Final report

Priority list of endemic diseases for the red meat industry — 2022 update

Project code: B.AHE.0327

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Abstract

This report provides an update of the costliest endemic diseases and conditions for the Australian beef cattle and sheep meat industries. Goats were not reviewed. The approach used in the 2015 report (B.AHE.0010) was applied and 2015 estimates of costs of disease were adjusted for demographic changes, inflation and livestock and commodity price changes, change in the distribution and prevalence of individual diseases, and modifications to controls and control practices undertaken.

The national cattle herd has reduced from 25.9M in 2011 to 22.7M in 2021 (down 12.3% overall), comprising an 8.2% reduction in the northern herd and 6.2% reduction in the southern herd size respectively. The sheep flock has reduced from 73.1M in 2011 to 68.0M in 2021 (down 7.0% overall), comprising a 34.5% reduction in the pastoral zone flock, a 6.7% reduction in the sheep/wheat zone flock but a 3.5% increase in the high-rainfall region flock. Cattle prices increased between 70–80% with sheep prices increasing between 50–60% in real terms between 2011 and 2021. The consumer price index increased 13.6% over this period. These demographic and commodity price changes impact upon the real change in the cost of disease between 2015 and 2022.

The 2015 report identified 17 cattle and 23 sheep diseases, this report presents 18 cattle and 22 sheep diseases. One cattle disease (bovine Johne's disease) was removed from the priority list as the current cost estimate shows it having a minor impact — especially given the trend towards deregulation of Johne's disease and the increased use of vaccination in the dairy industry. Hydatids and trichomoniasis were added to the cattle disease priority list. New research has clarified the prevalence of hydatid-affected carcases and quantified carcase impacts (including reduced carcase weight) requiring inclusion and a recent trichomonas survey of bulls at abattoirs found a high prevalence combined with anecdotal reports of below-average calving rates from some regions suggested trichomoniasis should be included with vibriosis as part of cattle venereal diseases. For sheep, no new diseases were promoted, but sarcocystis was demoted to a minor impact disease.

In order of total cost to cattle producers the priority list of diseases is buffalo fly, cattle tick, internal parasites, dystocia, neonatal calf mortality, pestivirus (or BVDV), bloat, vibriosis, botulism, clostridial disease, bovine ephemeral fever, grass tetany, calf scours, theileriosis, trichomoniasis, infectious bovine keratoconjunctivitis (pinkeye), hydatids and tick fever. Parasites predominate the highest costing cattle diseases. Buffalo fly, cattle tick and internal parasites each cost more than $100M per year to cattle producers. Infectious diseases impacting herd reproduction (pestivirus, or BVDV, vibriosis and trichomoniasis) and neonatal calf mortality along with non-infectious diseases of dystocia and bloat produce losses between $50-100M each year to industry. The remaining disease — predominately infectious — produce losses below $50M per year. Improved control of buffalo fly, cattle tick, bloat, vibriosis & trichomoniasis, BVDV and internal parasite is likely to return the greatest benefit to cattle producers and industry.

In order of total cost to sheep producers, the priority list of diseases is peri-natal lamb mortality, internal parasites, dystocia, flystrike, weaner illthrift, mastitis, perennial ryegrass toxicosis, arthritis, footrot (virulent and benign), ovine Johne's disease, hypocalcaemia, liver fluke, clostridial diseases, pneumonia, pregnancy toxaemia, caseous lymphadenitis, bacterial enteritis, campylobacter abortion, pyrrolizidine alkaloidosis, foot abscess and sheep measles. The costliest disease that impacts the sheep industry is peri-natal lamb mortality. Analysed separately, but closely associated with peri-natal losses are dystocia and mastitis which are effectively subsets of peri-natal lamb mortality but also include ewe mortality. All these diseases cost more than $100M per year. The

major parasitic diseases of sheep; internal parasites, flystrike and lice all costs more than $100M per year. The final disease that cost the sheep industry more than $100M per year is weaner ill thrift, which is particularly important for Merino producers. The next level of diseases includes arthritis, perennial ryegrass toxicosis and ovine Johne's disease that all cost more than $50M per year. The remainder of diseases, both infectious, reproductive and non-infectious cost less than $50M per annum.

Endemic diseases remain a significant cost to industry. Parasitic diseases dominate endemic disease costs of cattle whereas for sheep the dominant diseases are peri-parturient losses (lambs and dystocia deaths in ewes) and internal parasites. There are opportunities for improved control for most diseases that will return more profit to producers, however not all costs are returnable. Endemic diseases will always incur some combination of losses and treatment plus control costs. The challenge for industry is to find the optimal level of control (and disease) that maximises profit. There have been substantial changes to industry demographics and to the value of animals and this has impacted estimates of the cost of disease. Control programs, extension messages and research priorities need to respond flexibly to changes in the cost-benefit equation to ensure producers are always directed to optimise profit. These changes can make it difficult to identify and monitor trends in disease cost from raw estimates. This report provides the necessary detail to monitor disease trends and as such this series of reports becomes a valuable resource for industry. Regular revision of the priority list of endemic diseases is recommended

Executive summary

Background

Estimates of the industry cost of disease inform decision making at farm, industry and research level. Quantifying the impact of disease on product value, the effectiveness and cost of treatment and preventives combined with estimate of the distribution of disease and the prevalence of disease provides valuable information to industry. This allows:

- Producers to make rational decisions on controlling disease in their herd
- Industry to prioritise research
- More focused extension, and
- A framework for monitoring trends in disease and their costs (if done repeatedly)

Objectives

This report is an update of the 2015 Priority list of endemic diseases of the red meat industry (B.AHE.0010).

Methodology

The original priority list of diseases was developed by combining surveys of producers, veterinarians, industry and animal health companies, and finalised through a series of workshops. This list was revisited and the combined effects of changes to population demographics, inflation and prices, disease distribution and prevalence, controls and their costs to determine which disease should be included in 2022. The same approach to economically modelling disease as used in B.AHE.0010 was applied. In summary, assumptions for disease distribution, in-herd/flock prevalence, impacts on mortality/production and costs for prevention and control were updated in the (same) specifically designed Excel model. The spreadsheet model captured the production cycle and incorporated herd dynamics with the timing of disease (age and class of livestock) to determine impact. Opportunity for compensatory recovery (before sale) was incorporated and was disease specific. The cattle model examined northern and southern beef systems separately. The sheep model examined high rainfall zone, sheep/wheat zone and pastoral zone for sheep separately. The total cost of disease within each subset was estimated and combined to provide a whole-of-industry estimate of impact. Cost of disease was classified into treatment (individual affected animal), prevention (herd or flock level controls) and production (impact of disease on value of product produced) costs. The demographics for each subset were estimated from Australian Bureau of Statistics Agricultural Commodities Statistics for 2015-20 to maintain consistency with the 2015 report demographics. Commodity prices were updated using actual prices (where known — e.g. cattle and sheep prices, individual treatment costs) or adjusted for inflationary change since 2015 (e.g. labour costs). Where possible, the number of units of treatment and preventive products used within the industry for a specific disease were obtained from discussions with manufacturers and resellers (for which the authors are grateful).

Results/key findings

The updated priority list of diseases for 2022 was increased to 18 for cattle but reduced to 22 sheep diseases. For cattle, bovine Johne's disease was removed the list but hydatids and trichomoniasis were added. The deregulation of Johne's disease and the increased use of vaccination in the dairy industry combined to decrease the prevalence and impact of this disease to beef producers. New hydatids research shows a moderate prevalence (3–5%) of affected carcases and affected carcases are typically lighter than unaffected carcases making the loss to producers significant (in addition to loss of affected offal). Recent findings show trichomoniasis is prevalent, especially in the north.

For sheep, the list of priority diseases reduced to 22. Sarcocystis was removed from the list primarily because the prevalence sarcocystis reported in the National Sheep Health Monitoring Project has declined substantially from 0.9% of carcases to 0.1% of carcases with resulting decline in the financial impact of this disease. Camplyobacterial abortion was included within the new disease category of infectious abortion. This was extended to include *Listeria spp.* and *Toxoplasma gondii* along with *Camplyobacter fetus spp. fetus* as infections that can produce abortions.

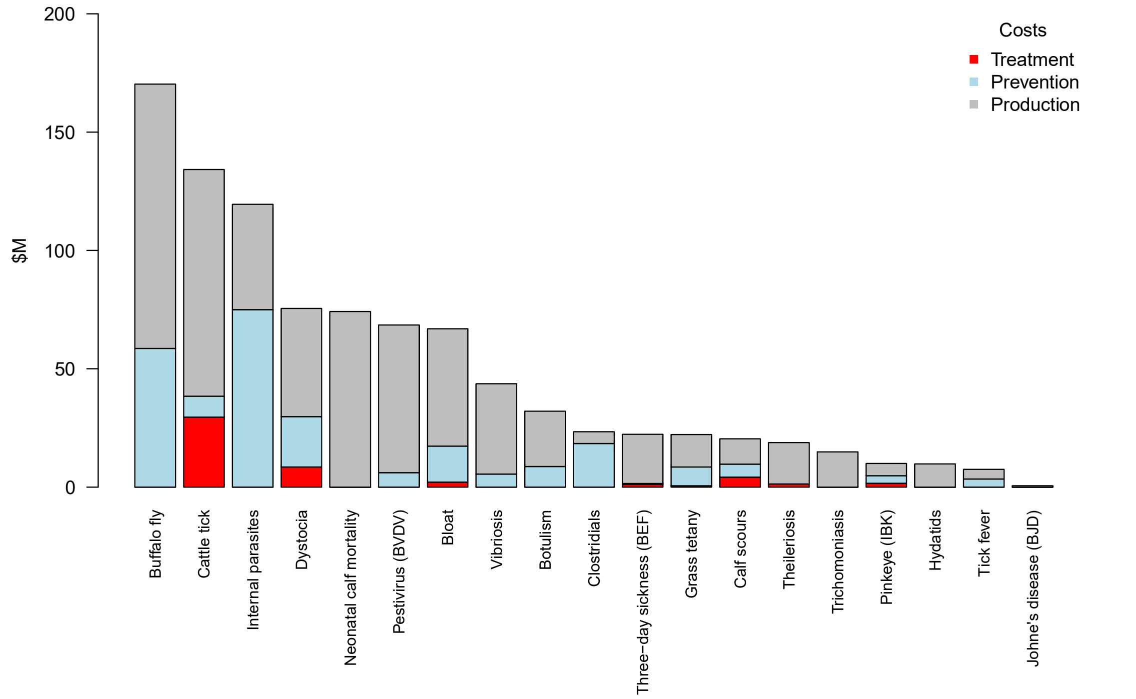
The identified diseases are listed below.

Cattle	
Buffalo fly Cattle tick Internal parasites Dystocia Neonatal calf mortality Pestivirus (bovine viral diarrhoea virus; BVDV) Bloat Vibriosis (bovine camplyobacteriosis) Trichomoniasis Botulism	Clostridial disease Bovine ephemeral fever Grass tetany Calf scours complex Theileriosis Pinkeye (infectious bovine keratoconjunctivitis) Hydatids Tick fever (Johne's disease – removed from list)

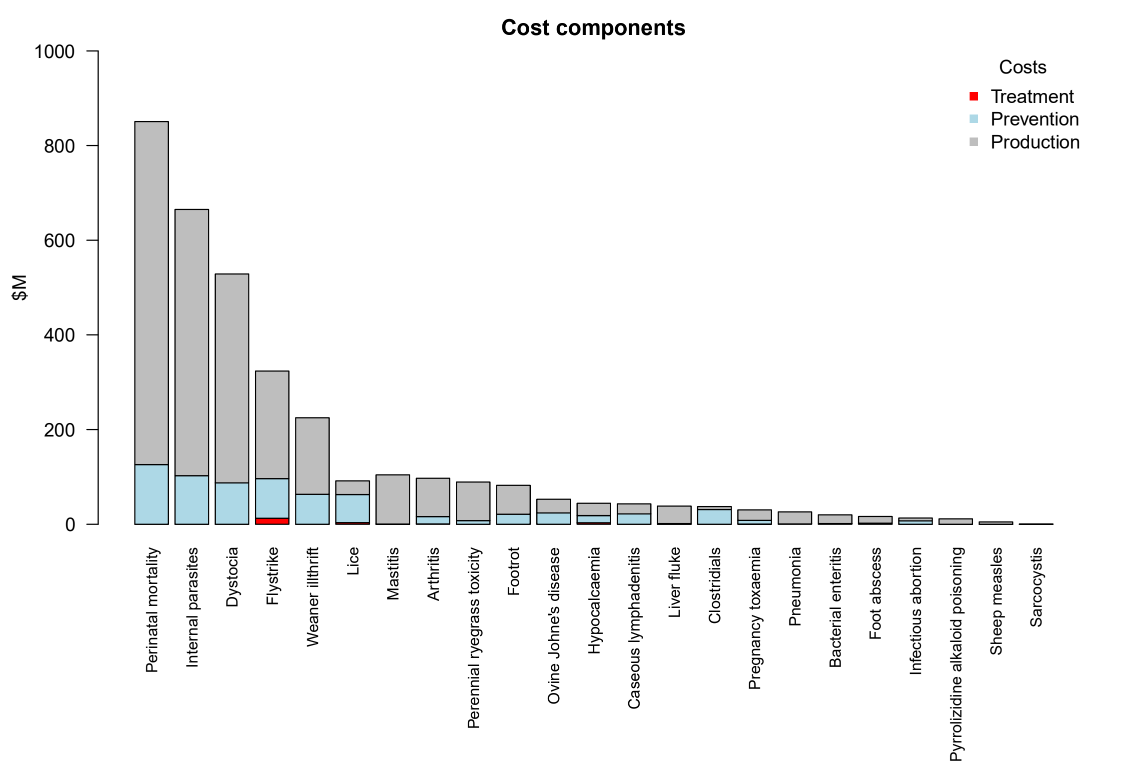
Sheep	
Peri-natal mortalities Internal parasites Dystocia Weaner ill-thrift Flystrike - body & breech Perennial ryegrass staggers Lice Mastitis Footrot Arthritis Ovine Johne's disease (OJD) Clostridial disease	Liver fluke Pneumonia Caseous lymphadenitis ('Cheesy gland') Pregnancy toxaemia Hypocalcaemia Foot abscess Bacterial enteritis Pyrrolizidine alkaloid poisoning Sheep measles Infectious abortion (Sarcocystis – removed from list)

The results of the estimated annual economic cost of the priority diseases for cattle and sheep are presented graphically below:

Cattle:



Sheep:



Summary:

Parasites — buffalo fly, ticks and internal parasites — dominate the costs to the beef industry with each costing industry more than $100M per year. Infectious diseases impacting herd reproductive performance (pestivirus; BVBV vibriosis (bovine camplyobacteriosis)) combined with neonatal calf mortality and the non-infectious diseases of bloat and grass tetany each cost industry between $50-100M. The other diseases each cost less than $50M per annum. The total cost of disease and the potential for returning profit to producers through better control differ across diseases. More effective buffalo fly and cattle tick controls would return significant profit to industry. Some diseases, such as clostridial disease (excluding botulism), appear optimally controlled by industry. In this case, disease (such as black leg) is rarely seen; little production losses are experienced; with the predominant cost being vaccination (prevention). The reader is referred to each disease for details on modelling assumptions and impacts.

The major diseases that impact the sheep industry are associated with perinatal lamb mortality. Analysed separately, but closely associated with peri-natal losses are dystocia and mastitis which are effectively subsets of peri-natal lamb mortality but also include ewe mortality. All these diseases cost more than $100M per year. The major parasitic diseases of sheep; internal parasites, flystrike and lice all costs more than $100M per year. Liver fluke, another internal parasite is considered separately and has a lower annual cost due to limited regional extent of suitable environment for the intermediate snail host to exist and complete the lifecycle. The final disease that cost the sheep industry more than $100M per year is weaner illthrift, which is particularly important for Merino producers. All these diseases have widespread impact across states and to a lesser extent climatic zones. The next level of diseases includes arthritis, perennial ryegrass toxicosis and ovine Johne's disease that all cost more than $50M per year. The remainder of diseases, both infectious, reproductive and non-infectious cost less than $50M per annum. As with the cattle industry the potential for returning profit to the industry varies across different diseases but the biggest potential impact is likely to be gained by making improvements in control of the costliest diseases. The financial impact of virtually all diseases increased substantially driven by higher livestock and wool prices and to a lesser extent increased costs.

Benefits to industry

The update of the priority list of endemic diseases of the beef cattle and sheep meat industry provides a necessary update to guide decision making by producers and industry on individual diseases. The series of reports provides a valuable resource for evaluating trends in disease impacts

Future research and recommendations

The absolute and relative impact of disease costs alongside an estimate of the gains from improved control (where possible) combined with a knowledge gap analysis will underpin the assessment of future research and extension proposals. This information will also guide research institutions into researching knowledge gaps providing greatest benefit for industry and help with funding applications by guiding research proposal cost-benefit estimates.

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Abbreviation	Description
ABS	Australian Bureau of Statistics
ATO	Australian Tax Office
BDV	Border disease virus
BVDV	Bovine viral diarrhoea virus
BCS	Body condition score
BEF	Bovine ephemeral fever
BJD	Bovine Johne’s Disease
BW	Bodyweight
CAE	Caprine arthritis encephalitis
CFW	Clean fleece weight
CPI	Consumer Price Index
CW	Carcass weight
FD	Fibre diameter
FEC	Faecal egg count
FECRT	Faecal egg count reduction test
HRZ	High rainfall zone
IGR	Insect growth regulator
IKC	Infectious keratoconjunctivitis
kg	Kilogram
LW	Live weight
M	Millions
N/kTex	Newtons per kilotex
NRMR	National Resource Management Region
NSHMP	National sheep health monitoring project
OJD	Ovine Johne’s disease
PA	Pyrrolizidine alkaloidosis
PCR	Polymerase chain reaction
PI	Persistent infection
PRG	Perennial rye grass
PRGT	Perennial rye grass toxicosis
WEC	Worm egg count
YO	Years old (refers to age of the animal)

1. Background

The original report of the *Priority list of endemic diseases for the red meat industries* (B.AHE.0010, by Lane *et al*. in 2015), which followed on from the report of *Assessing the economic cost of endemic disease on the profitability of Australian beef cattle and sheep producers* (B.AHW.087, by Sackett *et al.* in 2006) provides estimates of the economic impact of key endemic cattle and sheep diseases in Australia. This series of reports is used assess and rank disease impacts, to guide research, development and extension (RD&E) investments and to help private enterprise evaluate investments they may undertake in specific disease preventives and controls. Producers can use this information to assess the quality of their disease control programs by comparing their herd or flock's performance against the disease assumption used in the models to determine if they can improve their disease control, and more importantly, their economic performance.

A modification to the approach used in the original report (B.AHW.087) was applied in B.AHE.0010 where a template economic model of disease affecting a commercial flock or herd was developed. The model accounted for the variable impact of disease — such as mortality, weight loss, reproductive wastage, reduction in quality — and for when in the production cycle these impacts may occur. The model considered costs of treatment and prevention and the possibility of recovery (partial or full) in affected animals and any costs incurred for the recovery process when estimating impact of disease on realised income of the producer. This baseline economic framework was then modified for each disease under study to provide a whole-farm estimate of the impact of disease. The baseline framework was developed and refined by experienced farm management and veterinary consultants. Individual diseases were modelled by disease experts who were familiar with the underlying structure and premise of the model and who could apply their biological knowledge of the disease to the model to determine disease impact at farm, regional and national level.

The original disease models from B.AHE.0010 were adapted for this report. This was a deliberate plan, discussed during the original project, to ensure that any subsequent update applies a consistent approach to evaluating any change in disease impacts. This allows trends in disease costs to be meaningfully assessed. The original cost estimates from B.AHE.0010 must be adjusted to allow meaningful comparison to current cost estimates. The required adjustments include inflation, change to the demographics of the underlying animal populations, refinements to the estimate of impact of disease on animal performance and finally adjustment for any expansion or contraction of the disease within the target animal population. This report provides each of these adjustments; animal demographic and inflationary changes are presented and discussed before the diseases are presented and within each disease any advances in understanding of the impact of disease on animal performance and any change in distribution and/or prevalence of disease is presented such that the impact on the 2015-updated cost estimate can be presented and discussed. Then the estimate of today's cost of disease at farm level is compared to the real cost of disease from 2015 and the influence of any change to herd or flock demographics discussed as required. The subsequent extrapolation of cost to national level is also discussed in the context of disease change at farm level and changes to the farm population as well as inflation.

This report does not include an update for goat diseases; only sheep and cattle diseases are included. A new disease for cattle has been included (Hydatids), reflective of new knowledge of the impact of infection on carcase performance. For several diseases advances in scientific understanding since 2015 have provided greater precision in disease levels or impacts and as such the models have been updated to reflect these scientific advances. These are described within each disease as required. The original report gathered data from a combination of survey, abattoir data, expert opinion and analysis of treatment/preventive sales figures. The current update has used expert opinion, scientific and industry reports (especially those since 2015), estimates of sales figures and abattoir data analysis to refine the models. Finally, disease experts individually reviewed disease model assumptions and outputs.

1.1 Acknowledgements

The assistance of Drs Lee Taylor and Kelly Graham of Zoetis Australia and Dr David Homer of Nutrien Ag Solutions in estimating the size of the Australian cattle and sheep market for specific disease treatments and preventives is gratefully acknowledged.

2. Objectives

The objectives of this report are to provide:

1. Review the existing report — including confidence bars and spreadsheet structure — to identify changes to the calculations and approach (if any)
2. Establishment of the updated demographics of the sheep and beef red meat (Northern and Southern) industry.
3. Review epidemiology and assumptions for each existing disease (49 in total), include new controls and update the cost impacts of the disease
4. Develop spreadsheet models for new diseases (hydatid disease) update newly emergent diseases (theileriosis) and all associated material
5. Model economics of disease impacts (based on above); comparison to existing estimates (including within-herd and national levels)
6. Provide final report

These objectives have been met in full.

3. Methodology

3.1 Priority list of diseases

The original priority lists of diseases for cattle and sheep from B.AHE.0010 is presented in Table 1 and Table 2 respectively below. These diseases were reviewed. Estimated cost of the disease in 2022 was used to determine merit for remaining on the priority list and the estimated costs of other diseases examined to determine any new inclusions.

Table 1: Original priority list of cattle diseases (from B.AHE.0010, 2015)

Cattle tick	Botulism
Pestivirus (Bovine viral diarrhoea virus; BVDV)	Grass tetany
Buffalo fly	Calf scours complex
Dystocia	Theileriosis
Neonatal mortalities	Pinkeye (infectious bovine keratoconjunctivitis)
Internal parasites	Clostridial infection
Bloat	Tick fever
Bovine ephemeral fever	Johne's disease
Vibriosis (bovine camplyobacteriosis)	

Table 2: Original priority list of sheep diseases (from B.AHE.0010, 2015)

Peri-natal mortalities	Liver fluke
Internal parasites	Pneumonia
Dystocia	Caseous lymphadenitis
Weaner ill-thrift	Pregnancy toxaemia
Flystrike - body & breech	Hypocalcaemia
Perennial ryegrass staggers	Foot abscess
Lice	Bacterial enteritis
Mastitis	Pyrrolizidine alkaloidosis
Footrot	Sheep measles
Arthritis	Campylobacter abortion
Ovine Johne's disease (OJD)	Sarcocystis
Clostridial disease	

This list of diseases was reviewed for relevance and where required, adapted to reflect current circumstances.

3.2 Modelling disease cost

The developers of the original economic template for B.AHE.0010 team completed this work. This continuity ensured consistency between the two snapshots of disease and allowed for analysis of trends in disease cost to be undertaken.

3.3 Baseline demographics

The Australian Bureau of Statistics (ABS) Agricultural Commodities Report series by state and territory and National Resource Management Region (NRMR) was used to provide current demographics of the Australian cattle and sheep industries[1]. The ABS data series was used as part of the 2015 report (B.AHE.0010), where 2011 was the reference year.

The demographic changes (total population size and division between production system) are required to control for these effects in disease costs at industry level.

3.4 Inflation and commodity prices

The national consumer price index (CPI) was obtained from the Australian Tax Office. This was used to adjust prices used in the 2015 report to current (2022) pricing, where specific current item prices were not available.

Specific treatments and preventives were sourced from industry, the internet and expert opinion.

4. Results

4.1 Updated priority list of diseases

The updated priority lists of diseases for cattle and sheep are presented in Table 3 and Table 4 respectively below.

Johne's disease was removed from the original list of cattle diseases (the updated economic assessment of Johne's Disease is provided as an appendix). Hydatids was added to the original list. Sarcocystis was removed from the sheep diseases list and there were no added diseases.

Table 3: Updated priority list of cattle diseases

Buffalo fly	Clostridial disease
Cattle tick	Bovine ephemeral fever
Internal parasites	Grass tetany
Dystocia	Calf scours complex
Neonatal calf mortality	Theileriosis
Pestivirus (bovine viral diarrhoea virus; BVDV)	Pinkeye (infectious bovine keratoconjunctivitis)
Bloat	Hydatids
Vibriosis (bovine camplyobacteriosis)	Tick fever
Trichomoniasis	
Botulism	

[1] https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/latest-release

Table 4: Updated priority list of sheep diseases

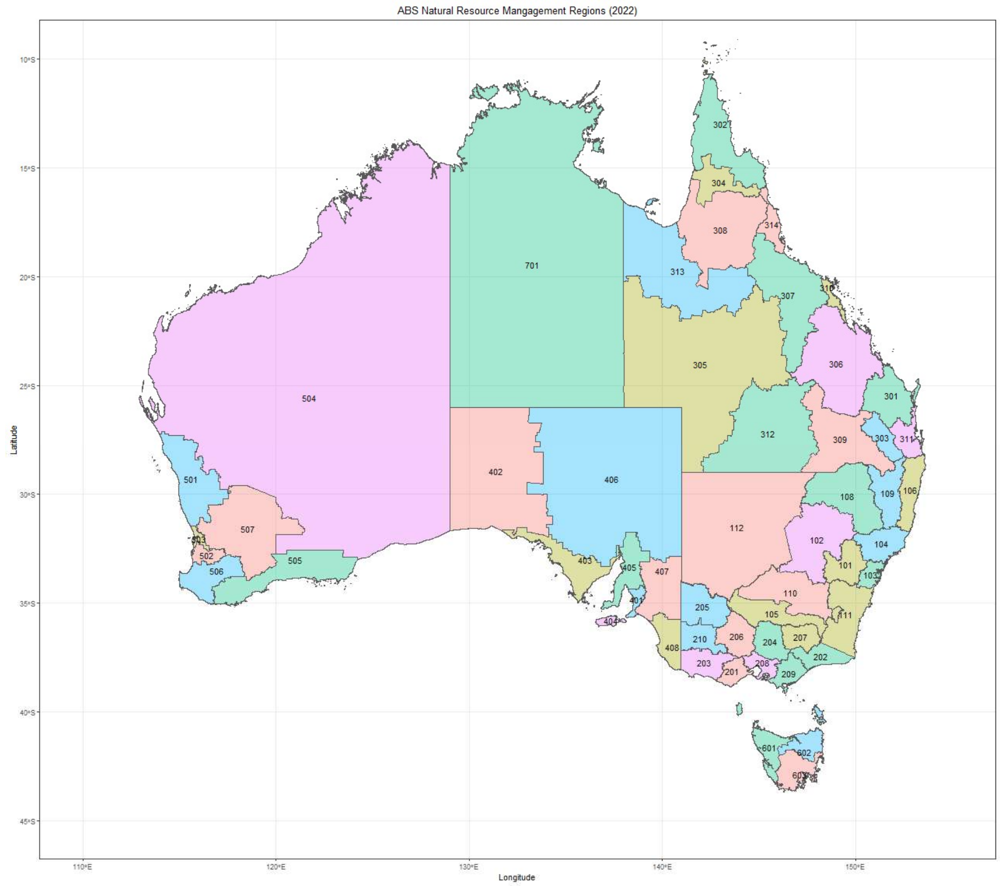
Peri-natal mortalities	Liver fluke
Internal parasites	Pneumonia
Dystocia	Caseous lymphadenitis
Weaner ill-thrift	Pregnancy toxaemia
Flystrike - body & breech	Hypocalcaemia
Perennial ryegrass staggers	Foot abscess
Lice	Bacterial enteritis
Mastitis	Pyrrolizidine alkaloidosis
Footrot	Sheep measles
Arthritis	Campylobacter abortion
Ovine Johne's disease (OJD)	
Clostridial disease	

4.2 Updated demographics

The ABS data files using national resource management region (NRMR) were obtained. Data was aggregated into financial years and combined. The number of cattle and sheep and number of cattle and sheep businesses (i.e. farms) by NRMR region and by state was averaged for the period 2015–2020. These are the same data source was used for B.AHE.0010 (where 2011 was the reference year). A shapefile of NRMR was downloaded from the ABS website[2] and this was used to map NRMR regions.

