177	8.26	215,552
Temperate South-east Coast and Tablelands	17,323	2,495,501	144	11.92	209,316
Tropical North-east Coast	11,970	2,909,426	243	15.21	191,301
Grand Total	**74,476**	**25,936,178**	**3,345**	**8.04**	**7,687,642**

Table 8: The population of sheep by sheep production region.

Sheep region	Number of sheep farms	Number of sheep	Average farm size (sheep/farm)	Density (sheep/area of zone in km^2)	Area of sheep region (km^2)
Armidale High Rainfall	1,131	1,938,893	1,714	65.94	29,406
Central Pastoral	1,471	6,849,496	4,657	1.68	4,069,052
Eastern High Rainfall	5,666	6,082,262	1,074	29.00	209,722
Eastern Wheat/sheep	10,885	16,452,003	1,511	75.34	218,365
North East High Rainfall	396	34,958	88	0.18	198,070
Northern High Rainfall	69	148,482	2,160	0.08	1,753,105
Northern Wheat/sheep	3,137	4,782,618	1,525	8.83	541,739
South West High Rainfall	8,906	15,441,585	1,734	122.90	125,646
Southern Wheat/sheep	4,434	5,298,655	1,195	38.60	137,278
Tasmania	1,552	2,344,469	1,510	34.47	68,018
Western High Rainfall	1,414	1,522,379	1,077	32.49	46,859
Western Wheat/Sheep	4,739	12,172,455	2,569	41.99	289,874
Grand Total	**43,800**	**73,068,253**	**1,734**	**37.62**	**7,687,136**

Figure 3: The beef production regions identified by Kennedy and Sergeant (2006).

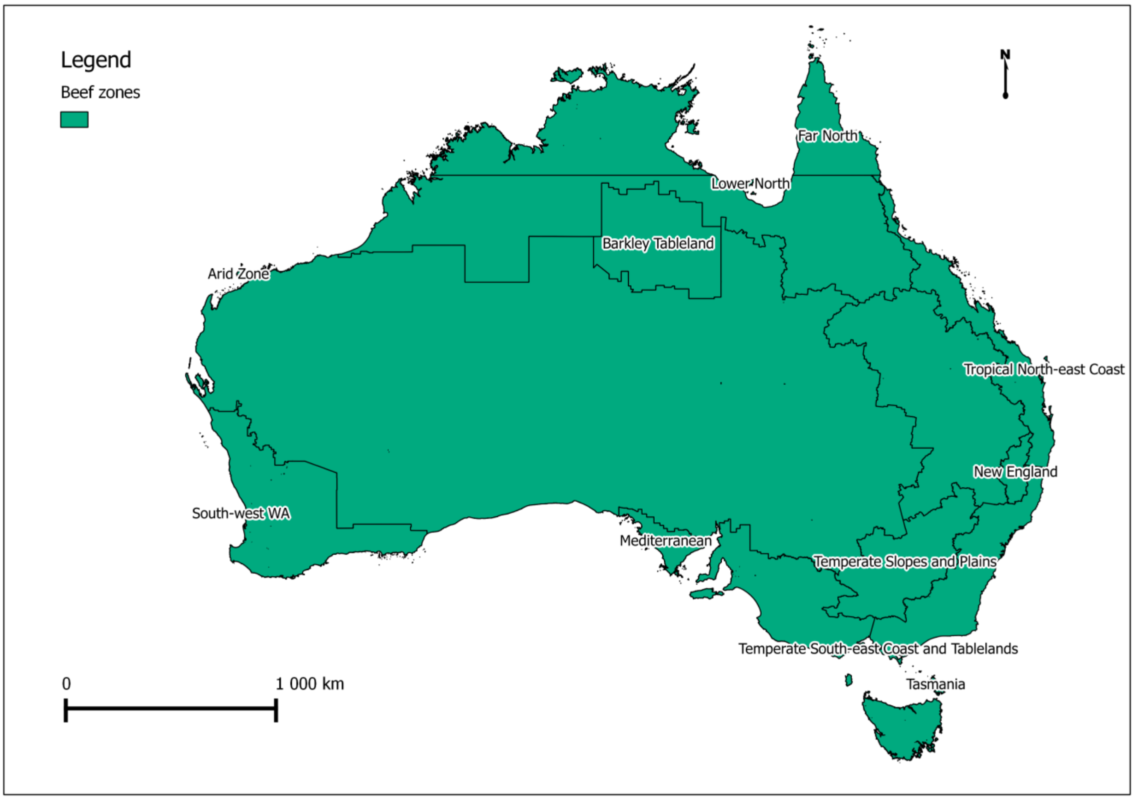


Figure 4: The sheep production regions identified by Hassells and associates Pty Ltd (2006).

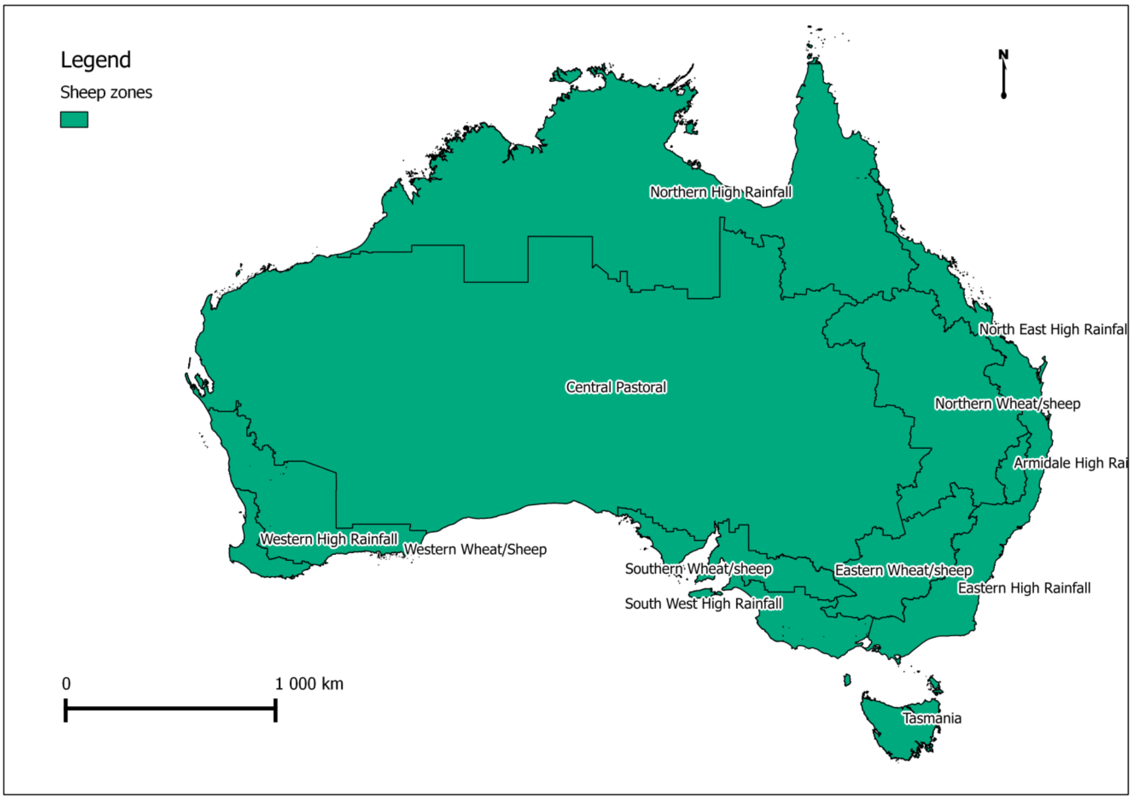


Figure 5: The density and distribution of meat cattle across Australia. The deeper the blue the higher the density of meat cattle.

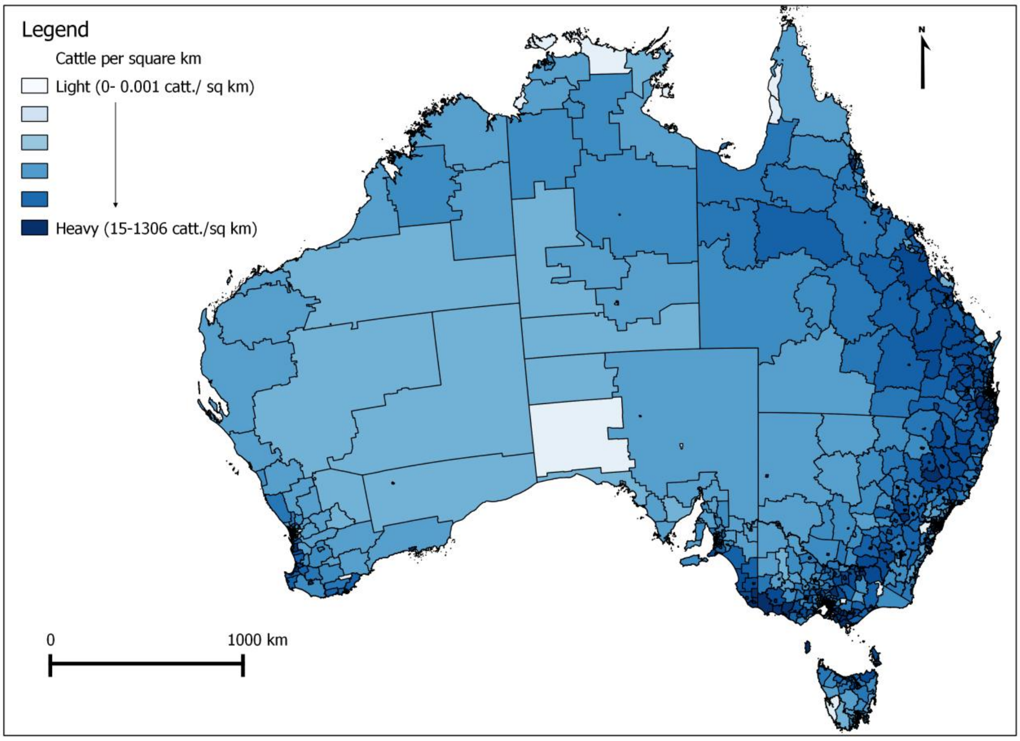


Figure 6: The density and distribution of total sheep across Australia. The deeper the blue the higher the density of sheep. Many areas (white polygons) were not surveyed by ABS.

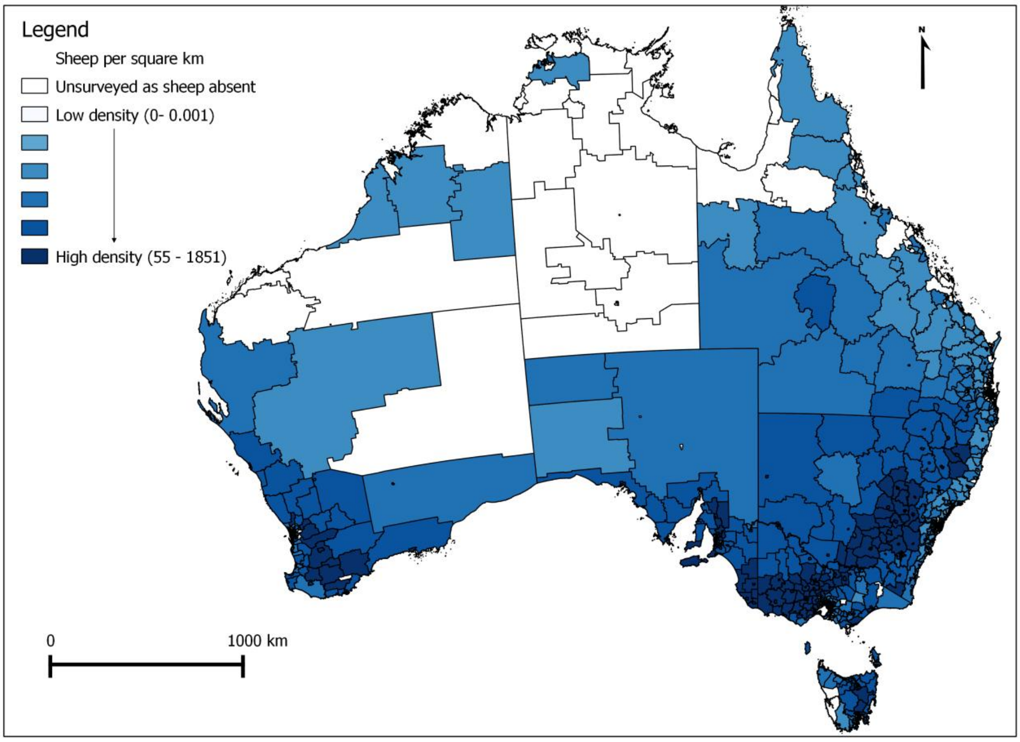
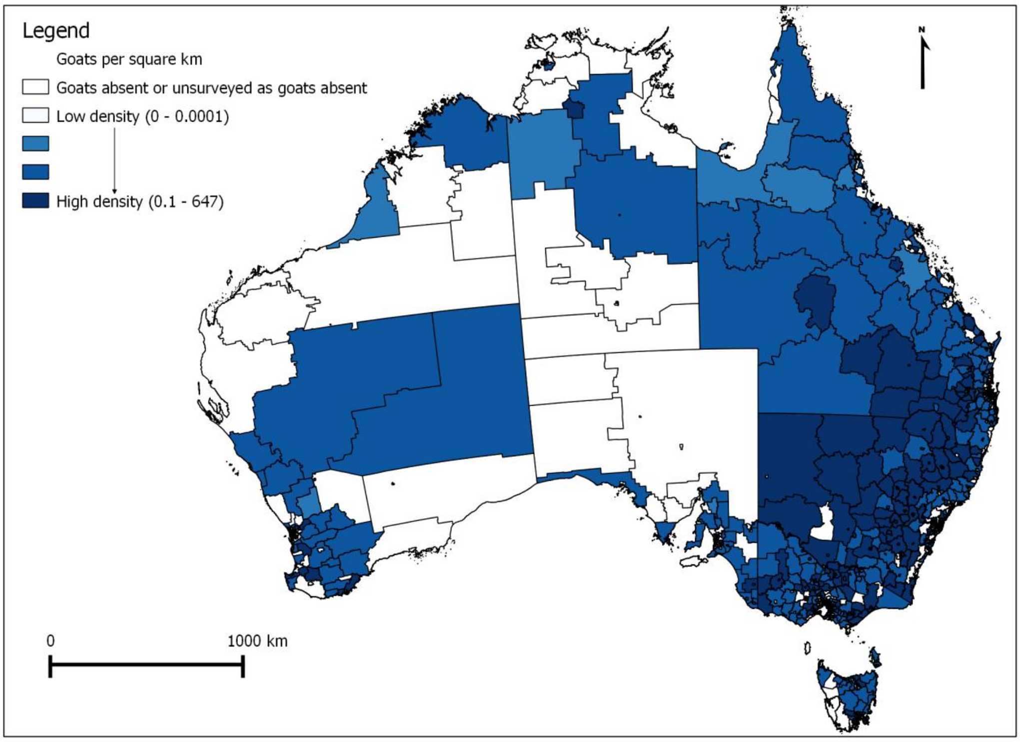


Figure 7: The density and distribution of goats across Australia. The deeper the blue the higher the density of goats. NB: goat densities are lower than for sheep or cattle despite similarities in colour graduations.