[2] https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.003July%202016?OpenDocument

Figure 1: Natural Resource Management Regions (NRMR) and identifiers used by the Australian Bureau of Statistics to report Agricultural commodities (2016 version)



The distribution of cattle numbers, cattle farming businesses and average herd size per cattle farming business by NRMR region is presented in Figure 2, Figure 3 and Figure 4 respectively, and in Table 5. The breakdown into northern and southern cattle industry components by state for herd size and number of beef cattle farms in 2020 is presented in Table 7 and Table 10 respectively and for 2011 in Table 8 and Table 11 respectively for 2020. The percentage change in herd size and number of beef cattle farming businesses since 2011 presented in Table 9 and Table 12 respectively.

The distribution of sheep numbers, sheep farming businesses and average flock size per sheep farming business by NRMR region are presented in Figure 5, Figure 6 and Figure 7 respectively and in Table 6. The breakdown of sheep production regions by state for flock size and number of sheep farms is presented in 2020 is presented in Table 13 and Table 16 respectively and for 2011 in Table 14 and Table 17 respectively. The percentage change in flock size and number of sheep farming businesses since 2011 presented in Table 15 and Table 18 respectively.

In summary, cattle numbers have decreased 12.4% whilst the number of beef cattle farms has decreased significantly, with 41.6% fewer beef cattle farming businesses between 2011 and 2020. The greatest percentage reduction was in the southern beef cattle industry. For sheep, there has been a reduction in sheep numbers of 7.0% and with 27.3% fewer sheep farms in the period between 2011 and 2020. The greatest reduction has been in the pastoral zone with an approximately 40% reduction in sheep and sheep farms during this period. Some of the reported changes in sheep numbers within the high rainfall, wheat-sheep and pastoral zones are due to changes in the ABS reported NRM regions between 2011 and 2022. These changes do not have a significant impact on the modelling outcomes.

Figure 2: Cattle herd size distribution across NRM regions of Australia (source ABS; average for period 2016–2020)

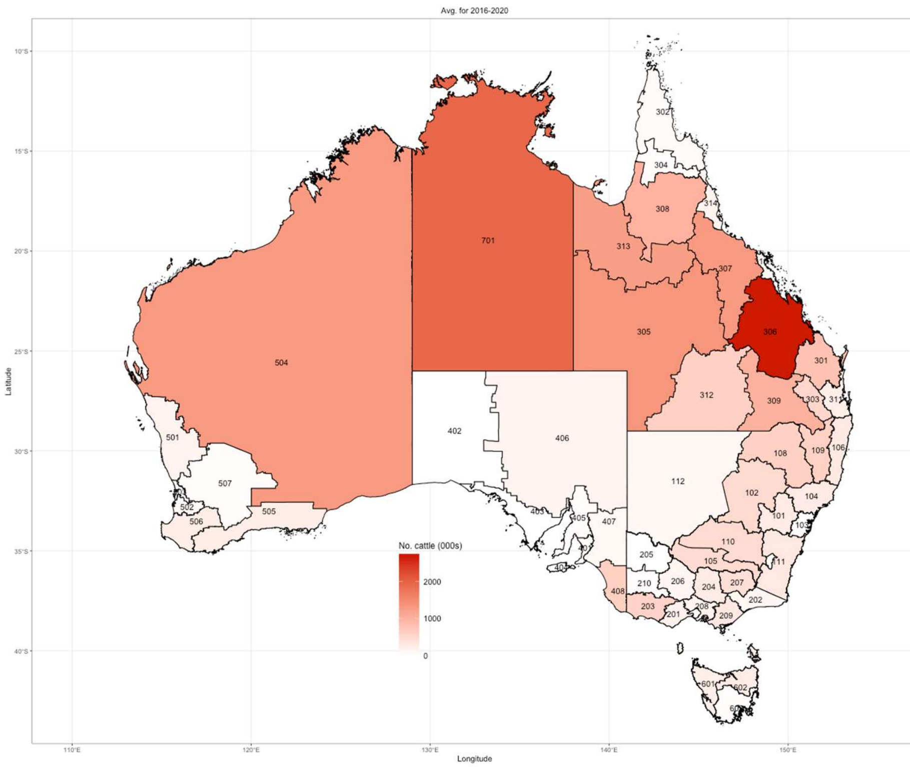


Figure 3: Number of cattle farm businesses across NRM regions of Australia (source ABS; average for period 2016–2020)

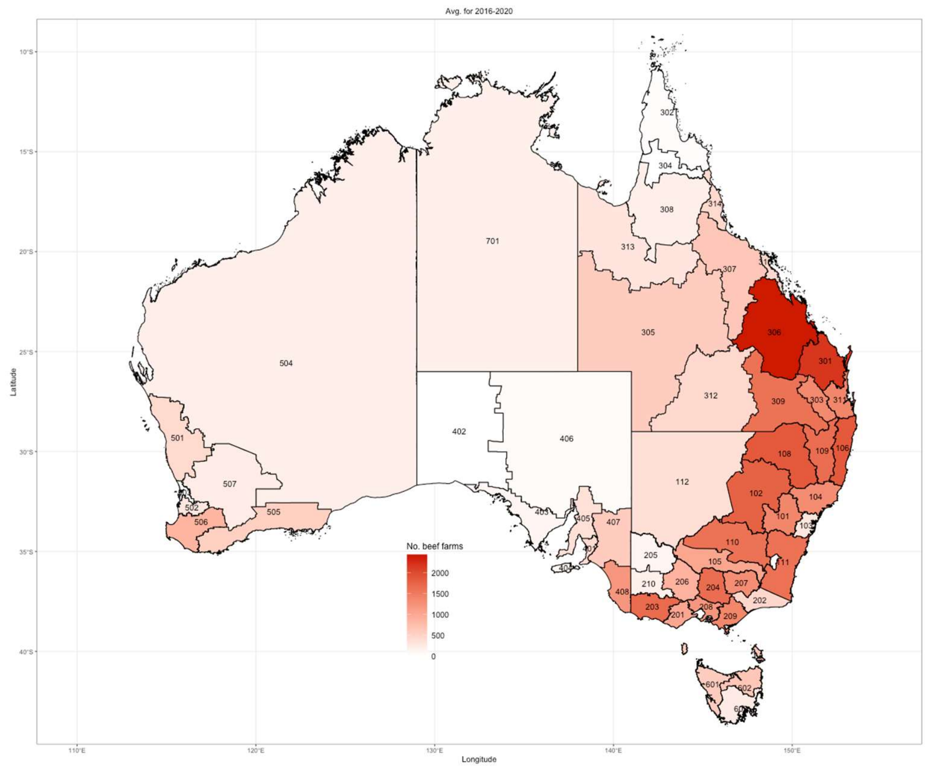


Figure 4: Average cattle herd size across NRM regions of Australia (source ABS; average for period 2016–2020)

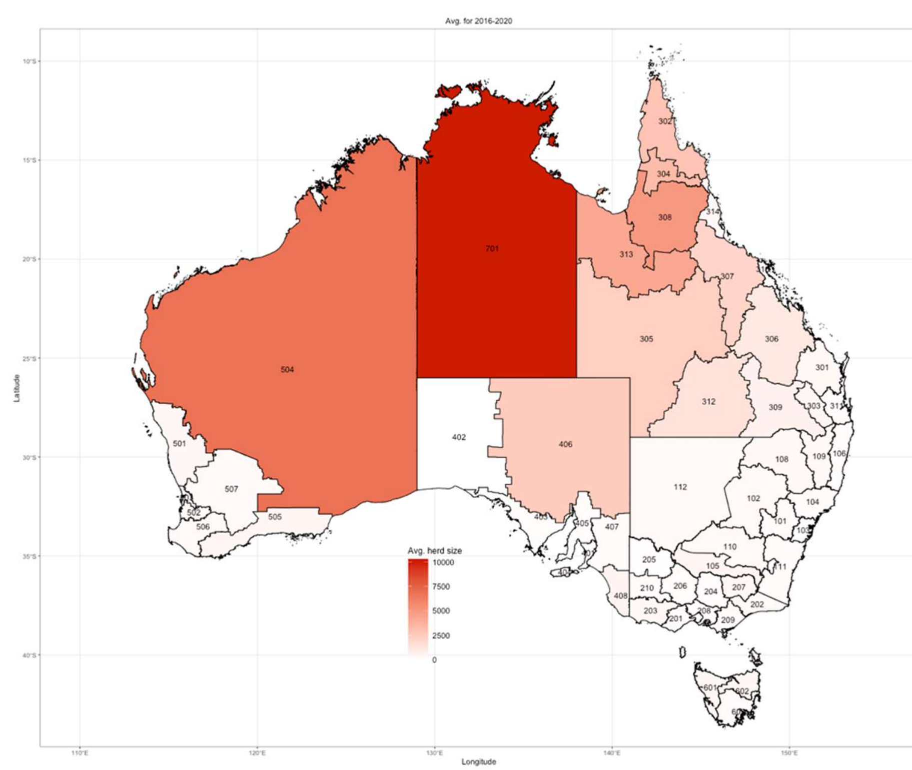


Table 5: Cattle herd and cattle farm business distribution by natural resource management region (ABS; 2016–2020)

State	NRM Region	NRM Name	% National Herd	Total Herd Size	% Beef Businesses	No. Beef Businesses
NSW	101	Central Tablelands	1.18	269,104	3.16	1,375
NSW	102	Central West	2.14	486,765	4.05	1,763
NSW	103	Greater Sydney	0.09	19,403	0.66	285
NSW	104	Hunter	1.17	265,311	3.00	1,305
NSW	105	Murray	2.09	475,568	2.35	1,023
NSW	106	North Coast	1.25	284,682	4.28	1,861
NSW	108	North West NSW	2.65	602,968	4.28	1,861
NSW	109	Northern Tablelands	2.54	576,983	3.78	1,645
NSW	110	Riverina	2.11	478,456	3.67	1,595
NSW	111	South East NSW	1.32	300,181	3.68	1,603
NSW	112	Western	0.49	111,372	0.83	361
VIC	201	Corangamite	0.80	181,680	2.31	1,007
VIC	202	East Gippsland	0.50	114,084	1.03	449
VIC	203	Glenelg Hopkins	2.50	567,617	3.85	1,674
VIC	204	Goulburn Broken	1.18	269,140	3.78	1,646
VIC	205	Mallee	0.04	8,048	0.25	110
VIC	206	North Central	0.57	129,824	2.03	884
VIC	207	North East	1.83	416,686	2.98	1,295
VIC	208	Port Phillip and Western Port	0.73	166,522	2.75	1,195
VIC	209	West Gippsland	1.34	305,435	3.14	1,366
VIC	210	Wimmera	0.17	38,576	0.43	187
QLD	301	Burnett Mary	3.44	782,429	5.00	2,176
QLD	302	Cape York	0.30	69,055	0.06	
QLD	303	Condamine	2.34	532,054	3.08	1,339
QLD	304	Cooperative Management Area	0.19	42,598	0.03	
QLD	305	Desert Channels	6.00	1,361,891	1.33	580
QLD	306	Fitzroy Basin	12.04	2,734,662	5.58	2,427
QLD	307	North Queensland Dry Tropics	5.73	1,300,929	1.47	640
QLD	308	Northern Gulf	4.38	994,933	0.46	200
QLD	309	Queensland Murray Darling Basin	4.42	1,003,799	3.66	1,591
QLD	310	Reef Catchments	0.53	120,191	1.03	450
QLD	311	South East Queensland	0.97	220,832	3.16	1,376
QLD	312	South West Queensland	2.63	596,492	1.02	442
QLD	313	Southern Gulf	5.49	1,246,097	0.68	295
QLD	314	Terrain NRM	0.65	148,029	0.99	431
SA	401	Adelaide and Mount Lofty Ranges	0.24	55,365	0.98	426
SA	402	Alinytjara Wilurara	0.00	0	0.00	0
SA	403	Eyre Peninsula	0.05	12,436	0.27	118
SA	404	Kangaroo Island	0.09	21,489	0.22	
SA	405	Northern and Yorke	0.17	38,804	0.80	348
SA	406	SA Arid Lands	0.61	137,766	0.13	
SA	407	SA Murray Darling Basin	0.44	99,843	1.34	585
SA	408	South East	2.69	610,033	2.75	1,195

State	NRM Region	NRM Name	% National Herd	Total Herd Size	% Beef Businesses	No. Beef Businesses
WA	501	Northern Agricultural	0.73	166,846	0.98	428
WA	502	Peel-Harvey	0.30	68,843	0.63	275
WA	503	Perth	0.02	5,372	0.04	
WA	504	Rangelands	5.75	1,305,067	0.44	192
WA	505	South Coast	1.02	232,121	1.24	540
WA	506	South West	1.05	238,506	1.96	852
WA	507	Wheatbelt	0.22	49,349	0.51	222
TAS	601	Cradle Coast	0.99	225,631	1.33	578
TAS	602	North	1.09	247,911	1.51	658
TAS	603	South	0.19	42,453	0.55	241
NT	701	Northern Territory	8.51	1,932,742	0.43	188

Figure 5: National sheep flock distribution across NRM regions of Australia (source ABS; average for period 2016–2020)

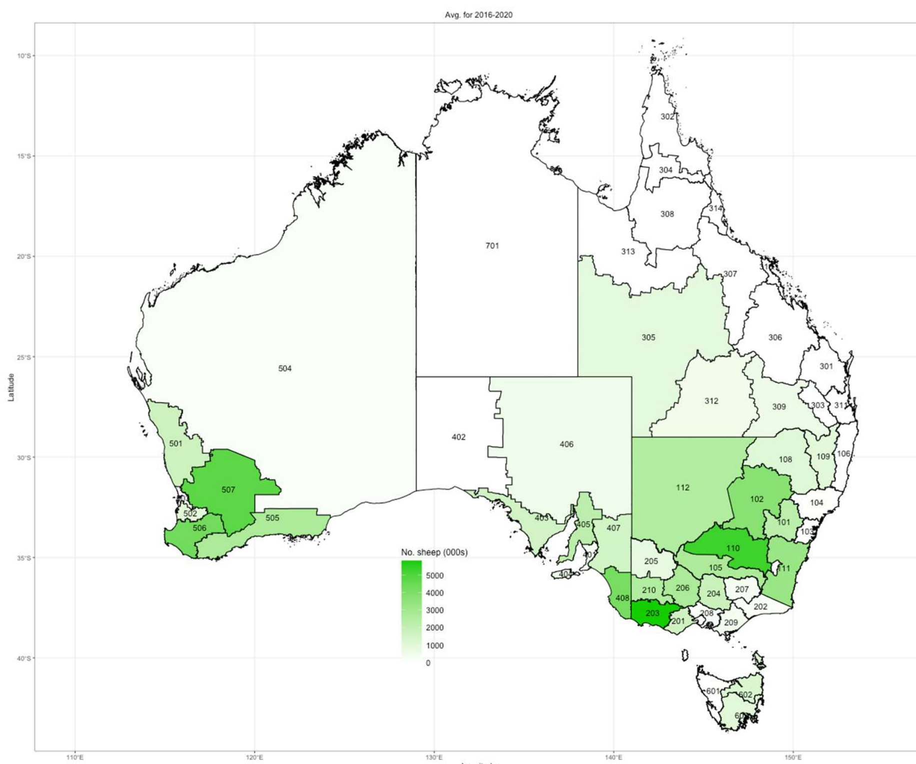


Figure 6: Number of sheep farm businesses across NRM regions of Australia (source ABS; average for period 2016–2020)

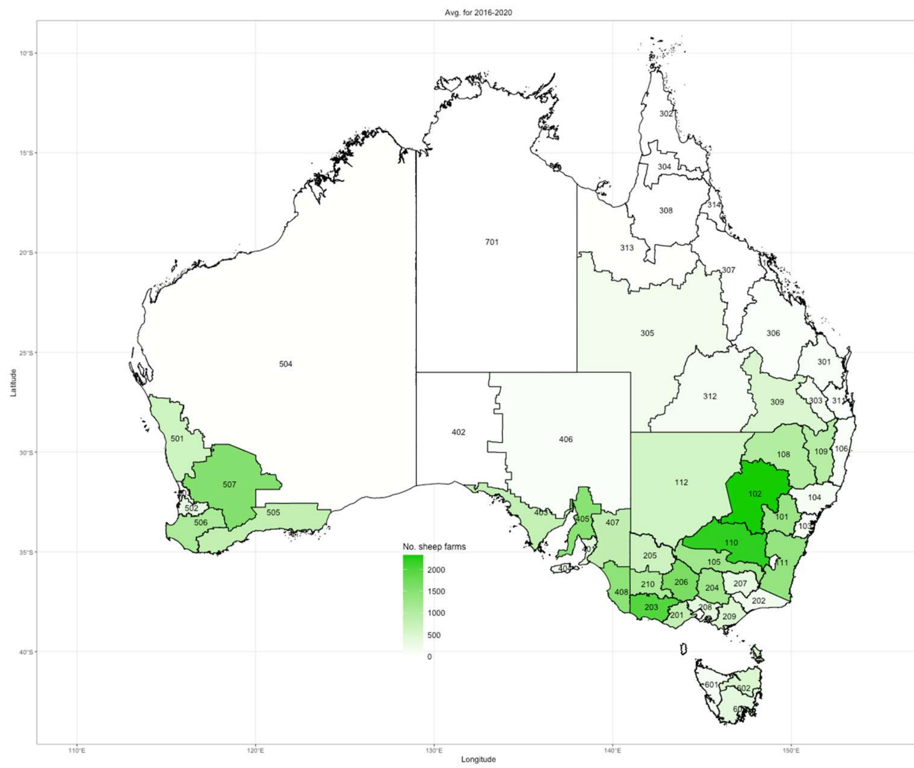


Figure 7: Average sheep flock size across NRM regions of Australia (source ABS; average for period 2016–2020)

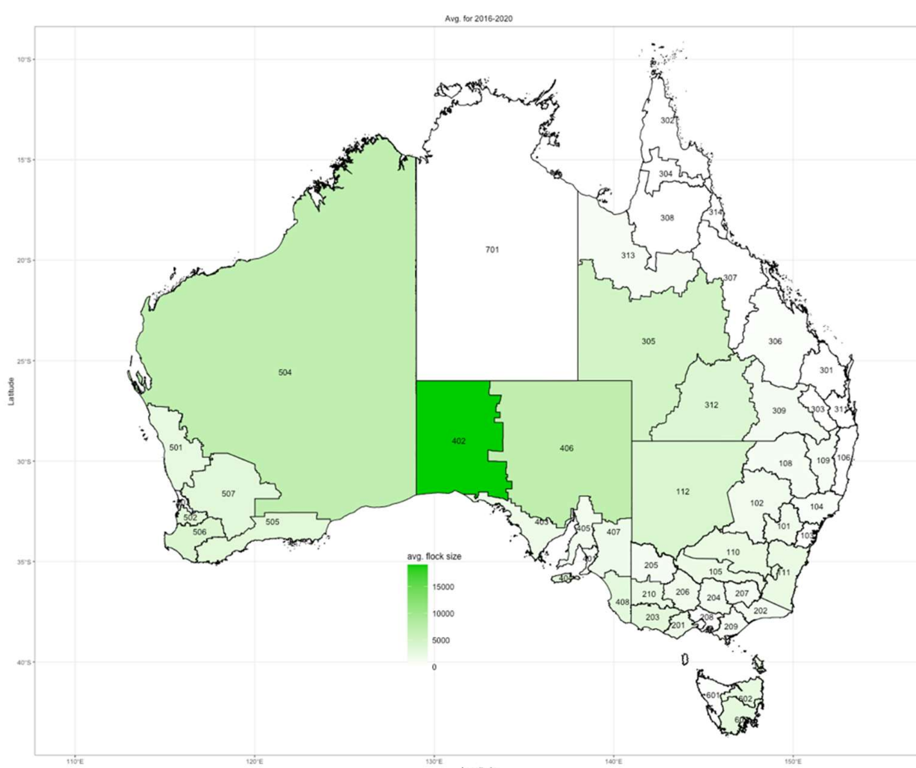


Table 6: Sheep flock and sheep farm business distribution by natural resource management region (ABS; 2016–2020)

State	NRM Region	NRM Name	% National Flock	Total Flock Size	% Sheep Businesses	No. Sheep Businesses
NSW	101	Central Tablelands	3.27	2,222,149	4.06	1,292
NSW	102	Central West	5.47	3,722,903	7.31	2,329
NSW	103	Greater Sydney	0.00	3,292	0.23	74
NSW	104	Hunter	0.10	66,041	0.41	130
NSW	105	Murray	3.93	2,675,562	3.88	1,235
NSW	106	North Coast	0.01	4,235	0.28	88
NSW	108	North West NSW	1.61	1,096,890	3.11	992
NSW	109	Northern Tablelands	1.44	976,042	2.98	951
NSW	110	Riverina	7.83	5,325,851	6.96	2,217
NSW	111	South East NSW	4.73	3,214,348	4.24	1,351
NSW	112	Western	3.68	2,499,506	1.92	612
VIC	201	Corangamite	2.29	1,559,888	2.60	828
VIC	202	East Gippsland	0.27	185,364	0.53	170
VIC	203	Glenelg Hopkins	8.55	5,811,112	6.26	1,993
VIC	204	Goulburn Broken	2.57	1,751,085	3.78	1,204
VIC	205	Mallee	1.15	783,357	2.11	672
VIC	206	North Central	4.00	2,723,551	5.12	1,630
VIC	207	North East	0.51	344,845	0.93	295
VIC	208	Port Phillip and Western Port	0.21	143,391	1.10	352
VIC	209	West Gippsland	0.60	408,294	1.51	480
VIC	210	Wimmera	3.69	2,508,603	3.34	1,066
QLD	301	Burnett Mary	0.01	5,101	0.24	76
QLD	302	Cape York	0.00	0	0.00	0
QLD	303	Condamine	0.05	34,993	0.58	184
QLD	304	Cooperative Management Area	0.00	77	0.01	3
QLD	305	Desert Channels	1.33	905,231	0.59	187
QLD	306	Fitzroy Basin	0.03	20,069	0.18	57
QLD	307	North Queensland Dry Tropics	0.00	368	0.02	7
QLD	308	Northern Gulf	0.00	0	0.00	0
QLD	309	Queensland Murray Darling	0.88	596,036	1.58	503
QLD	310	Reef Catchments	0.00	905	0.05	16
QLD	311	South East Queensland	0.00	2,708	0.17	54
QLD	312	South West Queensland	0.77	523,794	0.44	140
QLD	313	Southern Gulf	0.03	22,946	0.07	24
QLD	314	Terrain NRM	0.00	104	0.02	7
SA	401	Adelaide and Mount Lofty	0.47	320,946	1.10	350
SA	402	Alinytjara Wilurara	0.03	19,007	0.00	1
SA	403	Eyre Peninsula	2.27	1,542,861	2.46	784
SA	404	Kangaroo Island	0.94	639,760	0.61	193
SA	405	Northern and Yorke	3.18	2,165,519	4.62	1,473
SA	406	SA Arid Lands	0.80	542,660	0.25	79
SA	407	SA Murray Darling Basin	2.23	1,515,659	2.62	835
SA	408	South East	6.12	4,161,447	4.54	1,447
WA	501	Northern Agricultural	2.48	1,688,732	2.06	656
WA	502	Peel-Harvey	1.45	983,451	0.97	310

State	NRM Region	NRM Name	% National Flock	Total Flock Size	% Sheep Businesses	No. Sheep Businesses
WA	503	Perth	0.00	2,224	0.03	10
WA	504	Rangelands	0.30	202,918	0.09	30
WA	505	South Coast	3.96	2,693,181	2.58	823
WA	506	South West	6.28	4,270,799	3.45	1,097
WA	507	Wheatbelt	7.01	4,770,336	4.81	1,533
TAS	601	Cradle Coast	0.08	53,522	0.41	131
TAS	602	North	1.82	1,238,713	1.59	508
TAS	603	South	1.50	1,021,038	1.15	366
NT	701	Northern Territory	0.00	74	0.00	1
ACT	801	Australian Capital Territory	0.05	32,865	0.04	13

Table 7: Northern and southern beef cattle production system by state herd size distribution (2020)

Cattle	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Northern	-	-	11,153,990	-	1,305,067	-	1,932,742	-	14,391,799
Southern	3,870,793	2,197,613	-	975,735	761,037	515,995	-	2,547	8,323,720
Total	3,870,793	2,197,613	11,153,990	975,735	2,066,104	515,995	1,932,742	2,547	22,715,519

Table 8: Northern and southern beef cattle production system by state herd size distribution (2011)

Cattle	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Northern	-	-	12,449,623	-	1,059,821	-	2,197,359	-	15,706,803
Southern	5,383,931	2,365,851	-	1,109,640	894,561	466,583	-	8,807	10,229,373
Total	5,383,931	2,365,851	12,449,623	1,109,640	1,954,382	466,583	2,197,359	8,807	25,936,176

Table 9: Northern and southern beef cattle production system by state herd size percentage change since 2011 distribution (2020)

Cattle	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Northern	-	-	-10.4%	-	23.1%	-	-12.0%	-	-8.4%
Southern	-28.1%	-7.1%	-	-12.1%	-14.9%	10.6%	-	-71.1%	-18.6%
Total	-28.1%	-7.1%	-10.4%	-12.1%	5.7%	10.6%	-12.0%	-71.1%	-12.4%

Table 10: Northern and southern beef cattle production system by state number of farming businesses distribution (2020)

Cattle	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Northern	-	-	11,986	-	192	-	188	-	12,367
Southern	14,677	9,813	-	2,822	2,334	1,477	-	25	31,148
Total	14,677	9,813	11,986	2,822	2,526	1,477	188	25	43,514

Table 11: Northern and southern beef cattle production system by state number of farming businesses distribution (2011)

Cattle	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Northern	-	-	19,226	-	263	-	254	-	19,743
Southern	27,164	16,020	-	4,628	4,265	2,602	-	51	54,730
Total	27,164	16,020	19,226	4,628	4,528	2,602	254	51	74,473

Table 12: Northern and southern beef cattle production system by state number of farming businesses percentage change since 2011 distribution (2020)

Cattle	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Northern	-	-	-37.7%	-	-26.8%	-	-26.0%	-	-37.4%
Southern	-46.0%	-38.7%	-	-39.0%	-45.3%	-43.2%	-	-50.5%	-43.1%
Total	-46.0%	-38.7%	-37.7%	-39.0%	-44.2%	-43.2%	-26.0%	-50.5%	-41.6%

Table 13: Sheep production system by state flock size distribution (2020)

Sheep	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Pastoral	2,499,506	-	2,112,333	561,667	202,918	-	74	-	5,376,499
Sheep/Wheat	12,821,206	7,766,596	-	5,224,040	9,152,249	-	-	-	34,964,090
High rainfall	6,486,108	8,452,893	-	5,122,154	5,256,474	2,313,273	-	32,865	27,663,767
Total	21,806,821	16,219,489	2,112,333	10,907,861	14,611,640	2,313,273	74	32,865	68,004,356

Table 14: Sheep production system by state flock size distribution (2011)

Sheep	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Pastoral	3,251,045	493,416	3,653,238	1,128,932	364,994	-	1,855	-	8,893,480
Sheep/Wheat	21,070,130	6,957,062	-	3,381,602	6,018,036	-	-	54,092	37,480,922
High rainfall	2,503,522	7,761,539	-	6,498,008	7,616,824	2,344,469	-	-	26,724,362
Total	26,824,697	15,212,017	3,653,238	11,008,542	13,999,854	2,344,469	1,855	54,092	73,098,764

Table 15: Sheep production system by state flock size change percentage since 2011 distribution (2020)

Sheep	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Pastoral	-23.1%	-100.0%	-42.2%	-50.2%	-44.4%	-	-96.0%	-	-39.5%
Sheep/Wheat	-39.1%	11.6%	-	54.5%	52.1%	-	-	-100.0%	-6.7%
High rainfall	159.1%	8.9%	-	-21.2%	-31.0%	-1.3%	-	-	3.5%
Total	-18.7%	6.6%	-42.2%	-0.9%	4.4%	-1.3%	-96.0%	-39.2%	-7.0%

Table 16: Sheep production system by state number of sheep farming businesses distribution (2020)

Sheep	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Pastoral	612	-	1,258	80	30	-	1	-	1,982
Sheep/Wheat	6,772	4,571	-	3,092	3,011	-	-	-	17,447
High rainfall	3,886	4,118	-	1,989	1,418	1,004	-	13	12,428
Total	11,270	8,689	1,258	5,162	4,459	1,004	1	13	31,856

Table 17: Sheep production system by state number of sheep farming businesses distribution (2011)

Sheep	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Pastoral	743	565	1,818	103	98	-	3	-	3,330
Sheep/Wheat	13,356	5,714	-	2,370	2,795	-	-	32	24,267
High rainfall	2,319	4,691	-	4,339	3,330	1,552	-	-	16,231
Total	16,418	10,970	1,818	6,812	6,223	1,552	3	32	43,828

Table 18: Sheep production system by state number of sheep farming businesses percentage change since 2011 distribution (2020)

Sheep	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Pastoral	-17.6%	-100.0%#	-30.8%	-21.9%	-69.2%	-	-66.7%	-	-40.5%
Sheep/Wheat	-49.3%	-20.0%	-	30.5%	7.7%	-	-	-100.0%	-28.1%
High rainfall	67.6%	-12.2%	-	-54.2%	-57.4%	-35.3%	-	-	-23.4%
Total	-31.4%	-20.8%	-30.8%	-24.2%	-28.3%	-35.3%	-66.7%	-60.5%	-27.3%

This is an anomaly arising from ABS zone geographical changes

4.3 Inflation and commodity prices

The national consumer price index (CPI) was obtained from the Australian Tax Office (ATO). The quarterly CPI estimate from 2015 to 2022 is presented in Table 19.