Discussion

Adequate survey design depends upon knowledge of the distribution and abundance of the populations being surveyed. Critically, knowledge of approximate population abundance is required to calculate appropriate sample sizes and to interpret survey results. For example the correct method of analysis (e.g. probability distributions/formula) may depend on whether the population can be considered infinitely large or a small population where sampling without replacement occurs. Additionally, proper geographic stratification of sampling may be required to ensure that a survey is regionally relevant. Further many areas may have low populations of livestock and may not require sampling. Knowledge of these areas can considerably simplify sampling and reduce the expense of a survey. Finally, a basic understanding of the hierarchical nature of the population (e.g. how livestock populations are organised to herds/farms) is important when considering the basic sampling design (cluster based or multilevel sampling). This discussion paper thus presents data on the distribution and abundance of cattle, sheep and goats in Australia and discusses this in relation to survey design.

Hierarchical structuring of the population is marked in some areas of Australia. For example for sheep, in the central pastoral zone there are 1471 premises with a mean of 4657 sheep per premises. Conversely in the north east high rainfall zone there are only 396 premises with a mean of 88 sheep per premises. There are only 69 sheep farms in the very large northern high rainfall zone (although with a mean of 2160 sheep per premises). Clearly this indicates extreme regional variability in population structuring, both from a perspective of absolute population size and density and from a hierarchical perspective. This suggests:

1. Regionally tailored approaches to sampling are required,
2. Some zones can remain un-sampled as these have very small populations (financially insignificant from a national industry perspective). These are the north east high rainfall and the northern high rainfall zones for sheep,
3. Some form of multilevel sampling is indicated in most regions (as there are manageable populations if considered from a premises level perspective) but cluster based sampling would not be feasible in areas with high populations per premises.

A regional assessment of populations also indicates where the largest and most economically important regions exist. For example, the eastern wheat sheep, the western wheat sheep and the south west high rainfall zones all have sheep populations of greater than 12 million sheep, also with high densities of sheep. Although a regional approach to sampling is required, it is also clear that together these three regions account for more than half of all sheep populations and that to assess the economic impact of endemic disease on sheep it is most important to concentrate on these regions.

It is important to note that this data is biased by the collection method used by ABS. That is, many agricultural premises are not counted with the ABS methodology. This particularly includes premises that do not have an ABN, or ABN registered businesses that have a turnover off less than $5000. Thus, premises not considered by the ABS are likely to be the smaller premises or so called hobby farms and hence lower productivity farms that on an individual basis contribute little to the overall financial output of the livestock industries. However, when it is considered that there are likely very many of these premises it is likely that this uncounted segment of the population is relatively important on an overall industry level. Population assessments are therefore under-estimated by the ABS both on an estimate of livestock numbers but more markedly for the number of agricultural premises. The practical outcome of this when conducting survey design and analysis is:

1. Premises numbers are under-estimated. This will mean that sample sizes calculated are slightly inadequate.
2. Some regions may be under-represented in a survey, for example if there are many hobby farms around peri-urban fringes within a region.
3. A biased conclusion can be reached as to which diseases are most economically damaging and how damaging certain diseases are. For example, diseases that thrive in poorly managed small farms or in high density peri-urban may be under-represented in a survey.

There is a small and random error in the estimation of livestock and establishment sizes in each production region due to the structure of the data used. This error arose because some SA2 regions straddled a production zone. It was unknown what proportion of the livestock population within each SA2 region resided in which production zone. Therefore, an SA2 was assigned to a particular production zone based on whether the majority of the SA2 region fell within the production zone. This meant that some livestock that likely fell within another production zone were arbitrarily assigned to the wrong production zone. However, as most SA2 were reasonably small and the proportion of SA2 that straddled production zones was also small the error is also small.

Appendix 5: Distribution of Rural Veterinarians

Heath (2008) reported on the distribution and abundance of veterinarians in Australia. There were 7510 vets registered in Australia in 2006 of which approximately 3200+ were rural. To calculate the number of rural vets, he removed veterinarians from cities and from large regional cities (e.g. Newcastle) from a data set of all registered veterinarians. A similar methodology was followed here. Firstly the same dataset used by Heath (2008) was provided and opened in QGIS. Then vets from postcodes outside cities and regional cities were selected and geolocated to post code level using a national postcode database. Post code centroids were created and postcodes within each beef or sheep production zone determined. The number of rural vets found within each beef or sheep zone was then calculated.

Figure 8 displays the distribution of postcodes containing rural vets nationally. Table 9 and 10 display the number of registered vets per beef and sheep production zone.

Figure 8: The distribution and density of Australian rural vets by postcode.

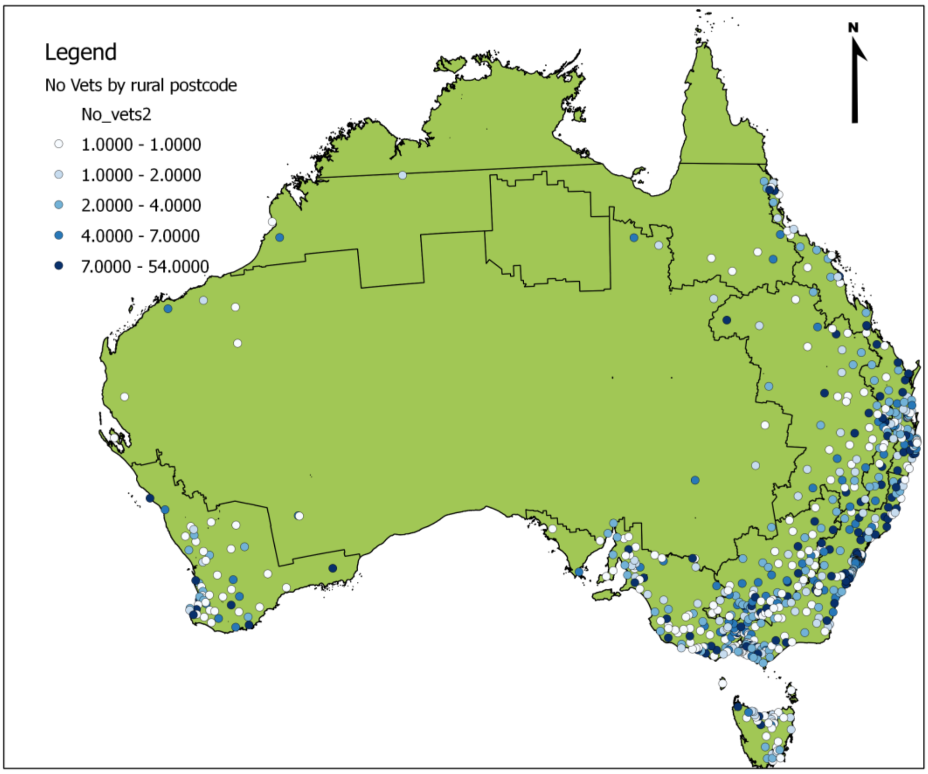


Table 9: The number of rural vets by beef production zone in Australia

Beef production zone	Number of rural vets
Arid Zone	52
Central Qld and North-west NSW	291
Lower North	29
Mediterranean	372
New England	61
South-west WA	176
Tasmania	131
Temperate Slopes and Plains	341
Temperate South-east Coast and Tablelands	1811
Tropical North-east Coast	409
Total	**3673**

Table 10: The number of rural vets by sheep production zone in Australia

Beef production zone	Number of rural vets
Armidale High Rainfall	61
Central Pastoral	47
Eastern High Rainfall	1803
Eastern Wheat/sheep	341
North East High Rainfall	409
Northern High Rainfall	29
Northern Wheat/sheep	291
South West High Rainfall	286
Southern Wheat/sheep	91
Tasmania	131
Western High Rainfall	116
Western Wheat/Sheep	61
Grand Total	**3666**

Appendix 6: Economic impacts of endemic red meat livestock diseases

Background

An important objective of the proposed MLA survey of endemic disease of livestock outlined in the TOR is: 'Calculations of the economic cost of sheep, cattle and goat diseases diagnosed in abattoirs and on their properties of origin. Mortalities, lost production, treatment and prevention cost (labour, drugs).' Simply identifying and valuing the cost of disease at farm and abattoir is the objective of the survey (Johann Schroder pers.com. June 2013).

Animal health economics is an important part of on farm, industry and national decision making. Several economic tools have been used to assess animal health management options including partial budgeting and gross margin analyses at the farm level and cost benefit analysis at the societal level (Dijkhuizen et al., 1997). These tools could be useful to investigate how disease control affects returns and could be scaled up for an estimation of national impact.

This discussion paper provides a brief review of how disease costs the livestock industry and a brief literature review of veterinary literature on how such costs can be estimated. Additionally, the paper briefly discusses how economics can be used to assess the optimum level of mitigation.

Understanding the cost of disease

Several texts detail how disease can affect livestock production and economics (Dijkhuizen et al., 1997; Thrusfield, 2007). In general, diseases causes production from a given quantity of resources to be of lower quantity and/or quality (Thrusfield, 2007). Essentially, disease causes:

1. Destruction of basic resources (e.g. breed stock)
2. Reduction of physical output or its unit value
3. Lowered production efficiency
4. Lowered suitability of product for processing (or increased costs such as trim out costs)
5. Zoonotic costs
6. More diffuse effects such as constraints on trade, public concern of food quality and animal welfare

To estimate the total economic costs of disease requires summation of output losses and control expenditures, and is a complex area (welfare economics) (Thrusfield, 2007). Welfare economics is a holistic approach which amongst other features assesses changes to market equilibrium (that allows calculation of producer and consumer surplus) and has been applied to livestock production (Ebel et al., 1992; McInerney, 1996).

Therefore a full assessment of the economic costs of disease can be relatively complex with assessment including market equilibrium effects and tangible and intangibles (e.g. consumer confidence). However, failure to assess economic effects beyond farm or abattoir productivity will miss many important facets of livestock disease impacts such as those on market equilibrium. This will result in a biased assessment of the economics of endemic disease in the livestock industry.

There are a number of economists in Australia who could potentially complete a holistic economic assessment, rather than simply a farm enterprise model extended nationally as was conducted in Sackett et al. (2006) (Andrew Alford, Pers. Com., March 2013). These may include people such as --------. Doubtless a more holistic assessment will require more resources. Therefore, the ability to conduct a more holistic economic analysis would depend entirely on the resources available, and MLAs initial thoughts are that a more holistic assessment will be beyond the scope of the project.

Means of assessing the economic costs of disease

A brief literature review[12] was conducted to assess methods that have been practiced to investigate the economic costs of diseases on livestock industries. Generally, these methods comprised a simple examination of on farm financial consequences of disease. Frequently such analyses were extrapolated to a national figure. Rarely did an economic analysis present a holistic economic picture.

A selection of economic methods used to investigate the cost of disease are listed below:

- Modelling such as computerised spread sheet modelling (Fasina et al., 2012; Houe, 1999; Houe et al., 1993; Sackett et al., 2006). These include assumptions of prevalence at herd level, changes to income and expenses associated with disease and average herd details such as size and production parameters. Generally they require significant expert knowledge and result in a generalised estimate at the farm level. They can be extrapolated to the national level ((Houe et al., 1993; Sackett et al., 2006)
- Longitudinal studies that estimated profitability by assessing growth rates, incidence of infection and cost of treatments (Maichomo et al., 2009) or by assessing direct costs due to veterinary intervention, the cost of mortality and non-medical costs due to slower weight gains and, in some cases, weight losses (Gharbi et al., 2006). These have been applied to Theileriosis (Gharbi et al., 2006).
- Observational studies comparing key parameters (e.g. herd structure, mortality, birth rates, mass gain etc.) in infected and non-infected individuals, herds and in locations with different levels of disease challenge (Perry, 2009).
- Literature review, existing notification data and spread sheet modelling to assess a comparative economic assessment of livestock diseases in Great Britain (direct effects). This used a similar approach to Sackett et al. (2006) but without the workshop (Bennett et al., 1999a; Bennett et al., 1999b).
- Stochastic modelling for cost of FMD (Singh et al., 1997)
- Economic analysis framework for assessing the impact of several diseases on reproductive performance in cattle (literature review) (Rushton, 2003)

[12] Literature searched in BIOSIS web of knowledge using search terms: Topic=(endemic disease) AND Topic=(veterinary) AND Topic=(cost) Timespan=All Years. All 87 references were scanned for relevance to methods of determining economic impacts of disease. Several were relevant and a synopsis presented in text.

Determining the level of mitigation of disease using an economic approach

McInerney (1996) introduced the notion of disease loss and the expenditure frontier. He highlighted the fact that diminishing marginal returns from additional disease control eventually makes disease control an unviable option. That is, he highlighted avoidable costs of disease using an expenditure frontier. These and similar approaches could be considered to investigate the utility of mitigation approaches.

Conclusion

Economic analyses are critical to decision making in animal health. There are many instances nationally and internationally where simple financial analyses allow the direct economic costs of a disease to be considered at farm and even at national level. However, such analyses are limited and a more holistic approach considering indirect and supply chain consequences would present a fuller picture. However, this would be more expensive than simple calculation of direct costs. Thus, it is important to be clear in the objectives, advantages and disadvantages of the proposed economic analysis. A cheaper economic analysis that focuses only on direct farm costs will provide valuable data but will be biased. An expanded TOR (to include market equilibrium effects) may be less biased but will be more expensive. Further discussion is required at the workshop.

Appendix 7: Notes taken in group workshop discussions

Group 1

Session 1

Three major points

1. Endemic disease- role of under-nutrition is the major contributing factor to many endemic diseases.
2. Economics: field data collection of on farm costs, partial budgeting modelling at different levels (e.g. production zones) to estimate costs to farms. Compare high and low production farms to identify where best interventions can be made.
3. Population: Regional and seasonal variation will lead to biases in data collection.

Population

Sampling frame- PIC code lists and LHPA lists- privacy

Registration boards

SIG from AVA- cuts to the vets active in the industry. ACV ASV- 40% 300 sheep vets, 1100 cattle vets.

DVO- through CVOs or biosecurity managers, won't hand over pic codes. E.g.

Institute of rural futures from ABS sampling frame- miss peri-urban areas, therefore PIC approaches

Leaflets at abattoirs.

NRM and catchment groups can catch

Small farms network.

Sampling frame in Victoria absent- therefore MacKinnon and 4-5 other suppliers- . (risk of missing all the goat people if don't sample small farms) 40% of the state sheep.

Levy payer database at MLA

Vets interested, but probably need

Cultural differences within regions and some will be good for private and some will be good for LHAP.

Ultrasound machines- lay operators- see lots of numbers, lay cattle preg testers in western Qld, if investigating reproductive wastage- or get a veterinary consultant to coordinate it.

Stock and station agents- Elders, CRT, range of people. Anthelmintic sales as well. APVMA provided sales across country. I.e. use of sales in different areas.

Endemic disease

Potential losses, and also contribute to syndromes

Ewe mortality- multifactorial – 35% of them died in two weeks around lambing

=preg tox (e.g. foot abscess causes, lack of feeding), dystochia, foot abscess, mastitis, hypocalcaemia= macronutrient

Under nutrition is the underlying everything i.e. is a risk factor for many diseases and should be on the list.

Worms,

No lice problems- i.e. is so endemic that accepting it and don't do anything

No flystrike in Vic in longitudinal study, controlled well, hence spending lots, therefore a direct farm cost

SHEEP

Abortion, post weaning and perinatal mortality= ewe mortality and lamb mortality= should still be there and due to disease or nutrition (goats = physiological causes as well) = conception to weaning = 30-35% losses= reproductive wastage

External parasites (blowfly and loss)

Internal parasites

Scouring (enteritis- colitis) – non parasitic enteritis/diarrhoea – *Campylobacter*, hypersensitivity to parasites etc.)