Table 19: Quarterly consumer price indices from Q1 2015 until Q4 2021 (ATO)

Year	31 March	30 June	30 September	31 December
2021	117.9	118.8	119.7	121.3
2020	116.6	114.4	116.2	117.2
2019	114.1	114.8	115.4	116.2
2018	112.6	113.0	113.5	114.1
2017	110.5	110.7	111.4	112.1
2016	108.2	108.6	109.4	110.0
2015	106.8	107.5	108.0	108.4

The ratio of Q4 2021 to Q1 2015 is 1.1358 (121.3/106.8); indicating that prices have increased by an average of 13.6% on late 2014 prices (when B.AHE.0010 was finalised).

The CPI-adjusted average weekly prices for saleyard cattle of various categories are presented in Table 20. The average real prices (c/kg liveweight) for the period 2019–2022 (and compared to 2011–2014 in 2022 prices) was: medium cows 292.53c (+134.27c, +84.8%); medium steers 383.33c (+173.86c, +82.4%); trade steers 439.48c, (+205.83c, +88.1%); feeder steers 442.21c (+214.35c, +94.1%); northern cows 282.93c (+116.82c, +70.3%); and northern bullocks 361.63c (+139.19c, +62.6%). It should be noted that year-on-year cattle prices are more volatile than the long-term annual trend presented (see Figure 8). However, the long-term trend provides a more robust estimate of returns than current prices, and this was used for modelling.

CPI-adjusted average weekly prices for saleyard sheep increase in sheep prices are presented in Table 21 with the average real prices (c/kg liveweight) for the period 2019–2022 (compared to 2011–2014 in 2022 prices) being: mutton 600.81c (+251.61c, +72.1%); trade lambs 816.53c (+289.05c, +54.8%); light lambs 830.33c (+267.66c, +47.6%); heavy lambs 826.16c (+265.51c, +47.36%); restocker lambs 872.98c (+323.68c, +58.93%); and Merino lambs 765.07c (+276.41c, + 56.6%). In addition to saleyard prices, on farm ewes in the model were given an additional store value of between $20-$40/head to reflect their long-term breeding value. Weekly prices are presented in Figure 9, which, like cattle, show volatility but with a general upwards trend.

Table 20: Average national saleyard prices (c/kg Liveweight) for cattle of various categories by year (source: MLA Market Information)

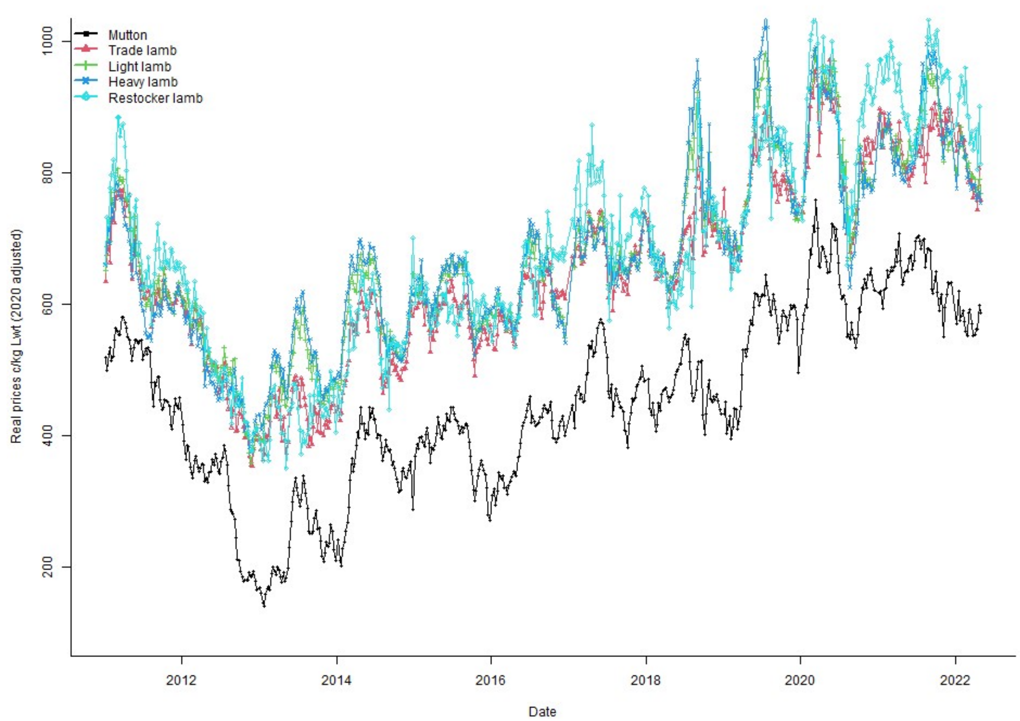
Year	Medium cow	Medium steer	Trade steer	Feeder steer	Nth Qld medium cow	Nth Qld grassfed bullock
2011	178	227	260	257	-	-
2012	163	217	242	237	-	-
2013	141	195	214	203	-	-
2014	151	203	219	214	166	222
2015	233	295	316	320	225	282
2016	258	342	375	382	252	316
2017	239	308	351	354	231	293
2018	209	282	308	305	205	280
2019	213	287	302	297	196	296
2020	284	358	401	411	276	348
2021	325	423	501	497	307	384
2022	348	465	554	564	353	419

Table 21: Average national saleyard prices (c/kg Liveweight) for sheep of various categories by year (source: MLA Market Information)

Year	Mutton	Trade lamb	Light lamb	Heavy lamb	Restocker lamb	Merino lamb
2011	506	661	673	648	712	604
2012	303	486	502	488	505	437
2013	233	427	488	507	428	400
2014	355	536	587	599	552	514
2015	384	581	613	618	600	545
2016	388	603	622	625	632	570
2017	479	675	684	679	735	627
2018	472	690	728	742	690	663
2019	544	770	802	809	787	749
2020	635	838	843	826	890	791
2021	649	850	867	870	932	789
2022	576	808	809	799	883	731

Figure 8: National saleyard prices for various indicator categories of cattle for the period 2011-2022

Figure 9: National saleyard prices for various indicator categories of sheep for the period 2011-2022



Average weekly wool prices for the period are presented in Figure 10 and in annual summary form in Table 22. Most lines of wool enjoyed modest real increase in value for the period between 2011–2014 and 2017–2020 of around 25–30%, except for a decline in real returns for coarser wool.

Figure 10: Average wool prices for various wool micron categories (wool micron price guide indicators) for 2011-2022

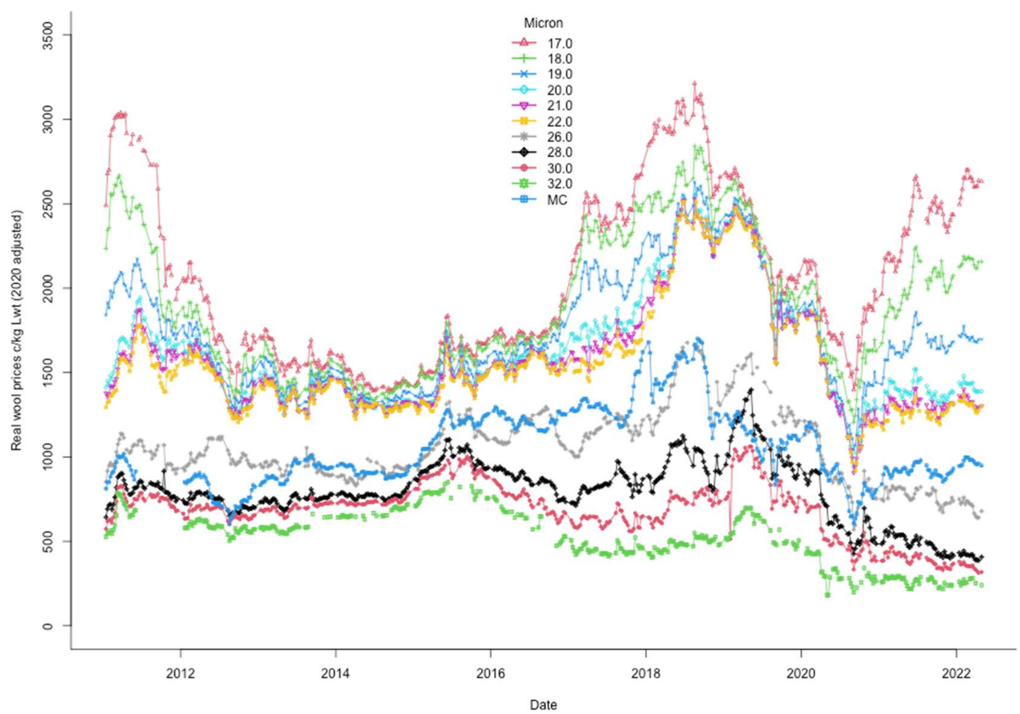


Table 22: Average wool price (c/kg) for various micron wools (wool micron price guide indicators) for 2011 to 2020

						Micron					
Year	**17.0**	**18.0**	**19.0**	**20.0**	**21.0**	**22.0**	**26.0**	**28.0**	**30.0**	**32.0**	**MC***
2011	2,658	2,268	1,931	1,669	1,598	1,525	1,012	803	732	655	933
2012	1,784	1,636	1,552	1,482	1,463	1,430	1,006	729	669	580	779
2013	1,593	1,495	1,448	1,396	1,384	1,372	942	746	698	583	918
2014	1,450	1,407	1,361	1,327	1,322	1,308	903	772	734	669	910
2015	1,613	1,583	1,504	1,446	1,436	1,414	1,125	977	910	781	1,160
2016	1,749	1,717	1,652	1,583	1,555	1,536	1,169	860	738	628	1,217
2017	2,416	2,308	2,050	1,784	1,678	1,597	1,146	828	622	450	1,314
2018	2,901	2,525	2,359	2,281	2,240	2,226	1,408	960	723	483	1,478
2019	2,306	2,245	2,150	2,110	2,103	2,140	1,367	1,082	862	580	1,134
2020	1,809	1,623	1,475	1,395	1,371	1,317	918	651	519	316	886
Avg last 4 years	2,358	2,175	2,009	1,893	1,848	1,820	1,210	880	682	457	1,203
% real change (2011-2014 To 2017-2020)	26.0%	27.8%	27.7%	28.9%	28.2%	29.2%	25.3%	15.5%	-3.8%	-26.5%	36.0%

* MC = Merino cardings

Where specific information on the costs of treatment or controls are not available (e.g. farm labour), CPI-adjusted 2011 figures were used in order to maintain consistency between the original 2015 estimate the and 2022 updated estimate.

4.4 Cattle Diseases

4.4.1 Buffalo fly

The disease

Haematobia irritans exigua is a blood sucking fly that lives for 10–20 days on a cattle host taking 10-40 daily feeds (Meat & Livestock Australia, 2011). Female flies leave cattle briefly to lay eggs in cattle dung before returning to the host. Fly populations are influenced by access to cattle, their dung and climate, being highest during warm wet conditions. Cattle can carry an average of 1,000 flies per animal (Holroyd, D. Hirst, *et al.*, 1984). Effective fly control can increase growth rates by up to 10% in cattle under high challenge (Meat & Livestock Australia, 2011). Some cattle are sensitive to flies or to *Stephanofilaria sp.*, the skin-residing parasite they transmit, resulting in intense irritation and skin lesions that reduce hide values. Buffalo flies adversely affect the welfare of cattle; they learn to self-administer treatments that give fly relief. Cattle sensitivity to flies is of low heritability and this limits the development of genetically tolerant cattle.

	Unknown aetiology									*Known aetiology*
2015								X		
2022									X	

Prevention

A controlled field study showed that live weight gain benefits are only achieved with sustained and effective chemical fly control (Holroyd, DJ. Hirst, *et al.*, 1984). Increased weight gains of between 10 and 17 kilograms have been observed in effectively controlled cattle compared to controls (Northern Territory Government, 2019). Occasional treatment is unlikely to have a long-term live weight impact but may bring short-term welfare benefits to affected cattle. Fly control also eliminates skin lesions (Holroyd, D. Hirst, *et al.*, 1984). Dung beetles have been shown to reduce the buffalo fly burden up to four fold in controlled studies (Doube, 2018). They achieve this by burying dung which denies access to egg-bound flies and by competing with fly larvae for resources and moisture. Other dung fauna, such as the exotic staphlinid beetle, which prey upon buffalo fly eggs and larvae could contribute as part of an integrated parasite management approach if able to be introduced.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015				X						
2022			X							

Treatment

An effective treatment will provide welfare benefits. O'Rourke (O'Rourke, K. Winks and Kelly, 1992) reported that 67% of north Australian producers applied buffalo fly prevention, and a further 5% whose cattle experienced infestation applied no treatment. A range of insecticide treatments are available (*Flies | Meat & Livestock Australia*, no date; Meat & Livestock Australia, 2011). Other treatments such as fly tunnel traps can be effective but are expensive, often impractical to apply and require stock to be trained, so few are in use. Resistance to chemicals is widespread, and likely to increase given most flies are associated with cattle (i.e. there is a small *in refugia* population so most flies are exposed to chemicals) and this provided strong selection for resistance (Heath and Levot, 2015). Long withholding periods and export slaughter intervals also limit use of many chemicals.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015								X		
2022							X			

Distribution

The fly is mainly distributed in coastal Queensland, the northern areas of the NT and WA, and the NE corner of NSW (Meat & Livestock Australia, 2011). Buffalo fly do not have a pupal overwintering strategy, but instead survive in focal pockets of (declining) numbers throughout the winter, that subsequently increase and spread once the weather warms (James, Madhav and Brown, 2021). The fly has been recorded as far south as Victoria and as far inland as Alice Springs following a series of mild winters and wet summers. It is believed the buffalo fly range has extended an extra 1,000 km south over the past 40 years. Wet summers let the fly move into the traditionally drier interior; potentially occupying an area two times larger than their natural endemic range. Increasing temperatures will have a few effects: an increased number of fly generations per year, longer active periods of challenge and further expansion south (warmer winters, reduced frosts), but an increase in the frequency of dry seasons will limit fly numbers in those years.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022						X				

Prevalence

Prevalence is affected by seasonal conditions. Particularly under early wet season conditions, high fly populations can occur very quickly as the life cycle can be less than 2 weeks (Meat & Livestock Australia, 2011). Populations are highest in near-coastal regions of northern Australia where humidity is highest. Populations become very low under dry or cool conditions. Where flies are persistent, populations sufficient to affect live weight production may persist for 2-6 months annually.

	Prevalence decreasing									*Prevalence increasing*
2015						X				
2022							X			

Economics

Assumptions: Buffalo fly – southern

Table 23: Assumptions: buffalo fly – southern (cattle)

Variable	2015 Assumptions	2022 Assumption changes	Confidence
Regional Extent	0%, 5% and 10% of herds with high, medium and low incidence	0%, 7.5% and 15% of herds with high, medium and low incidence	**

Variable	2015 Assumptions	2022 Assumption changes	Confidence
% herds infected	Entire herds are infested, but an average of 33% and 10% of the year in medium and low incidence herds, respectively	Entire herds are infested, but an average of 40% and 15% of the year in medium and low incidence herds, respectively	**
Mortalities	No mortalities caused	-	***
Weight loss	Where prevention is applied during infestation, in 25% of these situations there is effective prevention of permanent weight loss, which is 10% over the infestation period	-	*
Fertility	Nil effect	-	*
Market avoidance	Skin lesions cause 5% and 2% of cattle in medium and low incidence herds, respectively, to have net market value reduced by $0.10/kg	Skin lesions cause 5% and 2% of cattle in medium and low incidence herds, respectively, to have net market value reduced by $0.20/kg	*
Movement restrictions	Nil	-	***
Treatment	As for prevention	-	**
Prevention	70% of cattle in affected areas have some form of control applied. An average of $1/animal/month is required for full control. Partial control costs half this.	70% of cattle in affected areas have some form of control applied. An average of $1.15/animal/month is required for full control. Partial control costs half this. An estimated 1M doses of buffalo control/treatments are used in southern Australia each year	**

Based on these assumptions the annual cost of buffalo fly in cattle in southern Australia is estimated at $8.2M (Table 24).

Table 24: Economic cost of buffalo fly – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$0	$4.22	$2.05	$0	$7.91	$1.39	**$0.00**	**$12.13**	**$3.44**
Per Herd	$0	$0	$0	$0	$776	$377	$0	$1,456	$255	**$0**	**$2,232**	**$633**
Total	**$0M**			**$3.6M**			**$4.6M**			**$8.2M**		

The net gain from moving all southern herds experiencing buffalo fly to the lowest level of disease is estimated at $3.7M.

Assumptions: Buffalo fly – northern

Table 25: Assumptions: buffalo fly – northern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	10%, 50% and 30% of herds with high, medium and low incidence	15%, 60% and 20% of herds with high, medium and low incidence	**
% herds infected	Entire herds are infested, but an average of 80%, 33% and 10% of the year in high, medium and low incidence herds, respectively	Entire herds are infested, but an average of 100%, 50% and 20% of the year in high, medium and low incidence herds, respectively	**
Mortalities	No mortalities caused	-	***
Weight loss	Where prevention is applied during infestation, in 25% of these situations there is effective prevention of permanent weight loss, which is 10% over the infestation period	-	*
Fertility	Nil effect	-	*
Market avoidance	Skin lesions cause 10%, 5% and 2% of cattle in high, medium and low incidence herds, respectively, to have net market value reduced by $0.20/kg	Skin lesions cause 10%, 5% and 2% of cattle in high, medium and low incidence herds, respectively, to have net market value reduced by $0.35/kg	*
Movement restrictions	Nil		***
Treatment	As for prevention		**
Prevention	70% of cattle have some form of control applied. An average of $1/animal/month is required for full control. Partial control costs half this.	70% of cattle have some form of control applied. An average of $1.15/animal/month is required for full control. Partial control costs half this. An estimated 17M doses of buffalo control/treatments are	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
		used in northern Australia each year	

Based on these assumptions the annual cost of buffalo fly in cattle in northern Australia is estimated at $162.1M (Table 26).

Table 26: Economic cost of buffalo fly – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$9.77	$5.13	$2.60	$31.15	$8.16	$1.48	**$40.92**	**$13.29**	**$4.09**
Per Herd	$0	$0	$0	$8,581	$4,504	$2,287	$27,350	$7,161	$1,301	**$35,931**	**$11,665**	**$3,588**
Total	**$0M**			**$55.0M**			**$107.1M**			**$162.1M**		

The net gain from moving all northern herds experiencing buffalo fly to the lowest level of infestation is estimated at $119.9M.

Total cost of disease

The total cost of buffalo fly in cattle across Australia is estimated at $170.3M. The 2015 estimate was $98.7M per annum (equivalent to $112.0M in 2022). The net gain from moving all herds to the lowest level of infestation is estimated at $123.7M.

<u>Changes since last report</u>

Buffalo fly is expanding geographically. Fly challenge intensity is greater and challenge periods are longer within endemic areas. Wet years support expansion into drier areas. Chemicals are becoming less effective due to resistance. Integrated pest management approaches are under development but are incomplete to date. High cattle prices have also contributed to the increase in cost estimate.

Buffalo fly was ranked 1st in this report as the costliest disease of the cattle industry. The original ranking in 2015 was 3rd.

4.4.2 Cattle tick

The disease

The one-host cattle tick, *Rhipicephalus microplus*, causes anaemia by virtue of blood sucking. As well, it is the vector for three tick fever organisms in Australia. Ticks favour warm moist conditions in their non-parasitic stage which is between when the engorged female leaves its host to lay eggs, and when larval ticks reattach for their 21-day feeding period. The non-parasitic stage can extend to 7 months. Cattle ticks can also parasitise a wide range of other animal species, including horses. Holroyd *et al.* (Holroyd, Dunster and O'Rourke, 1988) reported that in years with highest tick burdens, Droughtmaster cattle in a dry topical environment were up to 25kg heavier through a reproductive cycle, had conceptions rates up to 30% higher and weaned calves up to 24 kg heavier when tick infestation was fully controlled. Johnston *et al.* (Johnston, Haydock and Leatch, 1981) had previously found average annual live weight effects of <10 kg and no effect on conception rates. Tick control increases annual growth of Brahman cross heifers from weaning to the end of mating at 2.5 years of age by >10 kg without affecting maiden pregnancy rates (Holroyd and Dunster, 1978; Johnston, Haydock and Leatch, 1981). Heifer pregnancies were unaffected by tick control in either study.

	Unknown aetiology									*Known aetiology*
2015									X	
2022									X	

Prevention

Breed, genetics and acaricides are the most frequently used controls. Increasing *Bos indicus* content is associated with higher resistance to tick attachment, but within *Bos indicus* there remains substantial variation in resistance; the heritability is 34% (Mackinnon, Meyer and Hetzel, 1991). However, modern genetic approaches are identifying more genes associated with tick resistance and resilience (Biegelmeyer *et al.*, 2015). White *et al.* (White *et al.*, 2003a) estimated that the effect of ticks on live weight production could be reduced by 60% in Australia by genetic changes alone. The shift away from high grade Brahman cattle is increasing the need for better preventative measures such as vaccines, genetic change and environmental controls. An efficacious first-generation Australian vaccine was available for a short period in the 1990s, but the requirement for regular boosters every few months limited commercial uptake and the vaccine was discontinued (Willadsen, 2008). No new Australian-ready vaccine has become commercially available since then, but research to identify novel vaccine protein candidates that induce longer-lasting and more effective immunity remains ongoing (Mahoney, 2021). Recently discovered immune response differences between resistant and susceptible strains will likely inform future tick vaccine development. There is a long history of ticks acquiring resistance to control chemicals, often within a few decades (Abbas *et al.*, 2014). Integrated controls that include chemical rotation, chemical combinations, genetic selection, vaccination, botanical repellents, pasture rotation and environmental management are increasingly being seen as essential. Sackett *et al.* (Sackett *et al.*, 2006) stated the annual quarantine cost to NSW and Queensland to be $2-7M and <$2M, respectively.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015								X		
2022							X			

Treatment

O'Rourke *et al.* (1992) (O'Rourke, K. Winks and Kelly, 1992) reported that 78% of cattle in high-rainfall regions were treated for ticks, and ~48% of cattle in the balance of the tick zone of northern Australia were treated, with approximately 5% across both regions not treated. Playford (Playford, 2005) reported that $16.8M was spent on acaricides in 2003. Some labour is associated with all treatments. Hide values, currently ~$30, can be reduced by 25% with an average of 20% affected. While treatment is an option it is not considered to be cost effective.

Low efficacy/ unproven treatments available — *Effective treatments available*

2015							X			
2022							X			

Distribution

Dry and cool climate areas combined with tick-free zones restrict the tick and thus the disease to eastern and northern areas of Queensland, Northern Territory and Western Australia. Climate changes will likely expand suitable tick habitat further south within high-rainfall regions — modelling suggests suitable cattle tick habitat will extend into southern Queensland and northern New South Wales (White *et al.*, 2003b). Increasing minimum temperatures also support expansion of *R. microplus*, which is uniquely sensitive to cold (Osbrink *et al.*, 2022). However, extended dry periods — especially when combined with low ground cover — markedly increases larval mortality rates. There is likely to be increased annual variation in tick distribution and cattle challenge from ticks arising from increased climatic variability. This will in turn make economic impacts fluctuate from year to year.