Plant poisoning (example rye grass)

Arthritis (huge problem) - practices such as husbandry for general arthritis, *Chlamydophila* is a separate, *Erysipelas*.

Pleurisy/Pneumonia- (predisposing factors in sheep is that they are predisposed, but also viruses

POPULATION of sheep are important and is dynamic, and this impacts and importance. SO was 80/20 merino / meat verse 50/50

Foot rot and foot abscess- in some regions it is very important and should be high, but in goats it is always important.

Sheep feedlots not too important now, but if grain prices collapse then there may be a massive expansion and hence diseases. – I.e. population dynamic- stochastic modelling to capture this in future.

Haemonchus is most important for goats and sheep in some regions (e.g. Dubbo)

Clostridials are very important but are easily controlled.

OJD should be higher in economic importance because lots of hidden costs, lots of social and lots of control

CLA in goats- always abscess on outside and not good in vaccination.

Trace element deficiencies and mastitis is an important emerging disease in sheep

BEEF CATTLE

SOUTHERN BEEF

Clostridial diseases are listed and the economic impact is higher and regionally very important.

Gastrointestinal

Pestivirus is damaging but probably not as damaging. Should be listed in reproductive wastage?

Agree with all the high economic diseases- Add:

Trace element deficiency (e.g. selenium/ cobalt- in high input and stocking rate and should be on list)

Plant toxicities.

Theileiriosis

Under-nutrition and starvation? Predisposing risk factor for many diseases.

Cryptosporidium? (Add to calf scours, also cause pneumonia)

Calf scours in booby calves etc. – is a syndrome as farmer can't identify the virus etc.

Bovine respiratory disease complex (linked to feedlots)

BJD- regulation, less likely to call a vet, if FMD was in then huge epidemic

Buffalo fly

NORTHERN

Plant poisonings (also for northern and also for sheep) - e.g. heliotrope. Failure to thrive- facial eczema (not) but similar. Sick mitochondria

BJD

FEEDLOTS

Lameness

BRD

Heat stress

Acidosis

Arthritis

GOATS

Rangeland goats are important between harvest and slaughter- stress issues, *Salmonella* i.e. water and goats together leads to disease = between harvest and slaughter and export need knowledge and intervention.

Abortion (physiological)

Internal parasites (*Haemonchus* and scour worms)

Transport issues- suffocation and stress

Q fever from zoonotic point of view- even in dairy goats, still getting disease even though vaccinated (5 years)

Farmed goats- inherited issues- teeth and udder (udder soundness, e.g. line teats- bore goats) do selection issues

Very little disease detected in harvested goats-

90% of goat meat from rangeland harvested goats, bore goats kept in poor conditions (genetic material is expensive) and then released to upgrade genetics and can't compete. But Australian ones aren't hardy

Just examine Boer mouths and do it probably- poor selection of goats.

Dohnes, Dorpers, Mutton Merinos- SA don't heavy rain pressure, so full genetic expression is available in breed, when Australianised, (especially Boer) and hence haven't had huge selection for rain or whatever- e.g. wet summers lead to mass mortality – i.e. all from arid, but in Australia get downfalls of rain and get disease.

Regional variation where areas of wet will lead to diseases.

Conformation lameness

Benign footrot is virulent

CLA (vaccine not effective- external abscesses)

OJD losses

Animal health economics

Losses

Costs

Cost benefit analysis- something to compare it to- i.e. some strategy to use to combat and prevent- alternative strategy. Limited by time frame- Need discrete time fame for discounting

Decision analysis not applicable, but at least stochastic

Partial budgets- accounting, relying on farmer biases, pimilea in western Qld. Individual farm level partial budget, and that can be aggregated to cost benefit and aggregate to regions.

Form a typical farm for a region, and then say the population and then aggregate up.

So similar to Sackett and Holmes but collect data on farm in an accounting exercise. No intangibles

Cost benefit analysis would be the only way to look at consumer and producer surpluses etc. and too expensive to collect data. Also need a final scenario to compare to (e.g. define the outcome and then explore that).

Benchmarking groups- get average, low and top performing farms. Then can define industry losses, i.e. can easily change it at a regional level.

Intangible- social impact- e.g. could pick one or two diseases such as OJD, ARGT, wild dogs.

Elderly farmers- no succession planning and legacy and hence a big issue.

Session 2

Three major points

- Data sources: Data does exist but little of it is perfect, and hence we will need to design some data collection. Some data is useful such as abattoir surveillance for certain circumstances.
- Massive number of historical data (e.g. trace elements). Need literature searches or infrastructure such as digitalisation of existing data to make it accessible
- Targeted sample collection is expensive, but syndromic data collection is astronomical**.**

Data sources

State govt sources, purchase involvement from state dpi- so can employ someone.

Laboratory data- case series.

Privacy issues.

Abattoir surveillance and knackery surveillance- bias animals (healthy at abattoir, sick at knackery)

Saleyard and abattoir surveillance for emergency animal disease surveillance. (Preg tox, cancers, broken legs etc. - healthy animals).

Syndrome reports SCAHLS (exotic disease compatible syndromes are reported from labs to SCAHLS)- reports exist- total cases over a period of time. May be a useful source.

University pathology- some data.

SA, NSW and Vic did a lot of trace element and soil deficiency work in recent decades and the data are out there but not accessible. Therefore need to capture this and present it.

For diseases that are well understood don't need to do another survey, need to do an uptake/adoption survey. I.e. is communication good enough and why is it failing.

Prospective, limited design (seasonal autopsies of sheep for OJD) surveyed every dead farm four times yearly for a couple of years. Students make it cheaper. Southern tablelands-12 farms. Questionnaire survey as well.

Kunjin surveillance through Canberra using private vets.

Economic data sources- ABARES, Lifetime ewe, better beef (for yardstick), ABS, market indicators (MLA), on farm costs of mitigation (including time).

Farmer delivery of data- e.g. mobile phone apps.

Serology banks, can be collected or can exist already (e.g. bovine at aahl). Existing biological specimen samples may be available at labs.

Potential contributors

New studies

- Saleyard and abattoir and knackery surveillance in Vic, lamb and kid mortality studies

MLA funded project on theileriosis

AHA on NSHMP

Public health arbovirus data collection

LHPA regional surveillance on pestivirus and leptospira- listed on 'flockandherd' website from RLPB

Original data is there.

Veterinary health research in Armidale

Expense of sampling

------ a day for -------

Private = ------ km each way, ------ from ------ (does veterinary surveys)

PhD students are very best value = $------ a year.

Animal science and ag students do really well and vets don't tend to want to.

Serology= $------ (Elisa less than ------) antibody capture Elisa ($------)

PCR (+$------) - volume thing. Bulk testing of 1000 will cut by --------%

For syndromic, lab investigation $-------+ for abortion= poor expenditure of MLA money.

BOSSS for surveillances

Workshop session 3- survey design

Three major points

1. Overall happy with the concept to meet MLAs TOR
2. Step 5, for diseases that are well understood, there should be a step to assess the reasons for poor uptake of mitigation.
3. Economic modelling- most will be a generic partial budget model, but could expand it to different methods and objectives for some diseases that are unique and to get money from elsewhere example processors to investigate economic costs more holistically.

Comments on concept

- Point 5- failure of uptake should be identified at step 5 and is a failure of communication and should be a project for further research (i.e. why is not uptaken).
- Point 5, disease understood should go to point 9 and 10.
- Point 2 existing data will be ongoing.
- Need randomisation for sample selection rather than using existing data bases
- Existing data is not free at dpi (historical existing data may not be free).

Point 1. Recall bias? Qualitative scores, mitigation etc. To ensure that capture everything, perhaps need to say what are other management problems around the district (e.g. reproductive wastage).

Point 3. Do we need criteria? Would they think about reproductive wastage? Would they say foot and mouth disease. Up to 20 per zone, maybe too many diseases.

Point 9. Economic modelling would be better as the full monte, e.g. for o/b jd. Can we get money from other programs in MLA to expand the modelling for areas relevant to them (e.g. process costs from meat processing sector)?

Need ongoing reporting from farmers online as a separate model.

Group 2

Session 1

1. Population

Sampling frame

- PICS - States send out questionnaires.
- ABARES sampling frames – ABAREs would require to be involved in development, testing and application of questionnaires; have field staff in regions.
- NSW LHPA lists.
- These lists have some data on farm size, e.g. stock numbers or area.
- Some processors (e.g. JBS) will send out questionnaires if seen to be in industry interest.

- Farmer association lists limited and not representative.

Regional Stratification

- Sheep: two regions only
  - intensive/improved pastures and
  - Extensive/native pastures.
- Beef cattle: ------- proposed 4 regions (see map):
  1. Extensive rangeland
  2. Semi-intensive and mixed farms
  3. Intensive
  4. Arid
- Beef feedlots – grain and grass based
- Goats
  - intensive
  - extensive

2. Endemic diseases

Additions to lists of high importance diseases:

- **Northern beef**: BJD, Bluetongue, Pestivirus, Phosphorus deficiency, *Pimelea* poisoning Trichomoniasis/Campylobacteriosis,
- **Southern beef**. Anthrax, ARGT, BEF, BJD, Calf scours (cf Rotavirus), PRGT, Theileriosis.
- **Feedlots**. Lameness
- **Sheep**. Bacterial enteritis, Footrot, Fluke, Grass seeds, Sheep measles.
- **Goats**. Clostridial diseases, internal parasites incl fluke, BJD/OJD, Plant poisonings

3. Economic costs of disease

- Consider occurrence (at herd and animal level) and losses (incl farm trading losses) as well as availability and expense of mitigation.
- Should be able to gather good farm data on prevention/treatment expenses.
- Intensive study of case farms may be required
- Most analyses would be partial farm budgets but broader impacts of some diseases such as BJD, BT must be recognised and potential studied by more holistic methods.

Three key points

- **Simplify the production zones for stratification**
- **Clearly describe costs of diseases on production**
- **But need to look beyond farm gate to prioritise importance of diseases.**

Session 2

4. List of existing data sources that could be useful

Potential to collaborate with other current projects to collect survey data on farm visits

Beef Cattle

- MLA Cash Cow project. Studied 78 northern breeding herds over 3-4 years incl serology (pestivirus, BEF, *Neospora* & lepto), faecal P, risk factors.
- Other MLA projects: e.g. Feedlot BRD (B.FLT.0225); northern cattle mortalities; JCU goat health..
- State DPI surveys: e.g. NT DPI Pastoral Survey 2012, NT serosurvey 2009-10 (tick fevers, IBR, pestivirus)
- NAMP
- NAHIS
- University projects, lab records and clinical investigations

5. Contributors to proposed MLA survey &

6. Expense of collecting data

- Herd and flock health vets/consultants
  - Est. $------ per hour plus ------ per km
  - Potential to collect survey data during farm visits (e.g. for preg testing) at discounted rate.
  - SA subsidises investigations of important diseases
- Universities often have good link with local abattoirs
- Veterinary students could be used as part of extra-mural work requirements
- DPI and LHPA staff
- ABARES – need to get costs
- BOSSS type surveillance dependent on mobile phone app operational (ref Ian Langstaff). May be particularly attractive to pastoral companies.
- Agents?
- Focus groups and forums (e.g. MLA Beef Up Forums in northern Australia)

Three key points

- **Utilise data form current and recent research projects**
- **Balance more valid data from face to face contact against greater expense**
- **Broad range of potential contributors for different aspects of survey.**

Session 3

Survey

General comments

- Is there a need for social research to understand why proven disease mitigation practices are not more widely applied?
- Local research data and demonstrations of effective mitigation helpful.
- Feedback to stakeholders including producers during project.
- Questionnaires limited by peoples knowledge and understanding and likely to be biased by recent and current seasonal and market condition so need to cross-reference responses to these (e.g. reported BEF can be cross-referenced to NAMP results)
- Must identify and survey regionally important diseases (e.g. venereal infections in northern beef).
- Cross-sectional studies affected by current conditions so prevalence will not be appropriate measure of occurrence. Model incidence, susceptibility and risk (e.g. BEF, pestivirus)
- Need to consider economic optimum investment in mitigation and sustainability of mitigation practices (e.g. anthelmintic)

Specific comments on flow-chart

- Two stages: Box 1-5 and 6
- Box 1: Question need for this step and prefer more investment in Box 6.
- Box 5: Rename "economic impact of disease known"
- Link Box 5 direct to Box 8
- New Box 10: Ongoing survey methodology/system that can update situation from time to time.

Group 3

Group 3

Session 1 - Three key points:

Data: each disease will have its optimal use (not a one size fits all).

Disease list: use a risk-based approach (likelihood vs. impact)

Economics: shift economic data collation to improve H & S report.

- Production systems defined within region – drill down to useful level.
- Interactions between diseases and on-farm management
- Sub-clinical disease impacts
- Market discounts (re-stocker and meat)
- Human/social/community costs

Identify data sources that can identify:

- Sub-clinical disease impact
- Human cost

Session 2 – Three key points

Expense of data collection: create a rolling project that allows for continuity (legacy)

Project contributors: Initiate jurisdictional reference groups.

Session 3 – flow-chart specific comments

- #5 (Disease is understood) back to sections #8 (Disease information) and #9 (Economic modelling).
- Risk factor data can be surveyed from #7 (Abattoir survey) using PICs collected via the abattoir survey.
- Make more made of existing data sources – relationship between #6 (Field survey), #7 (Abattoir survey) and #4 (Review). Opportunity to save money – balance with new data.
- Steps 1 to 5 are reasonably generic across diseases but methods may change according to disease for steps #6 to #8.
- Include social science: impact assessment/identify risk factors in #1 (Pilot survey) and #6 (Field survey).
- #9 (Economic modelling) – needs uniformity across models.

Session 1

What lists of populations are available? Sampling frames.

(Our group digressed to data sources for this section)

- State governments have PIC lists. Most comprehensive list of anybody who sells stock. Lists are current and include active and non-active PICs. In Tasmania the list is accessible for researchers – the privacy issues can be worked around for a research perspective. Active – people who have traded in the last X number of years. Issues may include currency and privacy, depending upon the jurisdiction.
- Disease records kept separate to PICs (in LIMS – Laboratory Information Management System). Also records of property visits.
- NLIS database

- Private vet lists –but could be problematic
- AVPSN (Australian Veterinary Practitioners Surveillance Network)– weekly snapshot in a quarter
- NAHIS
- SHMP – can check with industry what diseases can be included
- Biosecurity Services Groups – holds animals from condemned animals (export only)
- Non-export abattoirs (domestic) – difficult to engage on animal health
- State vet boards
- Australian Meat Industry Council (AMIC) – collate a level of data from abattoirs. Potential for commercial in confidence issues.
- State-based surveys
- Sentinel flock and herd projects
- Knackery data (Vic)
- Livestock Health and Pest Authorities (LHPA)
- Universities – current or past research projects and associated databases
- Industry organisations (NFF, State farmer organisations, Cattle Council etc.)
- Livestock agents
- Chemical sales
- Media searches
- NLIS database
- Breedplan/Lambplan – appropriate for particular conditions

Is the focus going to be retrospective or prospective?

Need to future proof data access. What makes good data? DAFF project to standardise data standards. (RG check with Ian Langstaff).

Barriers/concerns with existing data sources:

Many constraints will become apparent when one tries to access the data.

Comment: As a veterinarian, we engage in a small and select number of diseases, and don't engage in the common conditions as much as we should.

Comment: need take a supply chain approach, and include diseases and conditions i.e. grass seeds.