Distribution contracting — *Distribution stable* — *Distribution increasing*

2015					X					
2022						X				

Prevalence

Approximately 45% of Queensland's cattle are within the tick-free zone. There is a low prevalence of ticks in Queensland's endemic tick zones beyond 200 km from the coast following droughts in the 1990's, 2000's and current, where approximately 40% of cattle are reared. There has been limited resurgence of ticks during wetter years where dry seasonal conditions have effectively eliminated populations, however warmer winter nights will support greater *R. microplus* survival.

Prevalence decreasing — *Prevalence increasing*

2015					X					
2022						X				

Economics

Assumptions: Cattle tick (southern)

As tick is restricted to northern Australia, the annual cost of tick in southern Australia is limited to the assumed cost of quarantine and follow-up treatment of $6.0M.

Assumptions: Cattle tick (northern)

Table 27: Assumptions: cattle tick (northern)

Variable	2015 Assumptions	2022 Assumption changes	Confidence
Regional Extent	15%, 15%, 35% and 35% of herds with a high, medium, low and nil incidence	-	***
% herds infected	Infestations of clinical significance occur every year, 2 in 3 years, and in one year in three in high, medium and low incidence regions.	Infestations of clinical significance occur every year, 1 in 2 years, and 1 in 5 years in high, medium and low incidence regions.	**
Mortalities	No mortalities are caused by the tick. Note that tick fever causes loss, and most producers institute treatment to minimise tick impacts.	-	**
Weight loss	Annual weight deficit due to ticks in untreated clinically-affected cattle averages 15 kg.	-	*
Fertility	Conception rates are reduced by 10% in clinically-affected cattle.	-	*
Market avoidance	Clearing of ticks for market access is covered under treatment. 25% of hides have 25% reduced value.	-	**
Movement restrictions	Quarantine zones are in place and cost $1.7M annually to manage in Queensland	Updated to $2M annually	**
Treatment	75%, 50% and 50% of clinically-affected cattle are treated in high, medium and low incidence regions, respectively.	- Treatment and prevention are interchangeable for endemic tick regions	**
Prevention	No specific cost as use of tropically-adapted breeds is primarily based on production potential rather than tick resistance specifically	- An estimated 10M doses is used for combined treatment and prevention control (Zoetis, pers comm)	***

Using these assumptions, demographics and prices the annual cost of cattle tick in northern Australia is estimated to be $128.2M (Table 28).

Table 28: Economic cost of cattle tick – northern

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$11.07	$3.69	$1.48	$0.40	$0.40	$0.40	$25.85	$15.31	$6.37	**$38.05**	**$20.13**	**$8.81**
Per Herd	$9,719	$3,240	$1,296	$353	$353	$353	$22,701	$13,447	$5,596	**$33,410**	**$17,677**	**$7,733**
Total	**$29.6M**			**$2.8M**			**$95.8M**			**$128.2M**		

Total cost of disease

The total cost for cattle across Australia at the current prevalence of disease is estimated at $134.3M per annum (including quarantine costs for southern Australia). The cost estimate from the 2015 report was $161.0M (equivalent to $182.3M today). The net gain from moving all herds experiencing tick infestation to the lowest level of disease is estimated at $66.1M.

Changes since last report

The home range of *R. microplus* is likely to extend southwards which may challenge current tick control lines and threaten tick-free zones. Increasing acaracide resistance combined with an ongoing absence of effective vaccines is partly offset by increased cattle resistance and resilience to ticks, although this is less present in *Bos taurus*, which dominate the south and into which the *R. microplus* home range may extend. A reduction in the frequency of bad tick years in moderate and low risk herds combined with the reduction in herd size has contributed to the reduction in estimated cost of disease.

Cattle tick is ranked 2nd in this report. The original rank from 2015 was also 2nd.

4.4.3 Internal parasites

The disease

Internal strongyle parasites in cattle are primarily a problem up to the age of two years, from which time acquired immunity generally suppresses clinical disease. There has been little published work on production responses since the study of Smeal (Smeal, Nicholls, Robinson, *et al.*, 1981; Smeal, Nicholls, Webb, *et al.*, 1981), where they found an average (but variable) 20-30 kg greater liveweight in 16-20 month animals after a suppressive parasite treatment program (since weaning) when compared to untreated controls. This value is likely to be representative of the maximum gain from effective internal parasite control in high rainfall southern regions compared to no control. Beef heifers in NSW given regular drenches to suppress worms were 28 kg heavier than heifers who were drenched with short acting products but which did not suppress worms at 12 months after weaning (Eppleston, Watt and van de ven, 2016). Taylor (Taylor and Hodge, 2019) found that a single worm treatment of recently weaned *Bos indicus* cross heifers in central Queensland were 8 kg heavier than untreated controls three months after treatments. This is likely representative of northern responses. We estimate that 60% of southern beef cattle are in higher rainfall areas (and therefore under similar parasite challenge to the Smeal study) with 10% in the pastoral zone (and therefore under very low parasite challenge). The equivalent figures for northern Australia are 3% (wet tropics) and 12% in moderate rainfall (parasite non conducive) regions. The remaining cattle in each region are in low rainfall areas and are typically subject to moderate challenge by internal parasites in most years. An analysis of faecal worm egg counts support these geographic distribution assumptions (Taylor and Hodge, 2014). Since the work of Smeal and colleagues in the 1980s there has been increased use and reliance on macrocyclic lactone-based drenches. This has provided greater efficacy in general but may have also hastened the emergence of resistance to this chemical group. Rendell (Rendell, 2010) identified resistance in at least one strongyle species to benzimadazoles (BZ group), levamisole (Lev group) and ivermectin (Mectin group) on 54%, 100% and 62% of investigated properties in south west Victoria. *Ostertagia* species demonstrated the greatest resistance across the chemical groups. Cotter (Cotter, Van Burgel and Besier, 2015) identified resistance to at least one anthelmintic on 17 of 19 Western Australian beef properties. These authors found reduced efficacy for pour-on formulations compared to injectable forms of the same chemical. The emergence of chemical resistance may reduce the efficacy of drenching programs. Dairy studies have identified multi-drug resistance (Mectin, BZs and Lev) on a high proportion of farms in Gippsland, Victoria (Bullen, 2015; Bullen *et al.*, 2016). Similar levels of resistance to liver fluke treatments have also been identified in dairy cattle in Australia (Elliott *et al.*, 2015). Between 30–40M doses of drench product for cattle is estimated used each year (Zoetis, pers comm). Whilst most product is used according to label instructions a proportion is not – either in the wrong class of stock, at the incorrect dose rate or used when a drench is not required. There is also an increasing level of drench resistance reducing drench efficacy and promoting increased drenching frequency. While aetiology of the disease is quite well known, the emergence of resistance, similarity between strongyle eggs and differences between strongyle species in fecundity has increased the need for farm- and mob-level drench resistance testing combined with larval culture to identify the worm species present and evaluate their resistance profiles, and this complicates parasite management. Consideration of the in refugia population is increasingly important for effective internal parasite control and for limiting the emergence and spread of drench resistance. Grazing mobs of exclusively young cattle on dedicated young-stock paddocks is a recognised risk factor for development (and spread) of drench resistance (Sutherland and Bullen, 2015).

Unknown aetiology *Known aetiology*

2015								X		
2022							X			

Prevention

Eliminating worms and preventing re-introduction is not feasible in most high rainfall regions. The parasite challenge is reasonably predictable within regions although preventing the introduction of drench resistance is an emerging challenge for cattle producers. This can be achieved by careful selection of introductions, quarantine and treatment (with effective products) on entry. Strategic worm control programs have been developed and continue to be refined for regions and production systems. Monitoring worm burdens using faecal egg counts is a practical way to assist disease management. Resistance/drench failure (partial or complete) is becoming a more important problem.

Low efficacy/ unproven preventives available *Effective preventives available*

2015							X			
2022						X				

Treatment

There is a range of anthelmintic products however no new chemical group has been identified in the past few decades. Resistance is an emerging problem – primarily of intensification – and combination drenches and/or effective drench rotation systems are required on many properties. There is greater need for monitoring systems to support calendar-based drenching programs.

Low efficacy/ unproven treatments available *Effective treatments available*

2015							X			
2022						X				

Distribution

Most internal parasite problems occur in higher rainfall areas and under more intensive stocking rates. The year-on-year distribution of worms tends to be constant although *Haemonchus* can extend or shrink in distribution each year depending on seasonal temperature and rainfall. While the distribution of parasites is constant, resistant strains may be emerging and expanding.

Distribution contracting *Distribution stable* *Distribution increasing*

2015					X					
2022					X					

Prevalence

The within-herd challenge by internal parasites is a function of region, climate and rainfall, production enterprise, stocking rate and efficacy (including resistance) of drenching program system(s) used. This challenge is stable and predictable on most properties.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: Internal parasites – southern

Table 29: Assumptions: internal parasites – southern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	60% of southern cattle are on properties in higher rainfall regions (> 600 mm per annum) with 10% in the pastoral zone (no requirement for worm control in most years)	-	***
% herds infected	10% of properties experience high levels of disease and production impacts 60% of properties experience moderate levels of disease and production impacts 30% of properties experience low levels of disease and production impacts	-	**
Mortalities	1% in clinical young stock; higher for Type 2 Ostertagiasis (incidence unknown)	-	**
Weight loss	Highly affected: up to 20 kg weight loss in young stock – 10 kg permanent; and 10 kg weight loss in yearlings – 5 kg permanent Moderately affected: up to 10 kg weight loss in young stock – 5 kg permanent; no weight loss in yearlings or older Lowly affected: up to 4 kg weight loss in young stock – 2 kg permanent; no weight loss in yearlings or older	-	*
Fertility	No impact	-	**
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Individual animal treatment not generally practised with control via	-	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	seasonal prevention programs (see below)		
Prevention	Effective control programs require 2 to 3 drenches from weaning to adulthood. Adults do not require drenching. 95% of highly affected properties average 4 drenches per year in young stock 75% of moderately affected properties average 4 drenches per year in young stock 30% of lowly affected properties average 1-2 drenches per year in young stock	Effective control programs require 3 to 4 drenches from weaning to adulthood. Adults do not require drenching. 95% of highly affected properties average 5 drenches per year in young stock 75% of moderately affected properties average 5 drenches per year in young stock 30% of lowly affected properties average 2-3 drenches per year in young stock	***

Based on these assumptions the annual cost of internal parasites in cattle in southern Australia is estimated at $99.9M (Table 30).

Table 30: Economic cost of internal parasites – southern (cattle)

	Treatment[3]			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$3,619	$1,960	$1,206	$1,605	$1,317	$1,186	**$5,225**	**$3,277**	**$2,393**
Per Herd	$0	$0	$0	$19.78	$10.71	$6.59	$8.77	$7.19	$6.48	**$28.55**	**$17.91**	**$13.07**
Total	**$0M**			**$59.2M**			**$40.7M**			**$99.9M**		

The net gain from moving all southern herds to the lowest level of disease is estimated at $25.4M.

Assumptions: Internal parasites - northern

Table 31: Assumptions: internal parasites – northern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	15% of northern cattle are on properties in higher rainfall regions (> 600 mm per annum) with 85% in the low-rainfall zone (no requirement for worm control in most years)	-	***

[3] All costs have been assigned to prevention

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
% herds infected	3% of properties experience high levels of disease and production impacts 12% of properties experience moderate levels of disease and production impacts 85% of properties experience low levels of disease and no significant production impacts	-	**
Mortalities	0.5% in clinically-affected young stock, higher for Type 2 Ostertargiasis (incidence unknown)	-	**
Weight loss	Highly affected: up to 20 kg weight loss in young stock – 10 kg permanent; and 10 kg weight loss in yearlings – 5 kg permanent Moderately affected: up to 10 kg weight loss in young stock – 5 kg permanent; no weight loss in yearlings or older Lowly affected: no effect	-	*
Fertility	No impact	-	**
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Individual animal treatment not generally practised with control via seasonal prevention programs (see below)	-	**
Prevention	Effective control programs require 4 to 6 drenches from weaning to adulthood. Adults do not require drenching. 80% of highly affected properties average 4 drenches per year in young stock 65% of moderately affected properties average 4 drenches per year in young stock 50% of lowly affected properties average 1-2 drenches per year in	Effective control programs require 5 to 6 drenches from weaning to adulthood. Adults do not require drenching. 80% of highly affected properties average 4.5 drenches per year in young stock 65% of moderately affected properties average 4.5 drenches per year in young stock	***

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	young stock – despite no scientific evidence that they are required	50% of lowly affected properties average 2-3 drenches per year in young stock Increased use of drench resistance testing is included	

Based on these assumptions the annual cost of internal parasites in cattle in northern Australia is estimated at $19.7M (Table 32).

Table 32: Economic cost of internal parasites – northern (cattle)

	Treatment[4]			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$4.80	$2.34	$1.22	$3.01	$1.56	$0.09	**$7.81**	**$3.90**	**$1.31**
Per Herd	$0	$0	$0	$4,211	$2,055	$1,069	$2,644	$1,366	$78	**$6,855**	**$3,421**	**$1,147**
Total	**$0M**			**$15.8M**			**$3.8M**			**$19.7M**		

The net gain from moving all northern herds to the lowest level of disease is estimated at $5.5M.

Total cost of disease

The total cost of internal parasites in cattle across Australia at the current prevalence of disease is estimated at $119.5M. The 2015 estimate was $93.6M per annum (equivalent to $106.2M in 2022). The net gain from moving all Australian herds to the lowest level of disease is estimated at $30.8M with most of this potential gain in southern Australia.

It should be noted that over-treatment of stock (resulting in financial losses from excess drench costs) may be present. The total cost of disease to the industry is only slightly more than the total spent on drench by producers. Therefore, the marginal economic response from extra drench may not be profitable in all cases. Increased use of drench resistance testing and larval culture to determine drench effectiveness is likely to expand into the future.

<u>Changes since last report</u>

Increasing resistance of both worm and fluke species to chemicals combined with an absence of new treatment chemicals[5] is increasing the impact and cost of internal parasites. Increasing use (and cost) of drench resistance testing has been included in prevention costs.

Internal parasites are ranked 3rd in this report. The original 2015 report ranked internal parasites as 6th.

[4] All costs have been assigned to prevention

[5] New products are often combinations of pre-existing chemical treatments

4.4.4 Neonatal calf mortality of unknown cause

The disease

Beef CRC data has confirmed that in northern Australia, about 2/3rd of foetal and calf loss occurs within a week of birth (Bunter *et al.*, 2013), but 1/3rd in southern Australia (Copping *et al.*, 2014). The aetiology of several percentage units is known and includes: reproductive diseases such as vibriosis and BVDV (Fordyce *et al.*, 2014) across Australia, and Neosporosis in southern Australia (Atkinson *et al.*, 2000); animal factors such as udder conformation (Bunter *et al.*, 2013) and dystocia, especially in heifers; losses associated with cow mortality which is primarily associated with available nutrition and the physiological state of the cow as reflected in body condition and stage of the reproductive cycle (Fordyce *et al.*, 2014). The aetiology of neonatal loss in excess of ~5-10% has remained largely unknown in northern Australia, though recent research has shown the major risk factors to be behavioural, nutritional and environmental (Fordyce *et al.*, 2014). Cow risk factors include breed, age, parity, multiple birth and body condition (Mansell *et al.*, 2021). Insufficient milk production and delivery and inadequate calf suckling are hypothesised to be how these risk factors mediate their effect (*Boosting calf survival | Meat & Livestock Australia*, no date). Pathogens such as causes of calf scours often interact with environmental conditions (e.g. lack of shelter, exposure) to increase risk (Mansell *et al.*, 2021). High neonatal mortality can indicate poor animal welfare conditions for the herd are present.

	Unknown aetiology									*Known aetiology*
2015		X								
2022			X							

Prevention

Prevention of high neonatal calf mortality rates with unknown cause may be achieved through managing nutritional and environmental factors, but this has not been demonstrated.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015		X								
2022			X							

Treatment

A small percentage of these calves are rescued and are hand-reared

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015					X					
2022					X					

Distribution

Calf loss of unknown cause is probably widespread, matching the prevalence of the risk factors, but has rarely been measured as it was in the Beef CRC and Cash Cow projects.

Distribution contracting — *Distribution stable* — *Distribution increasing*

2015					X					
2022					X					

Prevalence

In addition to losses due to cow mortality, median reproductive wastage (two thirds of which occurs in the neonatal period) in northern Australia varies from 5-16% depending on region and cow age (Fordyce *et al.*, 2014). Northern studies indicate that calf losses average around 7% (composed of approximately 3% within 48 hours of birth and another 4% to weaning), but with a range extending to beyond 30% (Chang, Swain and Trotter, 2020). There was a strong regional effect, with highest losses seen in regions of low soil fertility. Cows with low phosphorous soils have difficulty maintaining weight and in lactating, which contributes to calf mortality (Dixon *et al.*, 2017). Data from southern Australia (Copping *et al.*, 2014) suggests that calf loss levels and variation may not be dissimilar to that in Queensland's southern forest.

Prevalence decreasing — *Prevalence increasing*

2015					X					
2022					X					

Changes since last report

More information on risk factors has become available (especially perinatal lactation and the role of phosphorous), but no new interventions have been identified

Economics

Assumptions: Neonatal calf mortality of unknown cause - southern

Table 33: Assumptions: neonatal calf mortality of unknown cause – southern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	100% of herds with a low prevalence rate	-	**
% herds infected	An average of 2% of pregnancies are affected annually	-	*
Mortalities	Calf mortality is associated with each incident	-	***
Weight loss	No temporary weight loss	-	***
Fertility	Affected cows have usual re-conception rates	-	***
Market avoidance	No market impact	-	***
Movement restrictions	Nil	-	***

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Treatment	Treatment rarely used	-	***
Prevention	No controls have been developed	-	***

Based on these assumptions the annual cost of neonatal calf mortality of unknown cause in cattle in southern Australia is estimated at $32.1M (Table 34).

Table 34: Economic cost of neonatal calf mortality of unknown cause – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$	$0	$0	$0	$0	$0	$5.60	**$0.00**	**$0.00**	**$5.60**
Per Herd	$0	$0	$0	$0	$0	$0	$0	$0	$1,031	**$0**	**$0**	**$1,031**
Total	**$0M**			**$0M**			**$32.1M**			**$32.1M**		

There is no predicted net gain from moving all southern herds experiencing neonatal calf mortality of unknown cause to the lowest level of disease.

Assumptions: Neonatal calf mortality of unknown cause – northern

Table 35: Assumptions: neonatal calf mortality of unknown cause – northern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	30%, 20% and 50% of herds with a high, medium and low prevalence rate	-	***
% herds infected	An average of 4.2%, 3.3%, and 2.4% of pregnancies are affected annually in high, medium and low incidence herds, respectively	-	***
Mortalities	Calf mortality is associated with each incident	-	***
Weight loss	No temporary weight loss	-	***
Fertility	90% of affected cows reconceive, which is often higher than usual rates	-	***
Market avoidance	No market impact	-	***
Movement restrictions	Nil	-	***
Treatment	Treatment rarely used	-	***
Prevention	No controls have been developed	-	***

Based on the adopted prevalence and impacts of the disease on the classes of animals affected, GHD has calculated the annual cost of neonatal calf mortality of unknown cause in cattle in northern Australia at $42.1M (Table 36).

Table 36: Economic cost of neonatal calf mortality of unknown cause – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$0	$0	$0	$5.22	$4.10	$2.98	**$5.22**	**$4.10**	**$2.98**
Per Herd	$0	$0	$0	$0	$0	$0	$4,583	$3,601	$2,619	**$4,583**	**$3,601**	**$2,619**
Total	**$0M**			**$0M**			**$42.1M**			**$42.1M**		

The net gain from moving all northern herds experiencing neonatal calf mortality of unknown cause to the lowest level of disease is estimated at $9.7M.

Total cost of disease

The total cost of calf mortality of unknown cause in cattle across Australia at the current prevalence is estimated at $74.2M per annum. The 2015 estimate was $96.2M (equivalent to $109.2M in 2022). The net gain from moving all northern herds to the lowest level of disease is estimated at $9.7M.

Changes since last report

Changes arise due to changes in herd demographics and prices; there is no fundamental change in incidence of calf mortality between reports.

Neonatal mortality ranks 4th in this report. The original 2015 ranking was 5th.

4.4.5 Dystocia

The disease

Dystocia is most commonly due to foetal-maternal incompatibility – the foetus is too large (relatively or absolutely) to fit through the dam's pelvis – but may also occur due to malpresentation of the foetus. A northern Australian study found that every 1.0 kg increase in calf birth weight (average birth weight 30.8 kg) increased risk of dystocia by 1.4 times (Perry, 2008). Less commonly dystocia is secondary to other disease such as milk fever and malformation of the calf. Foetal-maternal incompatibility is the most important cause of dystocia in Australia occurring predominately in primiparous heifers and arising due to mismating (heifer too small, poor bull selection), overlong gestations and/or (most commonly) inadequate nutrition in growing pregnant heifers. Protein supplementation in the second trimester of pregnancy in northern cattle increased birthweights by 2.2 kg (33.0 kg c.f. 30.8 kg), resulting in a three-fold increase in dystocia risk (Perry, 2008). Phosphorous-deficient cows were lighter at calving and lost more body weight after calving than phosphorous-supplemented cows (Dixon *et al.*, 2017). Male calves are 10% heavier than female calves on average.

A 2000 survey of dystocia in Angus heifers reported an incidence of around 5.0% in heifers enrolled in controlled (growth-rate selective) breeding programs and an incidence of approximately 10.0% in uncontrolled mating. The incidence of dystocia in mature cows is low – an estimated maximum of 2% is assumed. The survival of calves to weaning following a difficult calving has been estimated to be 12% less than calves born normally.

For northern Australia we have assumed a lower average incidence of dystocia – 2.0% of heifers and 0.3% of cows — but it should be noted that individual studies have identified dystocia rates of around 5–10% in *Bos indicus* heifers and some groups of cattle (McGowan *et al.*, 2014). We have assumed fewer inspections of calving cows in the northern industry and subsequently all dystocic calves and around 25% of dams die following unaided dystocia.

The cause of the disease and predisposing risk factors are well known. Viral causes of arthrogryposis such as Akabane virus that can result in malpresentation may vary in incidence and distribution from year to year but are generally minor causes. Nutrition of the dam – especially yearlings and heifers – and during late gestation strongly influences maternal-foetal mismatch. Under-nutrition is the major predisposing factor for dystocia in northern animals.

	Unknown aetiology									*Known aetiology*
2015									X	
2022									X	

Prevention

Prevention of the majority of dystocia due to foetal-maternal mismatch is well known (Fordyce, Burns and Holroyd, 2006). Mating well-grown heifers (at or beyond Critical Mating Weight for the breed) to low birthweight bulls (high Calving Ease Direct and high Calving Ease Daughter Estimated Breeding Values)[6] combined with adequate supervised nutrition throughout pregnancy are key controls (Fordyce, Burns and Holroyd, 2006). Heifers on low energy diets between weaning and breeding had higher dystocia rates than heifers on high-energy diets (Norman, 2006). Good nutrition in the first two trimesters reduces the incidence of dystocia in heifers. Selecting an appropriate

[6] See https://breedplan.une.edu.au/understanding-ebvs/understanding-calving-ease-ebvs/

joining date for controlled breeding and ensuring maiden heifers are at least at critical mating weight are important management controls (Meat & Livestock Australia, no date). Foetal-maternal mismatch provides significant animal welfare challenges. The cost of preventing dystocia through selective genetics, including crossbreeding (Prayaga, 2004), and better nutrition has not been assigned as the benefits from these practices extend beyond just dystocia prevention. Dystocia due to foetal-maternal mismatch can be controlled by good management.

Low efficacy/ unproven preventives available … *Effective preventives available*

2015									X	
2022									X	

Treatment

Regular inspection of calving cattle combined with judicious assistance is an essential component of good animal husbandry. Veterinary assistance is occasionally required. A daily inspection cost at calving has been assigned to prevention. Assistance should be administered early enough to ensure a live calf can be delivered. This needs to be balanced against not intervening too early, especially in heifers.

Low efficacy/ unproven treatments available … *Effective treatments*

2015								X		
2022								X		

Distribution

All beef cattle are at risk of dystocia. Intensification of production systems is leading to more disease.

Distribution contracting … *Distribution stable* … *Distribution increasing*

2015					X					
2022					X					

Prevalence

The average prevalence of dystocia is assumed at 5% for southern heifers and <1% for southern cows, for which assistance is required in one in ten cases. Mortality of calves born to difficult calving is assumed to be 12% greater than background mortalities. Mortality in the dam is assumed at 0.5% of cases. Average dystocia prevalence is estimated at 10% for northern heifers and 1% for northern cows (Brown, Towne and Jephcott, 2006), with 80% of heifer deaths attributed to dystocia (Norman, 2006).

Prevalence decreasing … *Prevalence increasing*

2015					X					
2022					X					

Economics

Assumptions: Dystocia – southern

Table 37: Assumptions: dystocia – southern (cattle)

Variable	2015 Assumptions	2022 Assumption changes	Confidence
Regional Extent	All beef herds are at risk of dystocia – malpresentation can occur in any animal	-	***
% herds infected	5% of southern herds experience large-scale dystocia problems: up to 25% of heifers and 2% of mature cows experiencing dystocia 10% of southern herds experience moderate problems: up to 10% of heifers and 1% of mature cows experiencing dystocia 85% of southern herds experience minor problems: up to 5% of heifers and 0.5% of mature cows experiencing dystocia	-	**
Mortalities	A 1% cow mortality rate is assumed. The mortality rate of calves born to dystocic births is 12% higher than for non-dystocic births.	-	**
Weight loss	A 10kg and 5kg average temporary weight loss is assumed in dystocic heifers and cows respectively. There is an additional 5 kg weight loss assumed for dystocic heifers.	-	*
Fertility	No further impacts beyond direct mortalities listed above	-	*
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Treatment is by manual assistance to calve by the farmer (pull – costed at $50) with a 10% of cases being serviced by veterinarians (costed at $350). This provides an average cost of $80 per assisted dystocia with	Treatment is by manual assistance to calve by the farmer (pull – costed at $55) with a 10% of cases being serviced by veterinarians (costed at	**

Variable	2015 Assumptions	2022 Assumption changes	Confidence
	90% of southern cattle experiencing dystocia being detected and assisted.	$800). This provides an average cost of $130 per assisted dystocia with 90% of southern cattle experiencing dystocia being detected and assisted.	
Prevention	Daily inspections costs have been assigned to prevention. Twice daily inspection at calving is assumed for herds with severe problems and once daily for others.		**

The estimated cost of dystocia in cattle in southern Australia is $38.1M (Table 38).

Table 38: Economic cost of dystocia – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$5.37	$2.23	$1.12	$10.88	$4.23	$3.02	$6.34	$2.59	$1.30	**$22.59**	**$9.06**	**$5.44**
Per Herd	$989	$411	$205	$2,003	$779	$556	$1,166	$477	$239	**$4,157**	**$1,667**	**$1,000**
Total	**$8.3M**			**$20.3M**			**$9.6M**			**$38.1M**		

The net gain from moving all southern herds to the lowest dystocia prevalence band is estimated at $7.0M per annum.

Assumptions: Dystocia – northern

Table 39: Assumptions: dystocia – northern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	All beef herds are at risk of dystocia – malpresentation can occur in any animal	-	***
% herds infected	5% of northern herds experience large-scale dystocia problems: up to 20% of heifers and 2% of mature cows experiencing dystocia 15% of northern herds experience moderate problems: up to 10% of	-	*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	heifers and 1% of mature cows experiencing dystocia 85% of northern herds experience minor problems: up to 5% of heifers and 0.5% of mature cows experiencing dystocia		
Mortalities	A 25% heifer and 10% cow mortality rates are assumed. The mortality rate of calves born to dystocic births is assumed twice that of southern herds due to the lower assistance rate in the north (24% higher than for non-dystocic births).	-	*
Weight loss	An average of 5kg temporary and 5kg permanent weight loss is assumed in dystocic heifers that survive. No weight loss is assumed for dystocic cows that survive.	-	*
Fertility	No further impacts beyond direct calf mortalities listed above	-	*
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Treatment is by manual assistance by the farmer or veterinarian. An average cost of $50 per dystocia is assumed (non-veterinary ‘pulls’ only) but only 5% (severe), 2% (moderate) and 1% (low) of dystocia cases are detected and/or assisted in each of the three herd prevalence levels in the north.	Treatment is by manual assistance by the farmer or veterinarian. An average cost of $55 per dystocia is assumed (non-veterinary ‘pulls’ only) but only 5% (severe), 2% (moderate) and 1% (low) of dystocia cases are detected and/or assisted in each of the three herd prevalence levels in the north.	*
Prevention	Daily inspections costs have been assigned to prevention. Twice daily inspection at calving is assumed for herds with severe problems	-	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	and once daily for others. However, only 10% (severe), 3% (moderate) and 1% (low) affected herds use once daily inspections.		

The annual cost of dystocia in cattle in northern Australia is estimated at $37.3M (Table 40).

Table 40: Economic cost of dystocia – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0.14	$0.03	$0.01	$0.52	$0.16	$0.05	$9.80	$4.91	$2.45	**$10.46**	**$5.09**	**$2.51**
Per Herd	$127	$25	$6	$457	$137	$46	$8,633	$4,323	$2,162	**$9,217**	**$4,485**	**$2,214**
Total	**$0.2M**			**$1.0M**			**$36.1M**			**$37.3M**		

The net gain from moving all northern herds to the lowest dystocia prevalence band is estimated at $8.5M; although this may not be practically achieved due to difficulties of inspection and handling of the majority of dystocic animals in the northern environment.

Total cost of disease

The total cost of dystocia in cattle across Australia at the current prevalence of disease is estimated at $75.4M per annum. The 2015 estimate of loss was $97.8M (equivalent to $111.0M in 2022). The net gain from moving all herds (northern and southern) to the lowest dystocia prevalence band is estimated at $15.5M.

<u>Changes since last report</u>

Minimal changes, mostly due to demographic and prices changes since 2015.

Dystocia ranks 5th in this report. The original 2015 report also ranked dystocia 6th.

4.4.6 Bovine viral diarrhoea virus (BVDV or pestivirus)

The disease

Various strains of Type 1 BVDV (a pestivirus) are present and widespread and have probably been in Australia for as long as cattle have been here, but the more virulent Type 2 strain has not been identified here to date. BVDV impacts reproduction, growth rates, morbidity and mortality in grazing beef cattle. This contagious virus is mainly spread by direct contact with persistently infected (PI) cattle. Border Disease Virus (BDV), a related pestivirus predominately affecting sheep, is also able to infect cattle and can produce PI calves (Braun *et al.*, 1997), and this may ultimately limit cattle BVDV control and eradication program effectiveness. BVDV can also infect deer and pigs. The major problems arising from infection are conception failure, early-pregnancy abortion, and mortality of PI calves of which approximately 50% die by weaning age, and approximately 50% of surviving calves die annually thereafter (McGowan, Kirkland, Richards, *et al.*, 1993; McGowan, Kirkland, Rodwell, *et al.*, 1993; Kirkland *et al.*, 1990). A study of feedlots identified 0.24% of cattle as PIs (Hay *et al.*, 2016). This is similar to US feedlot studies (Guy H. Loneragan *et al.*, 2005), and suggests that around 1% of beef calves born in Australia are PIs. The virus has a predilection for the immune system, and this may increase the incidence of other diseases when animals are experiencing transient infection. Non-PI feedlot cattle who were exposed to a PI in nearby pens had approximately double the 50-day incidence risk for Bovine Respiratory Disease (BRD) by day 50 compared to non PI-exposed cattle (Hay *et al.*, 2016). This is also similar US feedlot findings (G. H. Loneragan *et al.*, 2005). McGowan (McGowan *et al.*, 2014) reported the average percentage of cattle pregnant within 4 months of calving was 57%, 43% and 34% in north Australian herds with <20%, 20-80% and >80% of cows sero-positive to BVDV, respectively. Prevalence of >30% of recent BVDV infection in early-mid pregnant cows was associated with almost 10% higher foetal and calf loss than in herds with <10% prevalence of recent infection, also reported by Kirkland (Kirkland *et al.*, 2012) and Morton (Morton *et al.*, 2013). Modelling of BVDV epidemiology in Australia and the known incidence of PI animals suggests that, depending on the relative prevalence of BVDV strains with varying abortigenic effect, between 0.5–1.0% of susceptible cattle become infected each day (McGowan *et al.*, 2020). So, on average, 1% of breeding females will experience failed conception or early embryonic loss with another 1.5% producing a PI foetus because of BVDV infection during mating/pregnancy. The consequence of 2.5% of breeding female affected each mating period is a reduction in weaning rate of 1–2% each year attributable to BVDV. Recent dynamic modelling of disease in Australian beef herds supports use of this average, although this study found actual reductions fluctuate depending upon the stage of the infection cycle within the herd (Fountain *et al.*, 2021). However, the cyclical nature of BVDV infection dynamics results in wide fluctuations around these averages. Economic studies have highlighted the large difference between mean and median impacts of BVDV on herd financial performance (Stott, Humphry and Gunn, 2010; Stott and Gunn, 2017). The key point is that most endemically infected herds experience modest impacts in most years, but a small number of herds may experience a major impact in any given year, as reflective of the variable disease dynamics. BVDV economists recommend using risk of large-scale loss as a more meaningful way to communicate impact of BVDV to producers that the long-term average (often modest) annual loss. Some live export market protocols require freedom from BVDV and/or no evidence of this disease being recently transmitted within the source herd. Others describe optimal (maximum) net benefit from control occurs when the marginal benefits exceed the marginal mitigation costs (Pinior *et al.*, 2017).

	Unknown aetiology									*Known aetiology*
2015										X

2022									X	

Prevention

A range of strategies is used to control infection and impacts. These include identifying immune animals and PIs using the large range of diagnostic tests available, biosecurity to prevent movement of PIs and or to identify movement of unborn PIs, and strategic use of a killed vaccine with efficacy of ~80% which is registered for use in Australia (Bergman and Reichel, 2014). The vaccine may increase pregnancy rates by reducing early pregnancy infections. The vaccine has a retail cost of $5-6/dose, requires two initial injections, and may be recommended for annual use in some herds. An average of ~0.75M and ~1M doses of vaccine are sold annually in northern and southern Australia in the early 2020s (Zoetis, pers comm).

Low efficacy/ unproven preventives available — *Effective preventives available*

2015							X			
2022							X			

Treatment

No specific treatment exists for BVDV.

Low efficacy/ unproven treatments available — *Effective treatments available*

2015	X									
2022	X									

Distribution

A recent feedlot study identified 0.24% of intake as being PIs, although 32% of intake batches contained at least one PI (Hay *et al.*, 2016). This is less than the original report, but similar to findings from US feedlots (G. H. Loneragan *et al.*, 2005).

Distribution contracting — *Distribution stable* — *Distribution increasing*

2015					X					
2022					X					

Prevalence

McGowan *et al.* (2014) reported that 15-21%, 39-50% and 35-40% of north Australian cow herds had prevalence of cows sero-positive to BVDV of <20%, 20-80% and >80%, respectively; recent infection was found in 4-16% of cow herds. St George (St George *et al.*, 1967) had previously reported that 61% of Australian cattle were seropositive and 79% of herds infected, indicating little change in prevalence in 45 years. Both Kirkland (Kirkland *et al.*, 2012) and Morton (Morton *et al.*, 2013) also reported a low proportion of cattle herds having recent BVDV infection. Both groups reported that half the herds they studied had 0-30% sero-positive animals, indicating high susceptibility to the virus.

Prevalence decreasing — *Prevalence increasing*

2015						X				
2022						X				

Economics

Assumptions: Bovine viral diarrhoea virus – southern

Table 41: Assumptions: Bovine viral diarrhoea virus – southern

Variable	2015 Assumptions	2022 Assumption changes	Confidence
Regional Extent	30%, 40%, 10% and 20% of herds with a high, medium, low and nil prevalence rate	Whilst the seroprevalence estimates of 2015 are unchanged, the proportion of herds experiencing disease (i.e. active infections during mating) were set to 5%, 50%, 40% and 5% of herds with a high, medium, low and nil prevalence rate. This gives an industry-level PI birth rate of 1% and 0.25% of mated females do not calve due to BVDV	**
% herds infected	An average of 6%, 3%, 0.3% and 0% of cows are naïve and infected in the first trimester of pregnancy annually in high, medium, low and nil incidence herds, respectively; pro rata reduction applied for vaccinated cattle. The consequence is that ~0.75% of cattle at 18 months of age are PIs.		**
Mortalities	50% mortality of PIs as weaners and then annually	-	***
Weight loss	No temporary weight loss	-	***
Fertility	Half of the cows infected in the first trimester abort	-	***
Market avoidance	No PIs exported for breeding	-	***
Movement restrictions	Nil	-	***
Treatment	No treatment available	-	***
Prevention	Vaccination of all cattle in 15% of herds, and heifers only vaccinated in 30% of herds	7% herds vaccinate all cows, 10% of herds just vaccinate heifers (0.9 M doses used per annum)	**

Based on these assumptions the estimated annual cost of BVDV in cattle in southern Australia is $36.2M (Table 42).

Table 42: Economic cost of bovine viral diarrhoea virus – southern

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$2.00	$0.72	$0.32	$14.84	$7.42	$3.27	**$16.83**	**$8.14**	**$3.59**
Per Herd	$0	$0	$0	$365	$132	$59	$2,715	$1,358	$599	**$3,081**	**$1,490**	**$657**
Total	**$0M**			**$3.4M**			**$32.8M**			**$36.2M**		

The net gain from moving all southern herds experiencing BVDV to the lowest level of disease is estimated at $16.7M.

Assumptions: Bovine viral diarrhoea virus – northern

Table 43: Assumptions: bovine viral diarrhoea virus – northern (cattle)

Variable	2015 Assumptions	2022 Assumption changes	Confidence
Regional Extent	30%, 40%, 10% and 20% of herds with a high, medium, low and nil prevalence rate	Whilst the seroprevalence estimates of 2015 are unchanged, the proportion of herds experiencing disease (i.e. active infections during mating) were set to 5%, 50%, 40% and 5% of herds with a high, medium, low and nil prevalence rate. This gives an industry-level PI birth rate of 1% and 0.25% of mated females do not calve due to BVDV	**
% herds infected	An average of 6%, 3%, 0.3% and 0% of cows are naïve and infected in the first trimester of pregnancy annually in high, medium, low and nil incidence herds, respectively; pro rata reduction applied for vaccinated cattle. The consequence is that ~0.75% of cattle at 18 months of age are PIs.		**
Mortalities	50% mortality of PIs as weaners and then annually		***

Variable	2015 Assumptions	2022 Assumption changes	Confidence
Weight loss	No temporary weight loss		***
Fertility	Half of the cows infected in the first trimester abort		***
Market avoidance	No PIs exported for breeding		***
Movement restrictions	Nil		***
Treatment	No treatment available		***
Prevention	Vaccination of all cattle in 3% of herds, and heifers only vaccinated in 15% of herds	2.5% herds vaccinate all cows, 5% of herds just vaccinate heifers (0.7 M doses used per annum)	**

Based on the adopted prevalence and impacts of the disease on the classes of animals affected, GHD has calculated the annual cost of BVDV in cattle in northern Australia at $31.8M (Table 44).

Table 44: Economic cost of bovine viral diarrhoea virus – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$0.76	$0.29	$0.17	$6.87	$3.48	$1.66	**$7.68**	**$3.80**	**$1.87**
Per Herd	$0	$0	$0	$652	$251	$150	$5,926	$3,001	$1,434	**$6,576**	**$3,226**	**$1,565**
Total	**$0M**			**$5.6M**			**$29.6M**			**$31.8M**		

The net gain from moving all northern herds experiencing BVDV to the lowest level of disease is estimated at $13.4M.

Total cost of disease

The total cost of BVDV in cattle across Australia at the current prevalence of disease is estimated at $67.9M per annum. The 2015 estimate of total industry loss was $142.4M (equivalent to $161.6M in 2022). The industry benefit from moving all herds experiencing BVDV to the lowest level of disease is estimated at $30.1M. Whilst this is a seemingly large reduction in cost of disease, it is not due to any change in disease incidence but arises from increased information on the prevalence of naïve females of breeding age within herds.

BVDV impact is uneven; the average herd cost rarely occurs. This is because an economically serious outbreak requires the combination of virus to be circulating through a naïve population of breeding females during or shortly after mating. This produces large-scale foetal infections leading to pregnancy loss and birth of PI calves, that rarely make market. This is impactful when it occurs. However, in herds where pregnancy diagnosis is routinely performed, breeders which experience embryonic loss are usually culled and the impact of pregnancy loss can be minimised. The highly affected herds had more than five times the loss of the lowly-affected herd. Herd managers need to consider the cost-benefit of control (as presented here), the reduction in risk of a major outbreak and the ongoing management challenge of preventing spread of virus in the herd when deciding if vaccination is the right strategy for their herd.

Changes since last report

The role of BDV in the maintenance and spread of BVDV into and within the cattle population has not been clarified; this has importance should Australia consider a BVDV eradication program which is highly unlikely in a national herd where whole herd musters can't be guaranteed and with only 80% efficacy of the current vaccine. Refinements downwards in the estimate of the number of naïve mated females has reduced reproductive and PI calf losses estimated. This has subsequently reduced the estimated cost of disease. The circulation of BVDV within the Australian cattle population is essentially unchanged since the original report.

BVDV is ranked 6th in this report. The original 2015 ranking for BVDV was 2nd.

4.4.7 Bloat (southern)

The Disease

Bloat is the excessive accumulation of gases of fermentation in the rumen. This, if unable to be eructated, can lead to abdominal distension and development of clinical signs of pain, respiratory and circulatory distress, collapse and in severe cases death. The most common cause of bloat in pastured cattle is due to formation of a stable froth in the rumen following rapid digestion of lush legumes with high digestible protein and low fibre (frothy bloat) (*Bloat | Meat & Livestock Australia*, no date). A recent online survey of southern beef producers found 70% of responders had identified at least one case of bloat on their property in the previous 12 months, with 35% reporting death and 31% reporting lost production as outcomes (*Bloat Survey Summary - Charles Sturt University*, 2021). Only 21% of respondents reported bloat as a rare event. Risk factors reported in the survey included: high clover or lucerne content of pastures. Most bloat was reported in the June to October period, with a peak in September. Bloat is a disease of intensification – improved clover-based pastures and use of leguminous crops such as lucerne are risk factors. High rainfall regions are most prone to bloat. Approximately half of southern cattle are held in regions that can produce pasture bloat under the right circumstances. A survey of a high-risk region found an annual prevalence of 3%.

	Unknown aetiology									*Known aetiology*
2015								X		
2022								X		

Prevention

Controlling access to at-risk pastures (strip grazing, hay supplementation etc.), use of bloat capsules (when available in the market) and vigilance all contribute to control. The Charles Sturt University survey reported that 70% of respondents regularly used preventive measures such as roughage supplements, bloat blocks, loose licks or liquids and bloat oil applied either to pasture or drinking water and limiting access to high-risk pastures and crops (*Bloat Survey Summary - Charles Sturt University*, 2021). Preventives are less effective under heavy challenge and outbreaks can occur suddenly with heavy losses. Most surveyed producers are seeking improved tools for control of bloat.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015							X			
2022							X			

Treatment

Treatment requires release of rumen gases – by natural means, stomach tube or rumen incision. Mild cases may be treated by gently walking to safe pastures. However, treatment is generally not possible as most severe cases are found dead. Treatment is also costly and time consuming. See (NSW Department of Primary Industries, 2014) for a summary of bloat treatments and preventives.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015		X								
2022		X								

Distribution

High rainfall areas with leguminous and productive pastures are high risk. Approximately 50% of southern cattle are in high rainfall regions.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

Prevalence is generally constant – but is influenced by season and feedbase (and availability of bloat capsules).

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: Bloat – southern

Table 45: Assumptions: bloat – southern

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	50% of southern beef herds are within the high rainfall area affected by bloat	-	**
% herds infected	5% of southern herds experience large-scale outbreaks: up to 15% of ruminants affected (not unweaned calves). 10% of southern herds experience moderate outbreaks: up to 5% of ruminants affected (not unweaned calves). 35% of southern herds experience minor outbreaks: up to 3% of ruminants affected (not unweaned calves). 50% of southern herds experience no disease	-	**
Mortalities	A 25% mortality rate has been assumed for clinical bloat	-	**
Weight loss	No weight loss, fertility or other production effects are assumed;	-	*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	all production losses are due to deaths.		
Fertility	Nil	-	***
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Treatment is by movement of moderately affected animals to safe pasture, stomach tubing/stabbing of severe cases; veterinary assistance is required for some stabbed cases. Only 50%, 25% and 10% of cases on severe, moderate and lowly affected herds are found and treated before death or self-resolution. An average cost of $50 per treated case has been assumed.	Treatment is by movement of moderately affected animals to safe pasture, stomach tubing/stabbing of severe cases; veterinary assistance is required for some stabbed cases. Only 50%, 25% and 10% of cases on severe, moderate and lowly affected herds are found and treated before death or self-resolution. An average cost of $60 per treated case has been assumed.	***
Prevention	Prevention is by hay feeding and grazing management. Bloat capsules (when available) are used in a proportion of herds. An annual prevention cost of $25/ dose is assumed with 75%, 50% and 25% of highly, moderately and lowly affected herds applying active prevention. We have not costed losses from forced avoidance of high-risk pastures/crops. These are too difficult to estimate with accuracy and lead to questions of suitability of the farming system.	Prevention is by hay feeding and grazing management. Bloat capsules (when available) are used in a proportion of herds. An annual prevention cost of $27.50/ dose is assumed with 75%, 50% and 25% of highly, moderately and lowly affected herds applying active prevention. We have not costed losses from forced avoidance of high-risk pastures/crops. These are too difficult to estimate with accuracy and lead to questions of suitability of the farming system.	***

Based on these assumptions the annual cost of bloat in cattle in Australia is estimated at $66.8M. The 2015 estimate was $76.8M (equivalent to $87.2M in 2022) (Table 46).

Table 46: Economic cost of bloat – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$4.50	$0.76	$0.18	$20.63	$6.88	$2.75	$0.65	$0.22	$0.13	**$81.72**	**$26.65**	**$14.39**
Per Herd	$819	$138	$33	$3,754	$1,251	$501	$119	$40	$24	**$14,873**	**$4,850**	**$2,619**
Total	**$2.1M**			**$15.2M**			**$49.6M**			**$66.8M**		

The net gain from moving all southern herds experiencing bloat to the lowest level of disease is estimated at $26.0M.

Changes since last report

No change to the incidence or distribution of disease or to the effectiveness of controls has been modelled. The increased average farm cost of bloat is reflective of the real increase in value of cattle over the past few years, however the reduced southern herd size has decreased total impact.

Bloat ranks 7th in this report. The original 2015 report also ranked bloat as 7th.

4.4.8 Bovine Campylobacteriosis (Vibriosis)

The disease

Bovine campylobacteriosis (vibriosis) is caused by a bacterium that is sexually transmitted between cattle. It has primarily been associated with embryo loss (Clark, 1971), which usually occurs prior to the typical time for foetal ageing in commercial beef herds; abortions are also regularly caused by vibriosis. The epidemiology of the disease is not fully understood as sensitive and specific tests for both the bacterium and evidence of infection are unavailable (Lew *et al.*, 2006). Diagnosis still relies upon culture and antibody tests (*Campylobacteriosis (cattle)*, 2021). Most transmission is venereal, but it should be noted that the bacteria can survive in raw and processed semen (Michi *et al.*, 2016). Infection tends to be asymptomatic in bulls, but cows may display genital infection with discharge. Uncontrolled herd spread has been associated with early term abortion, reduced pregnancy rates and extended calving patterns (*Vibriosis | Meat & Livestock Australia*, no date). Field studies showed that delayed conceptions resulted in a 5–12% reduction in weaning weights due to late calves (Michi *et al.*, 2016).

	Unknown aetiology									*Known aetiology*
2015				X						
2022				X						

Prevention

One vaccine is available and is primarily used in bulls at approximately $12.50/year including labour to administer. The efficacy of the vaccine has not been fully defined in Australia (Clark, 1971), however challenge studies elsewhere have shown high protection against establishment of infection in vaccinated bulls (Michi *et al.*, 2016). A single-dose vaccines is unlikely to clear pre-existing infection in bulls (especially older bulls). Bacteria tend to clear from the upper reproductive tract of infected cows with time, however some cows become carriers whereby bacteria can persist for up to 24 months in the vaginal flora, and this is irrespective of subsequent vaccination status (Michi *et al.*, 2016). Sub-optimal maiden heifer reproductive performance can be an indicator of the presence of vibriosis in a herd as this cohort is always susceptible and has no acquired immunity in non-vaccinating herds (Meat & Livestock Australia, 2019). Vaccine failures have been reported (Michi *et al.*, 2016). Schatz (Schatz, 2011) showed an 11% increase in early-mating conceptions in vaccinated compared to unvaccinated heifers. O'Rourke (O'Rourke, K. Winks and Kelly, 1992) reported that 19% of north Australian beef producers in 1990 vaccinated. Bortolussi (Bortolussi *et al.*, 2005a, 2005b) reported that 29-71% of bulls were being vaccinated against vibriosis in northern Australia in 1996-97, with 3% of properties vaccinating in northern WA. McGowan (McGowan *et al.*, 2014) reported that 68% of the co-operator clients in north Australian beef project vaccinated bulls against vibriosis. An average of 0.5M doses of vaccine is sold annually. Biosecurity management is very difficult as diagnosis is difficult, primarily because the bacterium is a strict anaerobe, and cohabits the reproductive tract with many other bacteria. Infection seems to be ephemeral in some studies (Lew *et al.*, 2006), which may create false perception during diagnosis. PCR tests have improved sensitivity (100%) and specificity (98.7%) (McGoldrick *et al.*, 2013), and this aids herd reproductive investigations.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015				X						
2022				X						

Treatment

The bacterium can be cleared with antibiotic therapies, but this is rarely done because of the difficulty of diagnosis and removal of streptomycin from use in food-producing animals. Permanently infected bulls should be culled. Culling non pregnant animals at pregnancy diagnosis with greatly reduce the prevalence within a herd. Thereafter, vaccinate replacement heifers if necessary. Eradication requires a dedicated vaccination program of all breeding animals and culling (NSW Department of Primary Industries, 2007).

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015							X			
2022							X			

Distribution

The bacterium is ubiquitous

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

McGowan (McGowan *et al.*, 2014) reported that 4-14% of herds in the north Australian project had a high prevalence of vaginal mucus antibody in breeding cows. In over 4,000 samples assayed, 9.4% were positive with little evidence of year or age differences. There was some evidence for lower prevalence of antibody-positive animals in regions where bull vaccination was more prevalent. As no published data are available for prevalence in southern herds, the same prevalence as in northern Australia is presumed.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: Vibriosis – southern

Table 47: Assumptions: vibriosis – southern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	10%, 40%, 10% and 40% of herds with a high, medium, low and nil prevalence rate	-	*
% herds infected	An average of 40%, 20%, and 10% of cows are infected annually in high, medium and low incidence herds, respectively	-	*
Mortalities	No mortalities caused	-	***
Weight loss	No temporary weight loss	-	***
Fertility	10% fewer of infected cows fail to calf	-	**
Market avoidance	No market impact	-	***
Movement restrictions	Nil	-	***
Treatment	Treatment rarely used	-	***
Prevention	Vaccination of bull in 40% of herds, and heifers only vaccinated in 1% of high-prevalence herds	- An estimated 270K doses of vaccine are sold annually in northern Australia	**

Based on these assumptions the annual cost of vibriosis in cattle in southern Australia is estimated at $23.2M (Table 48).

Table 48: Economic cost of vibriosis – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$1.95	$0.42	$0.34	$11.20	$5.60	$2.80	**$13.15**	**$6.03**	**$3.14**
Per Herd	$0	$0	$0	$359	$78	$63	$2,061	$1,031	$515	**$2,420**	**$1,109**	**$578**
Total	**$0M**			**$2.3M**			**$20.9M**			**$23.2M**		

The net gain from moving all southern herds experiencing vibriosis to the lowest level of disease is estimated at $12.4M.

Assumptions: Vibriosis – northern

Table 49: Assumptions: vibriosis – northern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	10%, 40%, 10% and 40% of herds with a high, medium, low and nil prevalence rate	-	**
% herds infected	An average of 40%, 20%, and 10% of cows are infected annually in high, medium, low and nil incidence herds, respectively	-	*
Mortalities	No mortalities caused	-	***
Weight loss	No temporary weight loss	-	***
Fertility	10% fewer of infected cows fail to calf	-	**
Market avoidance	No market impact	-	***
Movement restrictions	Nil	-	***
Treatment	Treatment rarely used	-	***
Prevention	Vaccination of bulls in 60% of herds, and 15% of heifers vaccinated in high-prevalence herds	- An estimated 430K doses of vaccine are sold annually in northern Australia	**

Based on these assumptions the annual cost of vibriosis in cattle in northern Australia at $20.5M (Table 50).

Table 50: Economic cost of vibriosis – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$1.39	$0.34	$0.26	$4.97	$2.48	$1.24	**$6.35**	**$2.82**	**$1.51**
Per Herd	$0	$0	$0	$1,200	$293	$229	$4,297	$2,148	$1,074	**$5,497**	**$2,441**	**$1,303**
Total	**$0M**			**$3.2M**			**$17.3M**			**$20.5M**		

The net gain from moving all northern herds experiencing vibriosis to the lowest level of disease is estimated at $10.8M.

Total cost of disease

The total cost of vibriosis in cattle across Australia at the current prevalence of disease is estimated at $43.7M. The 2015 estimate was $53.8M per annum (equivalent to $61.1M in 2022 prices). The net gain from moving all herds to the lowest level of disease is estimated at $23.2M.

Changes since last report

More work on clearance of infection in affected bulls and cows has come to light. Improved PCR tests are now available. Anecdotal reports suggests that Vibriosis is still commonly diagnosed.

Vibriosis ranks 8th in this report. The original 2015 report ranked vibriosis as 9th.