Small chunks of information everywhere – we need to consolidate these chunks.

Potential for large biases in data sources due to the original intent.

Assistance from data sources?

- need to 'sell' the concept differently to each jurisdiction
- monetary incentive for database owners?

Age profile with respect to survey format (online vs. telephone/mail)

How to deal with non-response? Randomised telephone survey.

How to come up with an optimal system – what we'd like to do vs. what we can do.

Frame against climatic conditions etc. conditions at the time data was collected.

2. Endemic diseases of concern

Diseases/conditions

Diseases of high economic importance to southern beef:

Bloat

Clostridial diseases

Gastrointestinal parasites

Grass tetany

Liver fluke

Pinkeye

Reproductive wastage

Rotavirus – neo-natal diarrhoea

Theileriosis

Weaner ill-thrift

Low probability but high impact if occurs:

Acute bovine liver syndrome

BJD

Hydatids

Leptospirosis

Pestivirus

Vibriosis

Diseases of high economic importance to northern beef:

Botulism

Bovine ephemeral fever

Buffalo fly

Nutritional deficiency (trace elements)

Pinkeye

Q-fever

Peri-natal mortality

Reproductive wastage (inc. vibriosis and trichomoniasis)

Tick and tick fever

Trace-element deficiency

Diseases of high economic importance to feedlot beef:

Acidosis

Bovine respiratory disease complex

Heat stress

Diseases of high economic importance to sheep:

Abortion and stillbirth

Arthritis

Blowfly

Cheesy gland

Clostridial diseases

Grass-seeds

Grass tetany

Footrot

Hydatids

Hypocalcaemia

Lamb pleurisy and pneumonia

Lameness (foot abscess and others)

Lice

Liver fluke

Ovine Johne's disease

Ovine brucellosis

Peri-natal mortality

Photosensitization

Plant poisoning – facial eczema

Plant toxicity

Post-weaning mortality

Pregnancy toxaemia

Sarcocystosis

Scabby mouth

Scouring (non-parasitic)

Selenium deficiency (trace element deficiency)

Sheep measles

Worms

Lower probability but high impact

Hydatids

Ovine brucellosis

Scabby mouth

Goats

CAE

Internal parasites

Q-fever

3. Animal health economics – the economic costs of disease

General comments:

Would like to move towards studies that are region specific, and production system specific within that region. Allows information to be more relevant to the end user such as producers, and as such final reports should be regionally specific.

Collect data that shows interaction between disease, resources, cost and prevalence.

The way information is presented will be limited by data.

Analyse from a whole farm perspective – before/after. What will it look like if we are able so solve this issue?

Costs of sub-clinical disease? How to collect this data? Prospective intervention studies – what is the scenario if one is able to completely control the disease. Work out market discount for various diseases, including re-stockers and meat.

Use a risk-based approach. If the project framework is set up correctly, there can be ongoing assessment.

Revisit disease list – which ones have become more prevalent since the Sackett and Holmes study?

Human cost? Both financial and stigma. What is the social impact?

Session 2

Group 3 revisited population at this point

General comments:

Areas defined by agroclimatic zones such as Dry, Mediterranean, Temperate etc.

Populations defined by productions systems within an area

Agents, stock inspectors, past studies (Kevin Bell – estimation of discount from sheep measles?)

Human cost – varies and depends upon disease: JD, pestivirus, ovine brucellosis

Use of historical data

Populations will vary according to disease – continually coming back to “It depends upon the disease”.

Recall bias - significant disease events such as footrot will be remembered for longer than lamb-marking percentages over time.

Use a case-study approach to gauge sub-clinical disease.

Human health data available at rural/regional hospitals to gauge level of zoonosis.

Populations can be defined in various ways, including geographically, production enterprises, time and season etc.

Expenses of data collection

- Flexibility in SHMP to collect information about other diseases. Need to go to industry to ask for this to happen.
- Legislative incentive/disincentive
- Bias
- Communication workshops
- Target funding
- Create a rolling project

Potential study contributors

Initiate jurisdictional reference groups to assist with project?

Academic – post-graduate students

State departments

Organisations that might like to contribute

Australian Cattle Vets

AVA

Vet schools

Post-graduate

State departments

TIA – Tasmanian Institute of Agriculture

Livestock Biosecurity Network

Pharmaceutical companies

Can increase producer engagement through education

Resources need to be targeted/allocated according to the disease in question and the identified gaps in the data.

Session 3 - Survey

Strengths

There's a plan!

Concerns

Step 5 –Sackett and Holmes desktop – how can we rely on this data to remove disease? Who will assess the level of understanding? Technical/producer interface. Producer awareness. Are assumptions being made about the level of disease?

What is the relationship between 1 and 5?

Production system and region – we understand what the diseases do to animals.

The economic cost of disease over time has been overlooked.

Keeping producers on side – good communication is vital.

Step 5 goes straight to Step 9

Economic modelling – scoping what is already out there. MIDAS/GRASS etc. for various regions.

Restrictions on budget – where do you make the savings? What is compromised? How do you evaluate where you put your resources? Worthy of discussion – where will you lose most? Difficult without unit costs – overcome by prioritisation. Must be iterative – have disease list, review existing data sources.

See resources used with existing databases.

Do things well in a smaller area than spread too thin nationally.

Priority disease list by region – use funding accordingly.

Plan doesn't mention geographical issues – different design for different areas. Biological samples (use) vary for diseases.

Abattoirs – how many diseases show lesions that can be identified? Diagnosing sub-clinical disease.

Abattoir survey – data collected by PIC, therefore can contact producers with respect to risk factors.

Distribution of jobs – according to disease? Not sure – scoping study to help draft TOR for survey. Have a standardised database collection that can be added to. Must have a central database. Like the legacy idea.

Social science: why don't farmers take up evidence and advice? Where does this fit with the plan? Can we have an outcome that produces better engagement? MLA project B.AHE.0057 (sheep health statement research).

Social impact: identifying risk factors and economic cost

Design for adoption. Is there a study showing disease and mitigation?

One disease interacting on another with respect to decision-making.

Relatively limited cost – opportunity cost – easier to capture social aspect now rather than later. Gathering social data – can assist in implementing the program most likely to succeed.

Including social aspect – reconsider outcomes of MLA's investment.

Ensure plan is flexible enough to handle diseases that do make it on to the list.

List is not exhaustive (e.g. ARGT). *Theileria* – respond to localised, well-motivated, strong requests.

Extension question: this project could add to umbrella programs (Making More from Wool) etc.

Appendix 8: List of workshop attendees

Attendee	Affiliation
Dr Graham Bailey	NSW DPI
Dr Rowena Bell	Tasmanian DPIPWE
Dr Paul Beltz	Vic DPI
Dr Mark Carter	Australian Sheep Veterinarians
Dr Lorna Citer	Animal Health Australia
Dr Brendan Cowled	AusVet Animal Health Services
Dr Susanne Fitzpatrick	Northern Territory DPIF
Ms Rachel Gordon	AusVet Animal Health Services
Dr David Kennedy	AusVet Animal Health Services
Dr John Larsen	MacKinnon Project
Dr Michael Laurence	Murdoch University
Dr Jane Littlejohn	Australian Wool Innovation
Prof Michael McGowan	University of Queensland
Dr Sam McMahon	Australian Cattle Veterinarians
Dr Paul Nilon	Nilon Farm Health
Dr Elizabeth Parker	James Cook University
Dr Diane Ryan	NSW DPI
Dr Johann Schröder	Meat and Livestock Australia
Dr Justin Toohey	Cattle Council
Dr Colin Trengrove	University of Adelaide
Dr Jack VanWijk	PIR South Australia
Dr Bruce Watt	NSW LHPA
Dr Santhi Wicks	ABARES
Dr Sarah-Jane Wilson	University of Sydney
Prof Peter Windsor	University of Sydney

Appendix 9: Field survey scenarios

Case study 1: Questionnaire survey of farmers

The distribution and abundance of disease at the farm level across Australia is required. In this scenario, a farmer can generally accurately diagnose disease presence or absence on their farm (e.g. disease is overtly clinical and clinical signs are pathognomonic) so a questionnaire data collection tool is appropriate.

a. Separate surveys across all production zones (e.g. beef)

Estimated prevalence= 0.5, α=0.05, precision=0.05, sensitivity of diagnosis=0.95, specificity of diagnosis= 1, population size= 30 (Barkley) to 17 323 (Temperate South-east Coast and Tablelands (TSEC&T))

Sample size required from Barkley = 29, Sample size from TSEC&T=415

If less precise estimates of prevalence can be accepted (e.g. ±10 % instead of ±5 %) then:

Sample size from Barkley = 24, Sample size from TSEC&T=107

Thus if this were repeated across all production zones with a desired precision of ±10 % , then approximately 1 284[13] samples would be required across Australia.

b. Stratified sampling across Australia (production zone is the strata)
The same assumptions except, population size= 74 476

107 farms required, spread proportionally across production zones.