4.4.9 Botulism

The disease

Botulism is caused by clostridial bacteria that produce a potent toxin under low-oxygen and warm (15–35°C) growth conditions, such as is present within rotting carcases or organic matter. There are many variants of botulinum toxin. But types C and D produce most clinical disease in Australia, and are widely distributed (Northern Territory Government, 2022). Cattle of all ages and gender are highly susceptible to botulinum. Cattle exposure often follows the eating of toxin-contaminated carcasses or residues in animals trying to overcome nutrient deficiencies, especially of protein and phosphorus, or when rotting carcasses are accidentally included in food or water (e.g. mice into silage). Deficient appetites are common in north Australia where vast areas have low soil and pasture phosphorus (McCosker and Winks, 1994). Outbreaks are most common in non-vaccinated cattle kept on protein and phosphorous-deficient diets (Northern Territory Government, 2022). Most affected cattle die from flaccid paralysis, though sub-clinical toxin challenge regularly occur. There is no evidence that non-lethal botulism has significant impacts of annual live weight gain. Henderson (Henderson, Perkins and Banney, 2013) reported that herds not vaccinated against botulism had about 5% higher (not significant) female cattle annual mortality rates in a study of 36 northern herds, of which only two did not vaccinate. Severe outbreaks in which 40% of cattle in a herd die have been reported ((Trueman *et al.*, 1992). Reproductive losses occur in association with cow mortality. In addition, suckling calves are susceptible between when immunity is provided in colostrum of vaccinated cows and when the calves are vaccinated, usually at branding or weaning. Losses of such calves usually only occurs in extremely poor seasons and rates are very low. There is no evidence that incidence of botulism has any impact on market access or values. The cattle disease is not a zoonosis and poses no food safety issues.

	Unknown aetiology									*Known aetiology*
2015							X			
2022							X			

Prevention

O'Rourke (O'Rourke, K. Winks and Kelly, 1992) reported that 19% of north Australian beef producers in 1990 vaccinated cattle against botulism, with 42-74% vaccinating in most northern forest regions of Queensland; 1% of producers were aware of botulism presence but did not vaccinate. Bortolussi (Bortolussi *et al.*, 2005a) reported that 60-84% of cattle were being vaccinated against botulism in tropical Australia in 1996-97, with 5-33% of properties vaccinating in central Queensland. There is no current data on vaccine use. Suggested levels (moderate confidence) are 80% in the northern forest, 50% on northern downs, 10% in sub-tropical regions, and 1% in southern Australia. Most vaccination outside tropical regions is in response to diagnosed outbreaks, or when susceptibility increases in line with poor seasonal conditions. A range of highly efficacious vaccines is available, with average cost/animal/year of protection at about $2.00, including some labour. The duration of protection of vaccines continues to increase with vaccine refinement such that protection extending up to and beyond a year from a single dose are available (de Oliveira Junior *et al.*, 2019). Removal of carcases (domestic and wild species) is recommended where possible; toxin can survive for a year in carcases, but will rapidly inactivate at temperatures above 37°C. This means not all carcases are toxic and the toxicity of carcases varies widely. It is safer to assume that all carcases are potentially toxic. Whilst natural immunity can develop in cattle exposed to low doses of toxin, limiting botulinum exposure dose is not feasible under field conditions. It is also safer to assume that all non-vaccinated or improperly vaccinated cattle are at risk of toxicity. Non-toxic, effective and potentially cheaper recombinant vaccines are under development (Moreira *et al.*, 2020). The provision of sufficient and accessible supplementary sources of phosphorous and protein (or non-protein nitrogen, such as urea) are important for preventing botulism (Northern Territory Government, 2022).

Low efficacy/ unproven preventives available — *Effective preventives available*

2015										X
2022									X	

Treatment

No specific treatment exists for botulism. Rare sub-lethal clinical cases can be nursed back to full health over approximately one month.

Low efficacy/ unproven treatments available — *Effective treatments available*

2015	X									
2022	X									

Distribution

In the absence of verifying data, professional opinion (high confidence) is that botulism spores are prevalent throughout Australia, and especially in north Australia (Sackett *et al.*, 2006). The movement of cattle across the country in the past 50 years may have ensured both C and D types are equally prevalent.

Distribution contracting — *Distribution stable* — *Distribution increasing*

2015					X					
2022					X					

Prevalence

From reports commencing in the mid-1960s when botulism was recognised and vaccination was unavailable or not used, it is suggested (moderate confidence) that within the northern forest of north Australia, lethal dose challenge may occur on average in 0.3% of cattle yearly, and in 3% every 5yrs, with full protection usually afforded by vaccination; in the absence of published data, assumed rates in northern downs are 0.15% and 1.5%, in sub-tropical north Australia are 0.03% and 0.3% and in southern Australia are 0.01% and 0.1%, respectively.

Prevalence decreasing — *Prevalence increasing*

2015					X					
2022					X					

Economics

Assumptions: Botulism – southern

Table 51: Assumptions: botulism – southern (cattle)

Variable	2015 Assumption	2022 Assumption Changes	Confidence
Regional Extent	All cattle have the potential to be exposed to botulism	-	***
% herds infected	All cattle in a low-challenge environment in which an average of 0.03% of cattle are challenged annually	-	*
Mortalities	100% of unvaccinated challenged cattle	-	**
Weight loss	No temporary weight loss	-	**
Fertility	No impact	-	***
Market avoidance	No impact	-	***
Movement restrictions	Nil	-	***
Treatment	No treatment available	-	***
Prevention	Almost no routine vaccination used	-	***

Based on these assumptions the annual cost of botulism in cattle in southern Australia is estimated at $3.0M (Table 52).

Table 52: Economic cost of botulism – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$0	$0	$0	$0	$0	$0.52	**$0**	**$0**	**$0.52**
Per Herd	$0	$0	$0	$0	$0	$0	$0	$0	$95	**$0**	**$0**	**$95**
Total	**$0M**			**$0M**			**$3.0M**			**$3.0M**		

There is no expected net gain from changing current practice for southern herds.

Assumptions: Botulism - northern

Table 53: Assumptions: botulism – northern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	All cattle have the potential to be exposed to botulism	-	***
% herds infected	52% of cattle in a moderate-high challenge probability region where 0.2% of stock challenged annually 48% of cattle in a low-challenge probability region where 0.1% of stock challenged annually	-	*
Mortalities	100% of unvaccinated challenged cattle	-	**
Weight loss	No temporary weight loss	-	**
Fertility	No impact	-	***
Market avoidance	No impact	-	***
Movement restrictions	Nil	-	***
Treatment	No treatment available	-	***
Prevention	Within the high-, medium- and low-challenge regions, 80%, 50% and 10% of cattle are vaccinated annually	- An estimated 7.5M doses of botulism vaccine are administered annually in Northern Australia	*

Based on these assumptions the annual cost of botulism in cattle in northern Australia is estimated at $29.1M (Table 54).

Table 54: Economic cost of botulism – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$2.41	$1.34	$0.22	$0	$2.46	$1.23	**$2.41**	**$3.80**	**$1.45**
Per Herd	$0	$0	$0	$2,126	$1,181	$192	$0	$2,165	$1,085	**$2,126**	**$3,346**	**$1,277**
Total	**$0M**			**$8.7M**			**$20.4M**			**$29.1M**		

The net gain from moving all northern herds experiencing botulism to the lowest level of disease is estimated at $13.3M.

Total cost of disease

The total cost of botulism in cattle across Australia at the current prevalence of disease is estimated at $33.5M per annum. The 2015 estimate was $28.0M (equivalent to $31.8M in 2022). The net gain from moving only northern herds experiencing botulism to the lowest level of disease is estimated at $13.3M.

Changes since last report

Nil

Botulism is ranked 9th in this report. The original report ranked botulism as 10th.

4.4.10 Clostridial diseases (southern)

The disease

The clostridia genus of bacteria is classified according to the site of their pathogenicity. The neurot0xic group includes C. tetani and C botulinum, the histotoxic group has *C. chauvoie*, *C. septicum* and *C.novyi* and the entertoxic group includes *C. perfringens* (Compiani *et al.*, 2021). The common clostridial diseases of southern beef cattle are tetanus (C. *tetani*), botulism (C. *botulinum*), blackleg (C. *chauvoei*), malignant oedema (C. *septicum*), black disease (C. *novyi*) and entertoxaemia (C. *perfringens* type D). Clostridia bacteria are obligate anaerobic, spore-forming bacteria. They are widespread and spores can survive in the environment for long periods. Pathogenicity is related to sporulation which releases toxins. The low prevalence of phosphorous deficiency in southern Australia limits bone chewing – the main risk factor for botulism in the northern industry – provides for reduced impact of clostridial diseases in the southern compared to the northern industry (note that botulism is separately under that disease. Unhygienic calf castration can precipitate tetanus outbreaks. Histotoxic clostridia invade the animal and produce disease at the site of sporulation. Malignant oedema is associated with clostridial contamination of wounds (an exogenous exposure) where black leg is acquired following ingestion of *C. chauvoie* spores that are transported to muscles and tissues where they subsequently sporulate if favourable (anaerobic) conditions develop in the tissue, such as from a bruise. Blackleg is therefore regarded as an endogenous clostridium because spores may exist in most animals because of gut absorption. Entertoxic forms of clostridia are also ever-present, requiring a gut insult to produce favourable conditions for sporulation such as carbohydrate overload. Clostridial disease in at its forms is invariably fatal however highly effective and cheap vaccines exist against the major variants.

	Unknown aetiology									*Known aetiology*
2015									X	
2022									X	

Prevention

Effective combination vaccines are available and are widely used. This prevents most disease. Black disease is often associated with liver fluke infestations – but fluke areas are generally well known and preventive measures (fluke and black disease) are typically applied.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015								X		
2022								X		

Treatment

Treatment is generally ineffective – most cases are found dead. Tetanus can produce less fulminating disease depending on the dose of toxin absorbed.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015		X								
2022		X								

Distribution

Distribution is found in all cattle farming regions of the south and is an inherent risk of all cattle enterprises in these regions.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

The disease is ever-present.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: Clostridial disease (southern)

Table 55: Assumptions: clostridial disease – southern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	All beef herds are at risk of clostridial disease. However, the majority (85%) of producers use effective vaccination programs and do not see the disease.	-	***
% herds infected	1% of southern herds experience large-scale outbreaks (generally arising from failure to vaccinate or incorrect vaccine administration/storage) Up to 10% of young stock and 2.5% of rising two-year-olds affected. No adult losses 4% of southern herds experience moderate outbreak (again due to inadequate vaccination) Up to 2% of young stock and 0.5% of rising two-year-olds. No adult losses 10% of southern herds experience minor outbreak (again due to	-	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	inadequate vaccination – generally of individual animals) Up to 0.5% of young stock affected. No rising two-year-olds or adult losses 85% of southern herds experience no disease		
Mortalities	100% mortality rate assumed	-	***
Weight loss	No weight loss or other production effects are assumed; all production losses are due to deaths.	-	***
Fertility	No impact	-	***
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Treatment is by antibiotics and support. A cost of $50 per case has been assumed. However only 5% of cases are found alive and treated.	Treatment is by antibiotics and support. A cost of $60 per case has been assumed. However only 5% of cases are found alive and treated.	**
Prevention	Prevention is by vaccination. A dose is estimated to cost $1.00 (vaccine plus labour) and 50%, 70% and 90% of highly, moderately and lowly affected herds are assumed to vaccinate. All unaffected herds are assumed to vaccinate	Prevention is by vaccination. A dose is estimated to cost $1.50 (vaccine plus labour) and 50%, 70% and 90% of highly, moderately and lowly affected herds are assumed to vaccinate. An estimated 15M doses of vaccine are administered to southern cattle for clostridials each year	***

Based on these assumptions the annual cost of $23.4M in cattle in southern Australia (Table 56).

Table 56: Economic cost of clostridial disease – southern (cattle)

	Treatment			Prevention				Production			Total			
	H	M	L	H	M	L	F*	H	M	L	**H**	**M**	**L**	**F***
Per Cattle	$0.09	$0.02	$0.00	$1.28	$1.79	$2.30	$1.93	$40.99	$8.34	$1.38	**$42.36**	**$10.15**	**$3.68**	**$1.93**
Per Herd	$17	$3	$1	$234	$328	$421	$517	$7,501	$1,526	$252	**$7,752**	**$1,857**	**$674**	**$517**
Total	**$0.0M**			**$18.4M**				**$5.0M**			**$23.4M**			

* Free herds (unaffected)

The net gain from moving all southern herds to the lowest level of clostridial disease is $3.6M. Clostridial diseases typically produce a small or no impact in most herds however a large-scale outbreak in an unvaccinated herd can result in catastrophic losses for individuals.

<u>Changes since last report</u>

An estimated 15M doses of clostridial vaccines are sold each year. Most vaccine is administered to herds who subsequently do not experience disease. Therefore, the cost of this (effective) intervention has been included to provide a better fit to market sales data. Disease is seen in herds that do not employ effective vaccination programs.

Clostridial disease is ranked 10th in this report. The original report ranked clostridial disease as 15th. The inclusion of control costs (vaccination) in herds without disease accounts for the advancement in rank (despite no fundamental change to the pattern of disease).

4.4.11 Bovine ephemeral fever (three-day sickness)

The disease

Bovine ephemeral fever (BEF), or three-day sickness as it is more commonly known, is caused by a virus that is spread between cattle by biting insects. Disease commonly follows heavy summer rainfall, suggestive of an association with the emergence of large populations of mosquitos after breeding in shallow surface waters (Walker and Klement, 2015). The primary clinical signs are high fever and lameness. Because of its high prevalence clinical infection mostly occurs in cattle up to two years of age, except following successive dry years when insect vector populations are often insufficient to achieve high sero-conversion rates in young cattle (Uren, St George and Zakrzewski, 1989). An average of approximately one third of cattle in a group will be affected in a typical outbreak and the mortality rate in affected cattle averages ~0.5% (McGown *et al.*, 2010; Walker and Klement, 2015). Permanent weight loss in affected animals is thought to average 10 kg (Walker and Cybinski, 1989). Fordyce (Fordyce and Emery, 2009) reported pregnancy rates per cycle to halve in an outbreak in 2-year-old heifers during their maiden mating. The high fever associated with BEF can cause temporary sub-fertility in bulls and abortion. Acutely affected lactating cows often go dry and milk yield after recovery is often reduced by 10–20%, thereby affecting calf survival. No published data is available on the effect on calf output, which is debatable, as: temporary bull sub-fertility is usually only likely to affect single-sire matings (not usual practice); and, though abortion due to high fever is a possible outcome, the evidence for significant loss due to fever associated with BEF is lacking.

	Unknown aetiology									*Known aetiology*
2015								X		
2022								X		

Prevention

A vaccine given as two initial injections with annual boosters is available and can achieve a six-fold reduction in the incidence of clinical effects. A large north Australian trial with male and female cattle failed to show any significant benefits from vaccinating (McGown *et al.*, 2010). The disease was noted to occur during the study, but the period (2003-2009) was noted as of generally low incidence. In a subsequent larger study with female cattle aged two years and older conducted during generally wetter years, BEF prevalence had no effect on fertility (McGowan *et al.*, 2014). In this study, a quarter of northern beef producers vaccinated bulls, and virtually none vaccinated female cattle.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015				X						
2022				X						

Treatment

Injectable analgesics and anti-pyretic drugs prescribed and or administered by veterinarians are used in treating acutely affected cattle. Such animals are usually heavy, well-conditioned and older than two years. O'Rourke (O'Rourke, L. Winks and Kelly, 1992) reported that 14% of north Australian producers treated or vaccinated animals with BEF, with a further 12% were aware that BEF caused disease that they did not treat.

Low efficacy/ unproven treatments available — *Effective treatments available*

2015								X		
2022								X		

Distribution

The disease mainly occurs in northern Australia; approximating the distribution of the *C. brevitarsis* midge and *C. Annulirostris* mosquito. The overwintering mechanism of the virus is poorly understood, but it is not believed to be in cattle (van Vuuren and Penzhorn, 2015). Disease has progressed down eastern Australia as far as Victoria in some years, reflective of an expansion of the range of viral insect vectors. These more southerly coastal expansions of hosts and disease tend to occur in La Niña years (Walker and Klement, 2015). Inland intense low-pressure systems that bring large amounts of rain to the interior often are associated with an expansion of disease into central regions. Climate change may limit disease in dry years but also promote wide scale outbreaks during wet years.

Outbreaks after drought are commonly reported. This combination may bring larger amplitude (i.e. 'boom-bust') cycles of disease between years. However, the lack of understanding of the viral overwintering mechanism makes predicting outbreaks difficult; recent weather patterns alone are insufficient.

Distribution contracting — *Distribution stable* — *Distribution increasing*

2015					X					
2022					X					

Prevalence

Across northern Australia McGowan *et al.* (2014) found that ~8% of all heifers (aged 2-3 years) and cow groups and >10% of cattle tested had experienced recent infection. At least 70% of herds had high sero-prevalence, and ~90% of cattle were seropositive. No herd had fewer than 20% sero-positive animals.

Prevalence decreasing — *Prevalence increasing*

2015					X					
2022					X					

Economics

Assumptions: Bovine ephemeral fever (three-day sickness) – southern

Table 57: Assumptions: bovine ephemeral fever (three-day sickness) – southern

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Infection usually only occurs under moist hot conditions every few years	-	***
% herds infected	5% of the cattle in this region are exposed every 5 years	-	**
Mortalities	0.5% mortality in affected cattle	-	*
Weight loss	Temporary weight loss of 10 kg in affected cattle	-	**
Fertility	50% chance of outbreak occurring during mating with pregnancy rates down by 20%	-	*
Market avoidance	10% of affected steers have market value reduced by $0.20/kg	10% of affected steers have market value reduced by $0.40/kg	*
Movement restrictions	Nil	-	***
Treatment	10% of affected animals may be treated ($25 ea)	10% of affected animals may be treated ($30 ea)	*
Prevention	No significant vaccination occurs	-	***

Based on these assumptions the annual cost of BEF in cattle in southern Australia is estimated at $0.1M (Table 58).

Table 58: Economic cost of bovine ephemeral fever (three-day sickness) – southern

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0.03	$0	$0	$0	$0	$0	$0.48	**$0**	**$0**	**$0.51**
Per Herd	$0	$0	$5	$0	$0	$0	$0	$0	$89	**$0**	**$0**	**$94**
Total	**$0M**			**$0M**			**$0.1M**			**$0.1M**		

No net gain is expected from moving all southern herds experiencing BEF to the lowest level of disease.

Assumptions: Bovine ephemeral fever (three-day sickness) – northern

Table 59: Assumptions: bovine ephemeral fever (three-day sickness) – northern (cattle)

Variable	2015 Assumptions	2022 Assumption changes	Confidence
Regional Extent	Occurs across north Australia	-	***
% herds infected	40% of the cattle in this region are exposed every year; 50% of cattle are affected every 3 years, and 10% of cattle every 5 years	Frequencies as left, but immunity in adult cohorts differ between H, M and L prevalence herds, making clinical disease in adults more common during outbreaks in M and L herds than H herds	*
Mortalities	0.5% mortality in affected cattle	-	*
Weight loss	Temporary weight loss of 10 kg in affected cattle[7]	Temporary weight loss of 10 kg in affected cattle	**
Fertility	50% chance of outbreak occurring during mating in moderate- and low-incidence regions with pregnancy rates down by 20%	-	*
Market avoidance	Nil	-	*
Movement restrictions	Nil	-	*
Treatment	5% of affected animals may be treated ($25 ea)	5% of affected animals may be treated ($30 ea)	*
Prevention	25% of bulls vaccinated, with little vaccination of other cattle classes ($2.50 ea)	25% of bulls vaccinated, with little vaccination of other cattle classes ($10.00 ea)	**

Based on these assumptions the annual cost of BEF in cattle in northern Australia is estimated at $22.4M (Table 60).

[7] The 2015 estimate erroneously modelled weight loss as permanent. This has been corrected for the 2022 estimate

Table 60: Economic cost of bovine ephemeral fever (three-day sickness) – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0.00	$0.21	$0.11	$0.04	$0.04	$0.04	$2.21	$1.89	$0.90	**$2.24**	**$2.13**	**$1.05**
Per Herd	$0	$182	$99	$33	$33	$33	$1,931	$1,652	$790	**$1,963**	**$1,867**	**$921**
Total	**$1.1M**			**$0.4M**			**$20.7M**			**$22.4M**		

The net gain from moving all northern herds experiencing BEF to the lowest level of disease is estimated at $11.0M.

Total cost of disease

The total cost of BEF in cattle across Australia at the current prevalence of disease is estimated at $22.5M. The original 2015 estimate was $59.8M, but with the modification to weight loss (temporary, not permanent) this reduces to $21.8M per annum (equivalent to $24.7M in 2022). The net gain from moving only northern herds experiencing BEF to the lowest level of disease is estimated at $11.0M.

<u>Changes since last report</u>

A more cyclical nature of outbreaks may follow increased season variation due to climate change. The cyclical nature of infection can (paradoxically) result in more adults affected by clinical disease during outbreaks because more animals avoid infection for longer. Losses increase as the age of animal affected increases.

Bovine ephemeral fever is ranked 11th in this report. The original ranking from 2015 was 8th. The increasing seasonal variation is contributing to a reduction in average annual cost of disease.

4.4.12 Grass tetany (hypomagnesaemia)

The disease

Grass tetany is seen in beef herds grazing improved pastures on solodic and solodised soils in the higher rainfall regions of south-eastern Australia (disease is essentially absent outside of this region). These soils are dense clays with high salt contents and strongly adsorbed sodium and magnesium ions. Magnesium is essential for proper functioning of muscle and nerve tissue and is involved in complex relationships with other ions — especially calcium and potassium — in moderating cell function. Absorption of magnesium by grazing cattle may be insufficient if there is inadequate magnesium (<2g/kg DM), calcium (<3g/kg DM), sodium (<1.5 g/kg DM) and/or phosphorous or if there are high levels of inhibitory substances such as potassium (>20g/kg DM) and nitrogen (>50g/kg DM) in the soil or pasture. These conditions are most common on improved grass-dominant pasture or cereal crops that have received potash fertilisers (*Grass tetany | MBFP | More Beef from Pastures*, no date). Magnesium demand is greatest in lactating cows and therefore grass tetany is mostly seen in late winter and autumn in freshly lactating (winter-spring calving) cows. Recent studies have shown that addition of magnesium to fertiliser increased the magnesium content of pasture grasses, suggesting pasture composition and fertiliser strategies are important controls for grass tetany (Kumssa *et al.*, 2020).

	Unknown aetiology									*Known aetiology*
2015									X	
2022									X	

Prevention

Grass tetany may be effectively managed by moving to spring calving. The ratio of potassium to calcium plus magnesium concentrations in pasture samples provides an indicator of grass tetany risk, with risk increasing as the ratio increases. Pastures with a ratio of 2.2 or greater are of high risk for grass tetany (*Grass tetany | MBFP | More Beef from Pastures*, no date). Short pastures (minimal fibre intake) and grazing cereal crops can present as high risk at certain times of year and stages of the calving/lactation cycle (risk is greatest from calving to 2–3 months of lactation). Overly fat or thin cattle are at increased risk and there may be a breed effect, with Angus more prone than other British breeds (*Grass tetany | Meat & Livestock Australia*, no date). The supplementation of cattle with 60 grams per day magnesium oxide (Causmag®, magnesium block, magnesium rumen boluses), controlling potassium intake (fertiliser programs), managing fibre intake (hay feeding) and minimising stress in grazing stock are ways that grass tetany risk and occurrence can be managed. MLA has tools to allow producers to assess their control options (*Tools & calculators | Meat & Livestock Australia*, no date).

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015									X	
2022									X	

Treatment

Most clinical cases are found dead before treatment. Intravenous calcium and magnesium supplementation can save clinical cases. Prevention is more important than treatment.

Low efficacy/ unproven treatments available *Effective treatments available*

2015								X		
2022								X		

Distribution

Approximately 60% of southern beef cattle are in high rainfall regions predominated by solodic and solodised soils. Up to 40% of herds can experience disease with up to 5% clinical incidence in mature cows in severe outbreaks.

Distribution contracting *Distribution stable* *Distribution increasing*

2015					X					
2022					X					

Prevalence

The within-herd incidence of disease is typically very low. Outbreaks can occur when a risk factor – such as high potash pasture, bad weather – occur in at risk cattle. Most cattle producers are aware of grass tetany and understand most requirements for managing disease in their herds. The feeding of hay and supplementation of cows with Causmag® is the main preventive. System-level controls such as modified fertilizer programs, pasture renovation, timing of calving and stocking density adjustments were not considered.

Prevalence decreasing *Prevalence increasing*

2015					X					
2022					X					

Economics

Assumptions: Grass tetany – southern

Table 61: Assumptions: grass tetany – southern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	60% of southern cattle are on properties in higher rainfall regions (> 600 mm per annum) with 10% in	-	***

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	the pastoral zone (no requirement for control in most years)		
% herds infected	5% of properties experience high levels of disease: 2.5% incidence in younger cows and 5.0% incidence in older cows. 15% of properties experience moderate levels: 1.0% incidence in younger cows and 2.0% incidence in older cows. 40% of properties experience moderate levels: 0.0% incidence in younger cows and 0.5% incidence in older cows. 40% of properties do not have grass tetany	-	**
Mortalities	50% mortality in younger cows and 80% mortality in older clinical cases are assumed	-	**
Weight loss	No weight loss or fertility impacts are assumed. Calves of affected dams are assumed to survive.	-	***
Fertility	Nil	-	***
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Treatment is applied in only 50% of cases as most cases die or are found dead. Intravenous calcium and magnesium is applied. Some require veterinary attention. An average cost of $100 per case is assumed.	-	**
Prevention	Effective control relies on use of hay and Causmag®. A total cost of $10 per adult cow is assumed for control	Effective control relies on use of hay and Causmag®. A total cost of $15 per adult cow is assumed for control	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	- 100% of highly affected properties use Causmag® and hay - 66% of moderately affected properties use Causmag® and hay - 33% of lowly affected properties use Causmag® and hay	- 100% of highly affected properties use Causmag® and hay - 66% of moderately affected properties use Causmag® and hay 33% of lowly affected properties use Causmag® and hay	

Based on the adopted prevalence and impacts of the disease on the classes of animals affected, GHD has calculated the annual cost of grass tetany in cattle in southern Australia at $22.2M (Table 62). The 2015 estimate was $24.3M (equivalent to $27.6M in 2022).

Table 62: Economic cost of grass tetany – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0.65	$0.26	$0.10	$4.89	$3.23	$1.61	$13.49	$5.40	$2.28	**$11.29**	**$5.38**	**$2.45**
Per Herd	$119	$48	$18	$900	$594	$297	$1,482	$993	$420	**$2,133**	**$1,017**	**$463**
Total	**$0.6M**			**$7.9M**			**$13.7M**			**$22.2M**		

The net gain from moving all southern herds to the lowest level of disease is estimated at $8.5M.

Changes since last report

No substantive changes, the industry cost has been impacted by the reduction in the southern herd size and the increase in cattle prices between reports.

Grass tetany is ranked 12th in this report. The original 2015 ranking was 11th.

4.4.13 Calf scours (southern)

The disease

Calf scours is the most common cause of death in milk-fed calves (Moran, no date). The cause is complex, usually contributed to by calf management, diet, environmental conditions and pathogens such as *E. coli*, rotavirus, coronavirus, *salmonella spp.* and/or cryptosporidia. It is commonly divided into two types, nutritional and infectious. Nutritional scours arise from a failure of milk digestion in the calf abomasum. This is often contributed to by management factors, including excessive cow milk production, leading to spill-over of lactose into the small intestine and subsequent scours. Infectious scours often follow as gut infectious agents proliferate due to the oversupply of nutrients in the gut. Calf scours is now an established problem of the southern beef cattle industry. Surveys[8] suggest that 80% of southern producers have at least one case of white scours each year. The majority (70%) of producers experiencing outbreaks have fewer than 5% of calves affected but 20% can have up to 15% of calves affected and 10% with up to 30% of calves affected. The case fatality rate can be 10%. Whilst the major pathogens are generally known, the frequency of outbreaks and the size of outbreaks may be trending upwards. Intensification and concurrent disease are risk factors for outbreaks.

	Unknown aetiology									*Known aetiology*
2015							X			
2022								X		

Prevention

Good cow colostrum production and effective calf feeding is essential. Vaccination has a role in some outbreaks but cannot prevent nutritional scours. Mixed pathogen involvement is common. Vaccination of the pregnant cow is required for some pathogens (e.g. *E. coli* K99). Parasite and trace element management can assist. Ensuring calves are protected from extremes of climate, cows calve into a clean environment, controlling stress during calving and minimising contact with other potential sources of infection are important controls. Moving unaffected cows and calves from affected herd mates to a clean new paddock can prevent outbreaks from magnifying (*Calf scours | Meat & Livestock Australia*, no date).

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015						X				
2022							X			

Treatment

Treatment is symptomatic – replacement of lost fluids and parenteral antibiotic support. Dehydration, malnutrition (whilst withheld from milk) and secondary infection are the main causes of mortality. Electrolytes and antibiotics are effective in most cases, but application is labour intensive. Human handlers can transfer pathogens between calves, so it is best to have a dedicated

[8] Incidence and prevalence surveys were not random – a selection or self-reporting bias is likely to be present

person to treat sick calves and to handle sick calves last. Prolonged use of antibiotics can affect health gut bacteria and should be avoided.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015						X				
2022						X				

<u>Distribution</u>

Distribution appears to be expanding (along with severity and size of outbreaks). Surveys indicate that intensification of production is associated with increased disease.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015							X			
2022							X			

<u>Prevalence</u>

The size of outbreaks is increasing on affected farms. Reports of up to 50% of calves affected have been received. Multiple pathogen involvement may be contributing. Furthermore, multiple pathogens and associated disease (trace element deficiency, parasites) may result in larger outbreaks on affected farms.

	Prevalence decreasing									*Prevalence increasing*
2015							X			
2022							X			

<u>Economics</u>

Assumptions: Calf scours (southern)

Table 63: Assumptions: calf scours – southern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	80% of southern beef herds have at least one case of calf scours per year.	-	***
% herds infected	5% of southern herds experience large-scale outbreaks: up to 30% of calves affected	-	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	15% of southern herds experience moderate outbreaks: up to 15% of calves affected 60% of southern herds experience minor outbreaks: up to 5% of calves affected 20% of southern herds experience no disease		
Mortalities	10% mortality rate is assumed	-	**
Weight loss	No weight loss or other production effects are assumed; all production losses are due to calf deaths.	-	**
Fertility	Nil	-	***
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Treatment is by electrolytes, antibiotics and support. A cost of $25 per case has been assumed. However only 5% of cases are found alive and treated.	Treatment is by electrolytes, antibiotics and support. A cost of $30 per case has been assumed. However only 5% of cases are found alive and treated.	**
Prevention	Prevention is by vaccination. A dose is estimated to cost $1.00 (vaccine plus labour) and 50%, 70% and 90% of highly, moderately and lowly affected herds are assumed to vaccinate.	Prevention is by vaccination. A dose of polyvalent vaccine is estimated to cost $7.00 (vaccine plus labour) and 50%, 40% and 30% of highly, moderately and lowly affected herds are assumed to vaccinate.	**

Based on these assumptions the annual cost of calf scours in cattle in Australia is estimated at $20.5M per year. The 2015 estimate was$23.0M per year (equivalent to $26.1M in 2022) (Table 64).

Table 64: Economic cost of calf scours – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$3.32	$1.66	$0.55	$2.93	$1.37	$1.03	$8.40	$4.20	$1.40	**$14.66**	**$7.23**	**$2.98**
Per Herd	$605	$302	$101	$534	$249	$187	$1,530	$765	$255	**$2,668**	**$1,316**	**$543**
Total	**$4.2M**			**$5.5M**			**$10.7M**			**$20.5M**		

The net gain from moving all southern herds experiencing disease to the lowest level of calf scours disease is estimated at $6.9M per annum.

Changes since last report

More multivalent vaccines against infectious scours have become available

Calf scours is ranked 13th in this report. The original 2015 ranking was 12th.

4.4.14 Theileriosis

The disease

Theileriosis is a tick-borne infection of cattle produced (in Australia) by the *Theileria orientalis* group of haemoprotozoan parasites. *T. buffeli* has been present in Australia since the early 1900s and was traditionally associated with asymptomatic infections. Since 2006 an increasing number of clinical infections due to pathogenic strains of the parasite – especially *T. ikeda, T. chitose and* Type 4 *T. orientalis* – have been reported, mostly along the eastern seaboard. These virulent forms of *T. orientalis are* identifiable by their common major piroplasm surface protein (MPSP), which can be identified using PCR (Watts, Playford and Hickey, 2016). There are at least 11 strains of varying virulence. Most clinical disease has been reported along the coast of New South Wales and Victoria, limestone coast region of South Australia and in the south-west of Western Australia. Mechanical transmission is recognised as a means of spread of infection, only 0.1 mL of blood is required to transmit the parasite. Less clinical disease is reported in Queensland (besides a hot spot in far north of the state) and this suggests prior infection with the more benign *T. buffeli* is partly protective against clinical disease from more virulent strains (Emery, 2021). *T. ikeda* and *T. chitose* are also more pathogenic than *T. buffeli*, meaning these more virulent strains typically appear first in outbreaks, and before prior infection with *T. buffeli* can provide protection (most outbreaks contain multiple strains of Theileria). In endemic situations, the most susceptible animals are calves and naïve introductions to the region. A longitudinal study found the majority of calves to be positive within 4–5 weeks of birth (Emery *et al.*, 2021). Most clinical disease is associated with the first wave of new infections into a region, but disease incidence and severity gradually lessen as cattle develop immunity. Some infected cattle become carriers, and these animals are less prone to subsequent disease but can also regress into clinical disease under periods of stress such as calving (Gebrekidan *et al.*, 2020). Disease is primarily due to the rupture of infected red blood cells by Theileria piroplasms (Jenkins, 2018). The emerging disease has been named bovine anaemia caused by *Theileria orientalis* group (BATOG) to separate the disease syndrome from infection with the endemic and typically non-pathogenic T. *buffeli* strain. There is a spectrum of BATOG disease ranging from non-pathogenic infection (mainly T. *buffeli*) through to severe anaemia, abortion, recumbency and death. Clinically affected animals lose weight. Mortalities of 10% in young stock (<2YO) and up to 3% of adults can occur in severe outbreaks, but these are typically associated with recent introduction of pathogenic strains into naive herds. Anaemia was strongly associated with reduced milk production and reduced reproductive performance in dairy cattle. Significant recovery times after severe anaemia can occur. Weight loss can be dramatic and abortion and reproductive failure are common sequelae. Immunity to Theileria is poorly understood, but likely to have a significant cell-mediated component (Jenkins, 2018).

	Unknown aetiology									*Known aetiology*
2015					X					
2022					X					

Prevention

There are no effective or registered preventive methods. Whilst tick control can assist control, only a small number of ticks are required to spread the parasite. The primary tick vector *H. longicornis* is a three-host tick; controlling this tick is more challenging than for single-host ticks like *R. microplus* because it can complete their life cycle without cattle (Emery, 2021). There is currently no vaccine against the pathogen or the tick. A vaccine will likely be essential to prevent disease due to the persistence in intermediate hosts (ticks) especially along the length of the eastern and northern seaboards. Innate genetic resistance to Theileria in cattle appears to be lacking, however recovered animals typically develop carrier states (often with multiple strains of Theileria) and have heightened resistance to subsequent infection and disease (Emery, 2021). Most infections occur within the first week of life. Limiting tick numbers at calving by locating calving paddocks away from high tick habitat (such as coastal bushland and wildlife) may reduce calfhood infections.

Low efficacy/ unproven preventives available — *Effective preventives available*

2015			X							
2022			X							

Treatment

There are no registered effective treatments for the parasite. Buparvaquone has been shown to be effective at controlling the infection but is not registered for use due to the long withhold period. Symptomatic treatment of the anaemia (nursing) can reduce mortalities. Treatment is time consuming and expensive. Recovery is slow as the animal needs to replace red cells lost due to the anaemia. Minimising stress and stopping unnecessary stock movements are important considerations for clinical cattle.

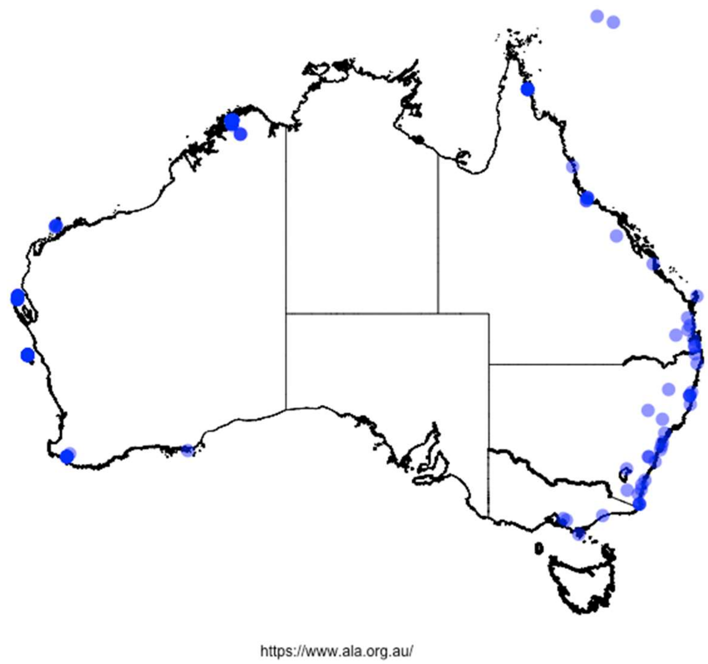
Low efficacy/ unproven treatments available — *Effective treatments available*

2015			X							
2022			X							

Distribution

Small scale typing studies found the seroprevalence of infected herds to be high in Queensland (85%) and Victoria (80%) with slightly lower prevalence in NSW (45%), however clinical disease is more prevalent in NSW and Victorian isolates than in Queensland. This is due to the higher prevalence of *T. ikeda* in these regions and the higher prevalence of *T. buffeli* in Queensland. The distribution of clinical disease follows the distribution of *Haemaphysalis spp* ticks, the exemplar being the bush tick host (*H. longicornis*). Theileria appears to have fully occupied the range of *Haemaphysalis spp* ticks now, suggesting further expansion is unlikely (Jenkins, 2018). Southern disease regions directly overlay the distribution of the three-host bush tick (*Haemaphysalis longicornis*) (Jenkins, 2018). The *Haemaphysalis* genus of tick prefers warm, moist environments, hence there is a coastal predominance of theileria The *Atlas of Living Australia* distribution of *Haemaphysalis spp* reports is presented in Figure 11, which is likely to be the minimum range of the tick due to under-reporting.

Figure 11: Distribution of reported sightings of *Haemaphysalis spp* ticks (1926-2022). From Atlas of Living Australia



	Distribution contracting				*Distribution stable*				*Distribution increasing*	
2015								X		
2022							X			

Prevalence

Approximately 55% of sampled Queensland cattle were seropositive. The NSW cow-level sample seroprevalence was approximately 25% and in Victoria it was 34%. In endemic regions the prevalence testing positive can exceed 80%(Emery *et al.*, 2021). However not all positive animals show disease signs. Large outbreaks are common in previously naïve herds. Paradoxically, the rate of clinical disease often decreases as the prevalence of infection increases (i.e. once infection becomes endemic). This is because the cattle population quickly becomes 'saturated' with disease and this limits new infections (Jonsson *et al.*, 2012). Newborn calves are the most common new infections in these circumstances.

	Prevalence decreasing									*Prevalence increasing*
2015								X		
2022							X			

Economics

Assumptions: Theileriosis (southern)

Table 65: Assumptions: theileriosis – southern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	50% of southern cattle population in exposed region (excludes the arid inland regions).	Whilst approximately 1/3rd of southern cattle reside in endemic regions of the bush tick host, the involvement of other *Haemaphysalis spp* ticks as vectors and the large scale movements of cattle suggest that at least 50% of the southern cattle population can be exposed to the parasite.	**
% herds infected	1% of herds newly infected and previously naive highly affected: 25% of herd (all ages) infected 10% of herds moderately affected: 15% of young stock, 5% of older stock infected 34% of herds lowly affected: 10% of young stock and 1% of older infected	1% of herds newly infected and previously naive highly affected: 25% of herd (all ages) infected 15% of herds moderately affected: 15% of young stock, 5% of older stock infected 34% of herds lowly affected: 10% of young stock and 1% of older infected	**
Mortalities	10% in young stock, 5% in older.	-	**
Weight loss	Significant weight loss in affected (20 kg in young stock, 10 kg in older stock).	-	**
Fertility	Clinical cases have reduced fertility (45% pregnancy rate versus 90% pregnancy rate). Clinical course of disease is 3 months therefore average reduction in pregnancies for clinical cases is 11%.	-	*
Market avoidance	Nil		**
Movement restrictions	Nil	-	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Treatment	Not available	An average of $25 per head in support care is included for 25% of clinical cases	***
Prevention	Not available	-	***

Based on these assumptions the annual cost of theileriosis in cattle in southern Australia is estimated at $17.8M per year (Table 66).

Table 66: Economic cost of Theileriosis – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	H	M	L
Per Cattle	$1.64	$0.61	$0.32	$0	$0	$0	$27.73	$8.72	$3.91	$29.37	$9.33	$4.23
Per Herd	$299	$111	$59	$0	$0	$0	$5,047	$1,587	$712	$5,346	$1,698	$771
Total	**$1.2M**			**$0M**			**$16.5M**			**$17.8M**		

The net gain from moving all southern herds experiencing Theileriosis to the lowest level of disease is estimated at $5.8M.

Assumptions: Theileriosis (northern)

Table 67: Assumptions: theileriosis – northern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	50% of northern cattle population in exposed region (coastal)	Exposure *to Haemaphysalis spp* tick vector host ranges and the high rate of movement of cattle towards coastal zones leads to approximately 50% exposure of the northern herd	**
% herds infected	Disease incidence is half that of southern industry 0.5% of herds newly infected and previously naïve, highly affected: 12.5% of herd (all ages) infected 5% of herds moderately affected: 5% of young stock, 2% of older stock infected 17% of herds lowly affected: 0.5% of young stock and 0% of older infected	This assumption is due to the higher prevalence of the less virulent *T. buffeli* strain in the north	**
Mortalities	10% in young stock, 5% in older.	-	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Weight loss	Significant weight loss in affected (20kg in young stock, 10kg in older stock)	-	**
Fertility	Clinical cases have reduced fertility (45% pregnancy rate versus 90% pregnancy rate), Clinical course of disease 3 months therefore average reduction in pregnancies for clinical cases is 11%	-	*
Market avoidance	Nil	-	**
Movement restrictions	Nil	-	**
Treatment	Not available	An average of $25 per head in support care is included for 10% of clinical cases	***
Prevention	Not available	-	***

Based on these assumptions the annual cost of theileriosis in cattle in northern Australia is estimated at $1.0M (Table 68).

Table 68: Economic cost of theileriosis – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0.50	$0.10	$0.01	$0	$0	$0	$3.81	$1.54	$0.17	**$4.32**	**$1.64**	**$0.19**
Per Herd	$315	$65	$8	$0	$0	$0	$2,384	$962	$108	**$2,699**	**$1,027**	**$116**
Total	**$0.1M**			**$0M**			**$1.0M**			**$1.0M**		

The net gain from moving all northern herds experiencing theileriosis to the lowest level of disease is estimated at $0.7M.

Total cost of disease

The total cost of theileriosis in cattle across Australia at the current prevalence of disease is estimated at $18.8M. The 2015 estimate was $19.6M per annum (equivalent to $22.2M in 2022). The net gain from moving all herds experiencing theileriosis to the lowest level of disease for their regions is estimated at $6.5M.

<u>Changes since last report</u>

Infection and disease is now established. The geographic distribution of the endemic region appears set by the host bush tick *H. longicornis*. Clinical disease is mostly seen in naïve animals — calves and introduced cattle — the high numbers of cattle moved each year increases the exposure to beyond the numbers of cattle that were born within bush tick endemic regions. The challenge to naïve cattle moved into endemic regions will be ongoing. Theileriosis is ranked 14th in this report. The original 2015 ranking was 13th.

4.1.15 Trichomoniasis

The disease

Bovine trichomoniasis is caused by a protozoan parasite (*Trichomonas foetus*) that is sexually transmitted between cattle (*Trichomoniasis | Meat & Livestock Australia*, no date). Infection is often subclinical but is associated with early pregnancy loss, abortion and pyometra (Irons *et al.*, 2022). Clinical disease is most often seen in young (naïve) cows as immunity develops in exposed cattle. Herd bulls play a major role in spread of disease, especially in herds using uncontrolled mating.

	Unknown aetiology									*Known aetiology*
2022									X	

Prevention

There is no commercially available vaccine for trichomoniasis. Older bulls can become chronically (but asymptomatically) infected, and they maintain the protozoa within their wrinklier prepuces. Maintenance of a young bull herd, seasonal mating, culling of cows with pyometra and testing of bull introductions are the primary controls. Previously exposed cows mostly develop immunity such that they typically recover from the loss of a pregnancy to become pregnant and carry the calf to term.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2022				X						

Treatment

There are no treatments. Chronically infected bulls and cows with pyometra should be culled.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2022					X					

Distribution

The bacterium is widespread but has a north-south prevalence gradient (Irons *et al.*, 2022). Northern herds (with a higher frequency of uncontrolled mating, and often with difficulty in maintaining a closed bull herd) have a higher prevalence of infected bulls. Northern state bulls were identified to have a prevalence of infection between 11–15%. A lower prevalence was found in southern herds, but this predominately northern study may have underestimated the prevalence of infection in southern bulls due to the sampling sites all being in the north. Increased use of artificial insemination, the maintenance of closed bull herds and use of seasonal mating practices more common in the southern industry will help to restrict spread of infection.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2022					X					

Prevalence

An exposure study found an 17.6% decrease in the mean number of calves produced over a three-year period comparing exposed to unexposed herds (Clark, Dufty and Parsonson, 1983). Reduction was greatest in the early years of exposure because most cows were naïve. The expected reduction in pregnancy rate in endemic herds is likely less; probably around 1–2% as only heifers and young cows will be naïve in most herds.

Prevalence decreasing — *Prevalence increasing*

2022					X					

Economics

Assumptions: Trichomoniasis – southern

Table 69: Assumptions: trichomoniasis – southern (cattle)

Variable	2022 Assumptions	Confidence
Regional Extent	2%, 10%,3% and 85% of herds with a high, medium, low and nil prevalence rate	*
% herds infected	An average of 6.3%, 3.1% and 0.8% of cows are infected annually resulting in 3.0% 1.5%, and 0.5% of cows failing to raise a calf annually in high, medium and low incidence herds, respectively	**
Mortalities	No mortalities caused	***
Weight loss	No temporary weight loss	***
Fertility	50% of infected cows fail to produce a calf	**
Market avoidance	No market impact	***
Movement restrictions	Nil	***
Treatment	Nil	***
Prevention	NIl	**

Based on these assumptions the annual cost of trichomoniasis in cattle in southern Australia is estimated at $3.7M (Table 70).

Table 70: Economic cost of trichomoniasis – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$0	$0	$0	$8.69	$4.35	$1.11	**$8.69**	**$4.35**	**$1.11**
Per Herd	$0	$0	$0	$0	$0	$0	$1,599	$800	$204	**$1,599**	**$800**	**$204**
Total	**$0M**			**$0M**			**$3.7M**			**$3.7M**		

The net gain from moving all southern herds experiencing trichomoniasis to the lowest level of disease (disease-free) is estimated at $3.7M.

Assumptions: Trichomoniasis – northern

Table 71: Assumptions: trichomoniasis – northern (cattle)

Variable	2022 Assumptions	Confidence
Regional Extent	5%, 25%, 10% and 60% of herds with a high, medium, low and nil prevalence rate	**
% herds infected	An average of 10%, 4% and 2% of cows are infected annually resulting in 5.0% 2%, and 1% of cows failing to raise a calf annually in high, medium and low incidence herds, respectively	**
Mortalities	No mortalities caused	***
Weight loss	No temporary weight loss	***
Fertility	50% of infected cows fail to produce a calf	**
Market avoidance	No market impact	***
Movement restrictions	Nil	***
Treatment	Treatment rarely used	***
Prevention	Vaccination of bulls in 60% of herds, and 15% of heifers vaccinated in high-prevalence herds	**

Based on these assumptions the annual cost of trichomoniasis in cattle in northern Australia is estimated at $11.2M (Table 72).

Table 72: Economic cost of trichomoniasis – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$0	$0	$0	$6.18	$2.50	$1.10	**$6.18**	**$2.50**	**$1.10**
Per Herd	$0	$0	$0	$0	$0	$0	$5,345	$2,160	$956	**$5,345**	**$2,160**	**$956**
Total	**$0M**			**$0M**			**$11.2M**			**$11.2M**		

The net gain from moving all northern herds experiencing trichomoniasis to the lowest level of disease (disease-free) estimated at $11.2M.

Total cost of disease

The total cost of trichomoniasis in cattle across Australia at the current prevalence of disease is estimated at $14.8M. The net gain from moving all herds to the lowest level of disease (disease free) is estimated at $14.8M.

Changes since last report

This is the first inclusion of trichomoniasis in this report. Trichomoniasis is ranked 15th in this report.

4.1.16 Infectious bovine keratoconjunctivitis (Pinkeye; IBK)

The disease

Infectious bovine keratoconjunctivitis (IBK, or Pinkeye) is a multifactorial disease that results in infection of the eye. The bacteria *Moraxella bovis* and more recently *Moraxella bovoculi* have been identified as agents of disease, but these pathogens are not isolated from all cases of pinkeye and there are several strains of varying virulence for each pathogen. *M. bovis* is often isolated from healthy eyes (Loy *et al.*, 2021); a temporal association between pathogen and disease is often not clear. Other pathogens such as *Chlamydia spp.*, *mycoplasma spp.*, bovine herpes virus and *Listeria monocytogenes* are associated with pinkeye-like disease (Loy, Clothier and Maier, 2021). It is likely that other factors (host, environment and other pathogens) that result in corneal damage are necessary for these Moraxella species to produce disease (Kneipp, Green, *et al.*, 2021b). Pinkeye pathogenesis may resemble bovine respiratory disease in that a number of predisposing factors and several microbiological agents are necessary in combination to produce clinical disease (Loy, Clothier and Maier, 2021). Pinkeye occurs in all cattle producing regions of Australia, but outbreaks remain unpredictable, suggesting there continue to be gaps in knowledge about pinkeye. Disease is more common in naïve animals; outbreaks are more common in young stock (Kneipp, Green, *et al.*, 2021b), and in spring and summer in the southern industry. Outbreak risk factors identified in Australia include dust levels (high > low), fly concentration (high > low), rainfall (high < low), location (southern > northern), farm grazing area (large farm > small farm), breed (zebu < taurus; Herefords higher incidence than Angus) and age of cattle (old < young) (Kneipp, Green, *et al.*, 2021b). Notably, season was not a strong predictor of risk in this survey, but this may have arisen because of the complex interaction between breed, rainfall patterns, timing of the beef production cycle and differences between the northern and southern cattle industries. Airborne particles (dust, plant debris, pollen, farm organic matter etc.) exposure is an important risk factor with over 90% of survey respondents associating dust with outbreaks. Wind speed was not linked to dust exposure, and this suggests that the simple corneal trauma hypothesis alone is inadequate. The bush fly (*Musca vetustissima*) and house fly (*Musca domestica*) are believed to be vectors for spread of Moraxella pathogens. Eye irritation/trauma is similarly associated, but alone is not predictive of outbreaks. A recent study of treatment drug use suggests up to 2.80 M cattle may be affected by pinkeye each year in Australia (Kneipp, Govendir, *et al.*, 2021), given that pinkeye treatments alone totalling $9.8M are spent by producers each year. This is greater than originally modelled in the 2015 report (Lane *et al.*, 2015). A more conservative estimate is that affected cattle may lose weight and there are significant welfare concerns with clinical disease – especially if both eyes are affected concurrently.

	Unknown aetiology									*Known aetiology*
2015							X			
2022						X				

Prevention

Pinkeye vaccines are available. Piligard has three strains of *M. bovis* (but no *M. bovoculi* strains); not all outbreaks are due to the strains contained within the vaccine. Worldwide there is at best modest evidence that vaccination protects against outbreaks (Kneipp, Green, *et al.*, 2021b). Managing dust, flies and eye trauma reduces, but does not eliminate, the risk of outbreaks. An Australian serosurvey found (only) 64% of isolates were homologous with vaccine strains; other infectious agents may be involved. Fly control is used on approximately 50% of affected farms. Minimising dust, isolating affected cattle and controlling flies are recommended practices during outbreaks (*Pinkeye (infectious bovine kerato-conjunctivitis, or IBK) | MBFP | More Beef from Pastures*, no date). *Bos indicus* are less prone to disease than *Bos taurus* and breeds with unpigmented eyelid margins (e.g. Herefords) are more prone than breeds with pigmented eyelid margins (Sheedy *et al.*, 2021).

Low efficacy/ unproven preventives available — *Effective preventives available*

2015								X		
2022							X			

Treatment

Topical antibiotics may be used to treat disease (ointments, sprays, powders). These need to be applied daily to ensure corneal levels remain at therapeutic levels. Veterinarians may inject a depot of antibiotics into the cornea that can last several days. Eye patches and isolation further reduce spread. Treatment is time consuming – repeat yarding needed — and this can be challenging when large herds are affected. There are also significant animal welfare aspects that must be considered. A significant proportion of farmers are unsatisfied with pinkeye treatment efficacy (Kneipp, Green, *et al.*, 2021a); more effective remedies are required.

Low efficacy/ unproven treatments available — *Effective treatments available*

2015								X		
2022							X			

Distribution

Disease is more common in the southern beef industry due primarily to the predominance of *B. indicus* cattle in northern Australia.

Distribution contracting — *Distribution stable* — *Distribution increasing*

2015					X					
2022					X					

Prevalence

Slatter *et al.* (1982) found a high prevalence of farms experiencing disease in southern Australia (80%) and reported a within-herd incidence range of 1% (Tasmania) to 8% (NSW). A more recent survey found 95% of respondents from across Australia had experienced pinkeye in their herd in the previous 12 months (Kneipp, Green, *et al.*, 2021b). An estimate of the proportion of cattle affected by pinkeye each year was 10.25% (Kneipp, Govendir, *et al.*, 2021). We have worked on around 0.5% of the national herd affected each year.