Case Study 2: Two stage freedom sampling

In this scenario, disease can be subclinical and cannot be diagnosed accurately by a farmer. Extensive published data exists as to on farm prevalence when a farm is infected. Two stage sampling is required with the second stage aiming to demonstrate a farm is free of disease/or detect disease.

a. Separate surveys across all production zones (e.g. beef)
The same assumptions (as above) are used in stage 1 sampling. Hence 1 284 farms are required.

However, the second stage sampling tests the presence or absence of disease on a farm. It is assumed that beef cattle are being surveyed, with an average farm size of 462 animals. An assumption is again made that the diagnostic test is 99% sensitive and 97% specific (e.g. a good ELISA). Design prevalence is estimated at 1%. A sample of 212 animals from each herd is required to demonstrate freedom. Note,

[13] Most production zones have thousands of premises. Hence 10 zones with thousands x 107 samples per zone added to samples from the far north and the Barkley (99 and 24 respectively).

that were less accurate tests used (e.g. se = 0.85 and spec = 0.90), a census would be required and would not be sufficient to demonstrate freedom.

Thus 1 284 x 212 = 272 208 animals are required to be sampled.

b. Stratified sampling across Australia (production zone is the strata)

The same assumptions except are used as above. Hence 107 farms are required, spread proportionally across production zones.

The seconds stage sampling is the same as above, hence 212 animals are required per farm.

Hence 107 x 212 =22 684 animals are required.

If a less conservative assumption on design prevalence is made, it is possible to substantially reduce the number of samples collected to demonstrate the presence or absence of disease at the farm level. For example if a design prevalence of 10% was used, only 30 animals are required, meaning a total of 36 000 and 3 210 animals are required respectively for surveys across each production zone or a stratified survey with production zone as the strata. Less conservative design prevalence would be appropriate for example for highly infectious diseases that can be surveyed using sero-surveillance where long lived immunity exists. Here large proportions of the population on a farm could be expected to have seroconverted if disease had been present. However, it is customary to use a very low prevalence to ensure that inferences are accurate so careful consideration of this would be required.

Case study 3: Two stage prevalence estimation

a. Separate surveys across all production zones (e.g. beef)

The same assumptions (as above) are used in stage 1 sampling. Hence 1 284 farms are required.

The second stage of sampling is to estimate the prevalence of disease. In the absence of *a priori* information on the prevalence of disease 50% is estimated, and other parameters are as above. If

±5 % precision is required, then 222 samples are required. If ±10 % is required then 86 samples are required per farm.

Hence 1284 x 86 = 110 424 samples are required.

This would also demonstrate freedom at 3.5% design prevalence.

b. Stratified sampling across Australia (production zone is the strata)

107 x 86 = 9 202 animals are required.

Appendix 10: Sample sizes to estimate overall prevalence and accounting for clustering

Sample size calculations to estimate a proportion across a clustered population are relatively complex, as standard sample size calculations at each level will not account for within or between herd clustering of disease resulting in unsuitable standard errors (and confidence intervals) in final estimates. If a single estimate of the proportion of infected animals across the country was required a cluster based sampling strategy would be required.

There are several strategies to select the 'correct' number of herds and animals within those herds. However, all rely on selecting an optimum sized sample to minimise standard errors (and costs) of estimates derived from the final study. One of the simpler strategies is to ensure that each individual in the population has an equal probability of being selected (this ensures a simpler final analysis). This can be achieved by randomly selecting the herds, then selecting a fixed proportion of animals within each herd (Levy and Lemeshow, 2011). A sample size at cluster level can then be calculated based on the degree of clustering of disease and costs of sampling at the herd and individual level as follows:

Weighted mean herd size = 290

Cost to sample a herd = -------

Cost to sample an individual (including lab costs) = --------

Intra-class correlation co-efficient = 0.20[14] (This is a relatively high estimate of ICC for an infectious disease)

$\bar{n} = \left(\left(\frac{c_h}{c_i}\right)\left(\frac{1-\delta_x}{\delta_x}\right)\right)^{\frac{1}{2}}$ where $\bar{n} = average\ cluster\ size\ (optimum\ average\ cluster\ size)$

$c_h = cost\ of\ herd\ sampling = --------$

$c_i = cost\ of\ individual\ sampling = --------$

$\delta_x = ICC = 0.35$

Therefore $\bar{n} = 9\ animals\ from\ each\ cluster.$

Since 9 animals on average should be taken from each cluster, this is 9/290= 3.1% of an average herd and indicates the sampling proportion.

[14] ICC= degree of similarity of individuals within a herd with respect to the measurement of interest. For example infection status. Varies between 0 and 1 with 1 meaning all individuals in a cluster the same. Reviews of ICC found that it varied from 0.0017 to 0.46 (McDermott, J.J., Schukken, Y.H., 1994. A review of methods used to adjust for cluster effects in explanatory epidemiological studies of animal populations. Preventive Veterinary Medicine 18, 155-173.) with highly infectious diseases leading to a higher ICC. Levy and Lemeshow (2011) page 317 calculate directly, but this would require pre-existing data.

This can then allow calculation of the optimum number of clusters to be sampled, if additional data exists for which to estimate several parameters (Levy and Lemeshow, 2011). However, a significant pilot study would be required to estimate these parameters and would be relatively expensive. Hence a more pragmatic approach is required to calculate the optimum number of clusters. An arbitrary decision on the overall sample size could be made and this data could be combined with optimal sample sizes at cluster level to determine the number of clusters to sample (Dohoo et al., 2009). Thus:

$n_h = \frac{n}{n_i}$ where $n = overall\ sample\ size$, $n_i = sample\ size\ at\ cluster\ level$, $n_h = number\ of\ clusters\ to\ sample$

Several overall sample sizes could be calculated from a starting point of a simple random survey, realising that a simple random survey sample size will result in much narrower CI in the final analysis. The starting sample size of simple random sampling could then be increased progressively and the effect on the cost of the survey could be estimated (a sensitivity analysis). Pragmatically, the sample size will be sufficient as the costs approach the maximum affordable. See Table 11.

Table 11: Sample sizes at herd and individual level for simple random versus multi-stage sample plans. It is estimated the cost of sampling herds is $-------- and individuals is $--------.

Sampling scenario	**Overall sample size**	**Herd sample size**	**sample size within herds**	**Costs of sampling each zone ($)**
Simple random sampling at individual level[15]	435	Randomly selected across all herds, therefore likely 435 due to 74 746 herds	1	--------
Same sample size, cluster sampling design	435	62	7 (mean, actually 3.1% of herds)	--------
Double sample size, cluster sampling design	870	124	7 (mean, actually 3.1% of herds)	--------

[15] Prevalence at 50%, large population, precision desired ±5%, α=0.05. Note the conservatively large prevalence estimation.

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