Outbreak *prevalence decreasing* — *Outbreak prevalence increasing*

2015					X					
2022					X					

Economics

Assumptions: Pinkeye – southern

Table 73: Assumptions: pinkeye – southern (cattle)

Variable	2015 Assumption	2022 Assumption Changes	Confidence
Regional Extent	80% of southern cattle properties experience at least once case per year. 80-90% of herds are *Bos taurus*.	-	**
% herds infected	5% of herds highly infected and previously naive (50% of calves and 1% of adults affected) 10% of herds moderately affected (20% of calves and 0.5% of older stock infected) 70% of herds lowly affected (5% of calves and 0% of older stock infected)	5% of herds highly infected and previously naive (50% of calves, 10% yearlings and 1% of adults affected) 10% of herds moderately affected (20% of calves, 2% yearlings and 0.5% of older stock infected) 70% of herds lowly affected (5% of calves, 1% yearlings and 0% of older stock infected) This equates to 4.7% of southern young stock affected and 0.5% of the total southern herd affected each year	**
Mortalities	1% in young stock		*
Weight loss	10 kilograms in young stock (5 kg permanent, 5 kg temporary) 5 kg in older stock (temporary)		**
Fertility	No impact		***
Market avoidance	10% of clinical disease in young stock develop severe corneal scarring precluding them from sale into some markets (e.g. feedlots)		***
Movement restrictions	Nil		***
Treatment	Treatment applied to 75%, 50% and 25% of clinical cases in highly, moderately and lowly affected	Treatment applied to 75%, 50% and 25% of clinical cases in highly, moderately	**

Variable	2015 Assumption	2022 Assumption Changes	Confidence
	herds. Treatment costs assumed at $10.00 head to $12.50 head across the course of disease (multiple yarding and handling, antibiotic treatments, patches etc.)	and lowly affected herds. Treatment costs assumed at $12.50–15.00 head across the course of disease (multiple yarding and handling, antibiotic treatments, patches etc.). Approximately 1.4% of cattle are assumed affected each year in southern Australia	
Prevention	Vaccination deployed in 50% of highly affected, 25% of moderately affected and 15% of lowly affected herds.	As left, vaccine costed at $7.50/head (including labour)	*

Based on these assumptions the annual cost of pinkeye in cattle in southern Australia is estimated at $8.9M (Table 74)

Table 74: Economic cost of pinkeye – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$2.70	$0.66	$0.09	$1.71	$0.86	$0.51	$2.84	$1.04	$0.21	**$9.78**	**$3.29**	**$1.06**
Per Herd	$497	$121	$16	$315	$158	$95	$987	$327	$84	**$1,799**	**$605**	**$195**
Total	**$1.5M**			**$3.0M**			**$4.4M**			**$8.9M**		

The net gain from moving all southern herds experiencing pinkeye to the lowest level of disease is estimated at $3.8M.

Assumptions: Pinkeye – northern

Table 75: Assumptions: pinkeye – northern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	85% of northern cattle herds are *Bos indicus* or crossbreed. Pinkeye is rarely seen in *Bos Indicus* breeds). Disease incidence is less than for southern industry		**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
% herds infected	1% of herds highly infected and previously naive (12.5% of all age groups affected) 3% of herds moderately affected (5% of young stock and 2% of older stock infected) 18% of herds lowly affected (0.5% of young stock and 0% of older stock infected)	- This equates to 0.4% of northern young stock affected and 0.05% of the total northern herd affected each year	*
Mortalities	1% of clinically-affected young stock		**
Weight loss	10 kilograms in young stock (5 kg permanent, 5 kg temporary) 5 kg in older stock (temporary)		*
Fertility	No impact		***
Market avoidance	10% of clinical disease in young stock develop severe corneal scarring precluding them from sale into some markets (e.g. feedlots)		***
Movement restrictions	Nil		***
Treatment	Treatment applied to 25%, 10% and 5% of clinical cases in highly, moderately and lowly affected herds	- Approximately 0.05% of cattle are assumed affected each year in northern Australia	*
Prevention	Vaccination deployed in 25% of highly affected, 10% of moderately affected and 1% of lowly affected herds.		*

Based on these assumptions the annual cost of pinkeye in cattle in northern Australia is estimated at $2.4M (Table 75).

Table 76: Economic cost of pinkeye – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0.65	$0.08	$0.00	$0.86	$0.34	$0.03	$0.96	$0.36	$0.03	$5.06	$1.72	$0.15
Per Herd	$425	$52	$2	$563	$225	$23	$2,337	$852	$77	$3,325	$1,128	$102
Total	**$0.1M**			**$0.2M**			**$0.8M**			**$1.1M**		

The net gain from moving all northern herds experiencing pinkeye to the lowest level of disease is estimated at $0.8M.

Total cost of disease

The total cost of pinkeye in cattle across Australia at the current prevalence of disease is estimated at $10.0M. The 2015 estimate was $13.3M per annum (equivalent to $15.1M in 2022). The net gain from moving all herds experiencing pinkeye to the lowest level of disease is estimated at $4.6M.

<u>Changes since last report</u>

More information on the multifactorial nature of disease has been identified and detailed series of Australian studies have provided insight into the risk factors for disease in Australia and an estimate on the level of disease (Kneipp, Green, *et al.*, 2021b; Kneipp, Govendir, *et al.*, 2021; Kneipp, Green, *et al.*, 2021a).

Pinkeye is ranked 16th in this report. The original 2015 ranking was 14th.

4.1.17 Hydatids

The disease

Hydatid disease is caused by an infection with the intermediate stage of the tapeworm *Echinococcus granulosus*. The definitive host (who carry the tapeworm) in Australia are canids (dogs, dingoes, their hybrids and foxes). Intermediate hosts (who harbour the cysts) include macropods, wombats, domesticated animals (cattle, sheep and pigs) and humans (Wildlife Health Australia, 2018). Wild macropods are the major reservoir for the parasite in Australia and they provide the primary transmission pathway for infection into canids and subsequently into domestic cattle, sheep and humans. Adult tapeworm in the small intestine of a canid definitive host release eggs that pass in faeces. These are subsequently ingested by intermediate hosts (such as grazing livestock) and hatch into hydatid oncospheres that burrow through the intestinal wall and enter the circulation. They subsequently establish as long-lived cysts in tissues such as liver, lungs, kidney, spleen, brain and muscle. Canids that eat cysts within contaminated tissues release protoscolex forms into the gut and these develop into adult tapeworms to complete the life cycle. Cattle are mostly dead-end hosts; few cattle hydatid cysts are fertile. This means cattle play a minor role in maintaining *E. granulosus* in the environment (Davidson, 2002). The tapeworm produces minimal impact on canid hosts; it is the cystic intermediate stage that can produce clinical disease within infected hosts. A recent feedlot study found cattle subsequently identified at meat inspection to contain liver hydatid cysts were 8.7 kg lighter on exiting the feedlot and hot carcase weights were 7.2 kg lighter than unaffected cattle (George, George and Kotze, 2020). Meat inspection data from east-coast abattoirs with high hydatid detection were analysed. Consignments with 100 or more cattle had 50% of lines having at least one hydatid-affected carcase, 40% having a within-line prevalence between 0–10%, 5% having a within-line prevalence 10–20% and 5% having a within-line prevalence of 20% or greater. The overall prevalence of hydatids in identified at meat inspection in these high-prevalence abattoirs was estimated at 5.3%. As the consignment prevalence of hydatids increased (+1%), the lot average carcase weight (-1.9kg), marbling score (-0.38) and MSA grade percentage (-0.15%) decreased. Hydatid-affected carcases were 50% less likely than unaffected carcases to attain an MSA grade (Shephard, 2021). Similar carcases weight losses due to hydatids are reported internationally (Rashid *et al.*, 2019).

Prevention

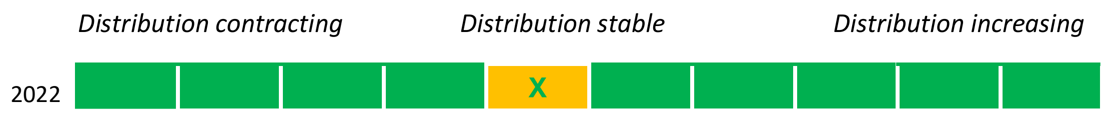
New Zealand declared freedom from hydatids in 2002 (Fisheries, 2014). The intermediate hosts for the hydatid biotype present in New Zealand was primarily adapted to sheep (90% cysts fertile) whereas most cattle cysts were infertile (85%) (Pharo, 2002) and New Zealand does not have a wild canid (host) population. This meant that controlling infection in farm dogs would break the cycle of infection into the sheep and cattle and thereby eradicate disease and this approach was successful in 2002. Australia has native and introduced species as both intermediate and definitive hosts and so eradication is not possible here; the large wild population of canids (wild dogs, dingoes and foxes) provide an ongoing source of infection for livestock despite any tapeworm treatment of domestic dogs. Vaccination of domestic intermediate hosts against hydatid cyst antigens (EG95) have been promising. Australian sheep demonstrated 96% reduction in the number of viable cysts compared to unvaccinated sheep after challenge (Lightowlers *et al.*, 2000), this has subsequently been repeated (Lightowlers, 2002). The impact of vaccination on subsequent cattle (or sheep) carcase performance is unknown.

Treatment

There are no effective treatments for intermediary hosts. Treatment of canid definitive hosts for tapeworms will reduce pasture contamination, but this is impractical for wild canids. Restricting canid access to offal can also limit infection of farm dogs.

Distribution

All of mainland Australia has a dingo/wild dog and/or a fox population; all cattle are potentially at risk of hydatids.



Prevalence

The prevalence of disease is likely stable given the long-standing endemic nature of disease and the dominance of the sylvatic (wild animal) cycle in maintaining disease.

Economics

Assumptions: Hydatids – southern

Table 77: Assumptions: hydatids – southern (cattle)

Variable	2022 Assumptions	Confidence
Regional Extent	10%, 60% and 30% of herds with high, medium and low incidence	*
% herds infected	The average prevalence within slaughter lines of 4.0%, 2.0% and 0.1% for high, medium and low categories	**

	1.6% of all carcases processed in southern Australia are assumed to have hydatids	
Mortalities	No mortalities caused	**
Weight loss	Permanent weight loss of 14 kg (~7.2 kg hot carcase weight reduction) is assumed	*
Fertility	Nil effect	*
Market avoidance	Hydatid-affected offal is devalued. An average loss of $7.50 per affected carcase is assumed from variable loss of liver, spleen, lungs and kidneys in affected organs). MSA downgrades averaging $50 per affected carcases have been assumed	**
Movement restrictions	Nil	***
Treatment	As for prevention	**
Prevention	Nil	**

Based on these assumptions the annual cost of hydatids in cattle in southern Australia at $2.3M (Table 78).

Table 78: Economic cost of hydatids – southern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$0.00	$0.00	$0.00	$0.53	$0.26	$0.01	**$1.00**	**$0.50**	**$0.02**
Per Herd	$0	$0	$0	$0	$0	$0	$97	$48	$2	**$184**	**$92**	**$4.6**
Total	**$0M**			**$0M**			**$2.3M**			**$2.3M**		

The net gain from moving all southern herds experiencing hydatids to the lowest level of disease is estimated at $2.2M.

Assumptions: Hydatids – northern

Table 79: Assumptions: hydatids – northern (cattle)

Variable	2022 Assumptions	Confidence
Regional Extent	15%, 65% and 20% of herds with high, medium and low incidence	*
% herds infected	The average prevalence within slaughter lines of 7.0%, 3.5% and 0.5% for high, medium and low categories. 3.4% of all carcases processed in northern Australia are assumed to have hydatids	**

Variable	2022 Assumptions	Confidence
Mortalities	No mortalities caused	**
Weight loss	Permanent weight loss of 14 kg (~7.2 kg hot carcase weight reduction) is assumed	*
Fertility	Nil effect	*
Market avoidance	Hydatid-affected offal is devalued. An average loss of $7.50 per affected carcase is assumed from variable loss of liver, spleen, lungs and kidneys in affected organs). MSA downgrades averaging $25 per affected carcases have been assumed	**
Movement restrictions	Nil	***
Treatment	As for prevention	**
Prevention	Nil	**

Based on these assumptions the annual cost of hydatids in cattle in northern Australia is estimated at $7.5M (Table 80).

Table 80: Economic cost of hydatids – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$0	$0	$0	$1.54	$0.76	$0.11	**$1.97**	**$0.98**	**$0.14**
Per Herd	$0	$0	$0	$0	$0	$0	$969	$480	$69	**$1,238**	**$615**	**$88**
Total	**$0M**			**$0M**			**$7.5M**			**$7.5M**		

The net gain from moving all northern herds experiencing hydatids to the lowest level of disease is estimated at $6.3M.

Total cost of disease

The total cost of hydatids in cattle across Australia at current prevalence is estimated at $9.8M per annum. The net gain from moving all herds to the lowest level of infestation is estimated at $8.6M.

Changes since last report

This is the first time Hydatids has been evaluated. It has a ranking of 17^{th}.

4.1.18 Tick fever

The disease

Bock reviewed tick fever in north Australia (Bock, 1999). Tick fever is the combined diseases caused by three protozoan parasites (*Babesia bovis, Babesia bigemina, Anaplasma marginale*) that inhabit host red blood cells and are transmitted between cattle by various life stages of the cattle tick, *Rhipicephalus microplus*. *A. marginale* can also be spread mechanically by blood-contaminated equipment like syringes. Haemolysis is a common feature of each disease. Most disease is caused by *B. bovis* ('Primefact: Tick fever', 2020) which is likely linked to the rapid proliferation within infected ticks and their larvae whereas *B. bigemina* takes longer to mature within the tick host and the parasite is only spread by nymph and adult ticks and *A. marginale* is mostly transmitted by the more sedentary male ticks. The severity spectrum of disease is from *A. marginale* (most severe) to *B. bovis* and then *B. bigemina* (least severe), with some variation in virulence of organisms. Cattle that recover from clinical disease tend to be carriers of the parasite for life. Increasing *Bos indicus* content generally confers greater resistance to clinical disease. Cattle aged up to at least nine months are not usually susceptible to tick fever. Transmission of disease is affected by parasitaemia rates in ticks and the survival and attachment rates of ticks which are highest in warm moist conditions. In a field transmission study, 20% of infected crossbred steers experienced severe clinical disease, with 2% mortality, which is consistent with reported field outbreaks in northern Australia during 1990-98. There is no published data to support significant permanent weight loss or reduced calf output due to tick fever.

	Unknown aetiology									*Known aetiology*
2015									X	
2022									X	

Prevention

A trivalent vaccine available from DAFF in Queensland is considered to achieve 85-95% immunity (Bock, 1999). This is a live vaccine, and has a four-day shelf life so its use must be planned, however immunity is lifelong in vaccinates (*Five ways to prevent tick fever in cattle | Meat & Livestock Australia*, no date). Managing tick populations to achieve infection in juvenile cattle is a key strategy, which must take account of parasites being present in as few as 0.04% of ticks (Bock, 1999). Vaccinating all calves at 3–9 months of age provides the best combination of protection against clinical disease and maintenance of adequate herd immunity. O'Rourke (O'Rourke, K. Winks and Kelly, 1992) reported that approximately 20% of cattle within the infected region are vaccinated. An estimated 600K doses of tick fever vaccine are sold annually, with most going into weaners. Tick control also prevents infection. Increasing the Bos indicus content of herds also reduces tick attachments (*Cattle tick fever | Meat & Livestock Australia*, no date) and increases innate resistance to tick fever (*Five ways to prevent tick fever in cattle | Meat & Livestock Australia*, no date). Pasture rotation can help break the tick life cycle; especially for high-risk stock such as young stock and heavily pregnant cows. Planned control treatments of cattle kill the egg-laying female ticks. Repeating treatment for 4–5 consecutive tick life cycles can markedly reduce the tick population, whilst ensuring residual natural exposure maintains some herd immunity (http://www.wrightwaydesign.com.au, no date).

Low efficacy/ unproven preventives available — *Effective preventives available*

2015									X	
2022								X		

Treatment

Treatment is rarely instituted under field conditions. Oxytetracycline is reported effective against *Anaplasma*. Imidocarb is effective against *Babesia*.

Low efficacy/ unproven treatments available — *Effective treatments available*

2015							X			
2022							X			

Distribution

Dry and cool climate areas combined with tick-free zones restricts the vector, thus the disease to eastern and northern areas of Queensland, Northern Territory and Western Australia. Approximately 45% of Queensland's cattle are within the tick-free zone. There is a low prevalence of ticks in Queensland's endemic tick zones beyond 200 km from the coast following droughts in the 1990's, 2000's and current, where approximately 40% of cattle are reared. There has been limited resurgence of ticks during wetter years where dry seasonal conditions have mostly eliminated them, however as discussed under ticks, the warming climatic does support a southwards expansion of the habitat of *R. microplus* due to increasing minimum winter temperatures.

Distribution contracting — *Distribution stable* — *Distribution increasing*

2015					X					
2022						X				

Prevalence

Tick fever and the mortality it causes are dramatic. Bock reported that 4-23% of over 7,000 cattle surveyed in NW Queensland in the dry years of 1996-97 had tick fever immunity. However, in a sub-coastal herd in central Queensland, immunity in yearlings was 63% to *B bovis* and 95% to *Anaplasma* (Bock, 1999). Also reported that in the period 1990-98, only 25 cases of tick fever were confirmed across north Australia with an average of approximately 50 mortalities per year (Bock, 1999). Tick fever outbreaks are limited in high-prevalence areas as most juvenile cattle gain immunity, and it is in regions where infected ticks are not continually present and may be transported in on cattle that cattle are at most risk.

Prevalence decreasing — *Prevalence increasing*

2015					X					
2022						X				

<u>**Economics**</u>

Assumptions: Tick fever – southern

As tick fever is restricted to northern Australia, the annual cost of tick fever in southern Australia is nil.

Assumptions: Tick fever - northern

Table 81: Assumptions: tick fever – northern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	25%, 40% and 35% of herds with a medium, low and nil incidence		*
% herds infected	An average of 1% of cattle are naïve and have a severe clinical infection annually and once every 5 years in medium and low incidence herds, respectively	As left, but every age cohort affected	*
Mortalities	10% of clinically-affected cattle die		**
Weight loss	No temporary weight loss		*
Fertility	No measurable fertility impacts		**
Market avoidance	Low market impact, though some live export market protocols require no recent tick fever outbreaks		***
Movement restrictions	Nil		***
Treatment	Treatment rarely used		***
Prevention	33% of juvenile cattle within the infected region are vaccinated, plus 25% of bulls in their lifetime	Tick fever vaccine costs of $7.00 per dose (including labour) have been assumed. An estimated 600K doses of vaccine are administered annually	**

Based on these assumptions the annual cost of tick fever in cattle in northern Australia at $7.6M (Table 82).

Table 82: Economic cost of tick fever – northern (cattle)

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	H	M	L
Per Herd	$0	$0	$0	$0	$429	$427	$0	$1,016	$204	**$0**	**$1,445**	**$630**
Per Cattle	$0	$0	$0	$0.00	$0.49	$0.49	$0.00	$1.16	$0.23	**$0.00**	**$1.65**	**$0.72**
Total	**$0M**			**$3.4M**			**$4.1M**			**$7.6M**		

There is a gain of $2.5M from moving moderately affected herds to the lowest level of disease.

Total cost of disease

The total cost of tick fever in cattle across Australia is estimated at $7.6M. The 2015 estimate was $4.3M per annum (equivalent to $4.9M in 2022). The 2015 estimate would have been $6.3M if the 1% incidence for moderately affected herds was extended across all adult age cohorts (equivalent to $7.1M in 2022), as was assumed here.

Changes since last report

Nil

Tick fever is ranked 18th in this report. The original 2015 ranking was 15th.

4.1.19 Removed diseases

Bovine Johne's disease has been removed from the priority list. The economic assessment underpinning the removal is presented in section 6.1.1.

4.2 Sheep Diseases

4.2.1 Peri-natal mortalities

The Syndrome

Peri-natal mortality is a complex syndrome resulting in the death of newborn lambs of up to a week of age. The causes of mortality are numerous with starvation-mismothering, still birth, birth injury, dystocia, death in utero – prematurity, primary predation (foxes, wild dogs, pigs and crows) and cold exposure the most common causes. Other causes include neonatal infection with several minor causes making up the remainder. There is a complex interaction of nutrition, environmental factors, sheep genotype and management within the syndrome. A study into neonatal lamb deaths within the Sheep CRCs information nucleus flock found the probability of a lamb falling into any mortality category was predicted by mean birthweight, within birth type with single-born lambs more likely to die from dystocia and stillbirth and twin lambs were likely to die from birth injury, starvation-mismothering or from undiagnosed causes (Refshauge *et al.*, 2016).

Typical peri-natal lamb mortalities range from 10-35% (G. Hinch and Brien, 2013). Industry recommends that losses should not exceed 10% for singles and 20% for twins (www.Lifetimewool.com). Typical industry peri-natal losses are 10% for singles and 30% for twins (*Making More From Sheep - Home*, 2014). Allworth (Allworth, Wrigley and Cowling, 2017) observed peri-natal mortality in 10-12% of merino single lambs and 30% in twin merino lambs. In contrast, neonatal lamb mortality was much lower for meat-breed ewes, with 4% of single and 21% of twin lambs dying. Rates were slightly higher in maidens.

Often the causes of loss of neonatal lambs are dependent. Note that dystocia mortalities are also considered separately (along with ewe mortalities) as a subset of peri-natal lamb mortalities. The causes of peri-natal lamb mortalities are well known though complicated by numerous risk factors.

Prevention

It is unrealistic to prevent all peri-natal mortalities, though substantial industry improvements can be made. Prevention requires a multifactorial systems approach including management of the breeding flock, optimising nutrition (lifetime ewe management), genetic improvement, flock health and farm planning to improve pastures and shelter. Lockwood (Lockwood *et al.*, 2020) found that reducing mob size (by 100 ewes) during lambing for single and twin-bearing ewes is associated with an increase in lamb survival on average. Typical feeding costs are about $5.00 per ewe, though this is dependent on season and pastures. Long term gain through genetic improvement is beneficial, though this cost is not considered in this analysis, nor is the cost of land improvement including shelter, subdivision and breed selection. Supervision of the lambing flock cost is included here. Management is the key to prevention and must be managed in the context of optimising flock nutrition, other diseases and syndromes.

Low efficacy/ unproven preventives available *Effective preventives available*

2015							X			
2022								X		

Treatment

Treatment of peri-natal mortalities largely relates to supervision of lambing ewes. Intensive supervision must be balanced with minimising interruption of lambing ewes where risk is low.

Low efficacy/ unproven treatments available *Effective treatments available*

2015							X			
2022							X			

Distribution

The distribution is stable.

Distribution contracting *Distribution stable* *Distribution increasing*

2015					X					
2022					X					

Prevalence

In this study the prevalence of peri-natal mortalities was assumed to be 23% for Merinos and 17% for prime lamb flocks. Prevalence is generally constant – but influenced by season. The trend towards more meat-breed sheep may reduce the number of peri-natal mortalities in the longer term.

Prevalence decreasing *Prevalence increasing*

2015						X				
2022						X				

Economics

Assumptions: Peri-natal mortalities

Table 83: Assumptions: peri-natal mortalities in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	All regions	-	***
% flocks affected	Average peri-natal lamb losses due to all causes based on ewe flock include: - Merino X Merino: 23% - Dual purpose: 22%	Average peri-natal lamb losses due to all causes based on ewe flock include: - Merino X Merino: 23% - Dual purpose: 22% - Specialist prime lamb: 17%	***

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	- Specialist prime lamb (first cross ewes X terminal sire): 17% (Holst, Fogarty and Stanley, 2002a; Victorian Department of Environment and Primary Industries, 2012; K. Geenty *et al.*, 2013)	Same references as 2015 plus (G. N. Hinch and Brien, 2013a; Allworth, Wrigley and Cowling, 2017; Hutchison *et al.*, 2022) -	
Mortalities	See above. Nil ewe mortalities	-	***
Weight loss	Ewes that fail to rear lambs are 6% heavier in summer (Lee *et al.* 1995) have a subsequent fertility benefit of 4.5%. No other production losses are attributed to peri-natal mortality including impact on flock stocking rate or age structure.	-	***
Fleece weight	Ewes that lose lambs should produce about 6% more wool due to no lactation (Lee and Atkins, 1995a).	-	***
Wool	Ewes that do not rear lambs will produce slightly broader fleece and 2 N/kTex lower staple strength (Scrivener and Vizard, 1997)	-	**
Fertility	4.5% more lambs produced in following year	-	**
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	There is no treatment considered	-	***
Prevention	Supervision of flocks to reduce ewe losses primarily due to dystocia is adopted widely. On average, 80% of specialist prime lamb flocks and dual-purpose flocks supervise lambing with 50% of Merino flocks supervising lambing at a cost of $0.05/ewe day for 6 weeks. The most important aspects of prevention relate to genetic improvement and nutritional management, paddock selection and long-term	Supervision of flocks to reduce ewe losses primarily due to dystocia is adopted widely. On average, 80% of prime lamb flocks and dual-purpose flocks supervise lambing with 50% of Merino flocks supervising lambing at a cost of $0.06/ewe day for 6 weeks. The most important aspects of prevention relate to nutritional management, paddock selection and long-term investment in	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	investment in shelter which should be undertaken to optimise flock reproductive performance. The average cost of nutrition alone is assumed to be $1.50/ewe. Note that investment in shelter is not included.	shelter which should be undertaken to optimise flock reproductive performance. The average cost of nutrition above maintenance is assumed to be $2.00/ewe. Long term genetic improvement will reduce peri-natal lamb mortality but no cost is included. Note that investment in shelter and paddock subdivision not included	

Based on these assumptions the annual cost of peri-natal mortalities in sheep in Australia is estimated at $851M (Table 84). The 2015 estimate was $540.4M (equivalent to $613.4M in 2022).

If peri-natal mortality rates reduce by 5%, an additional $211M income would be generated before considering any extra costs to achieve the reduction. Whilst it is unrealistic to eliminate all peri-natal lamb mortalities, there are many opportunities to reduce some losses. If peri-natal mortality rates are reduced to industry recommendations of no more than 10% for singles or 20% for twins (www.Lifetimewool.com), an additional $296M income would accrue before costs. Consideration needs to be given to each strategy. The extra income gained must be viewed considering the extra costs to achieve these gains and the impact of additional lambs on flock structure, stocking rate and enterprise mix.

Table 84: Economic cost of peri-natal mortalities in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$1.98	$0	$0	$11.24	$0	$0	**$13.22**	**$0**	**$0**
Per Flock	$0	$0	$0	$3,956	$0	$0	$22,746	$0	$0	**$26,701**	**$0**	**$0**
Total	**$0M**			**$126.0M**			**$724.6M**			**$850.6M**		

Note that the costs of dystocia and mastitis are also included although they are separately under these diseases. The relative contribution of these diseases/conditions to peri-natal lamb mortality is shown in Table 85. Campylobacter-associated and other infectious abortions are also considered separately, although some peri-natal deaths are likely to be due to campylobacter abortions and other causes of abortion.

Table 85: Relative cost of peri-natal mortalities

Disease/syndrome	Direct losses of peri-natal lamb mortalities	% of total peri-natal losses
Peri-natal lamb mortalities	$772M*	
Dystocia	$463.0M	60%
Mastitis	$73.4M	9%

* Note that production losses of $724.6M in Table 84 is less than the $772M in Table 85 because it includes offsetting costs associated with increased wool production and increased bodyweight in the ewe following lamb loss.

Changes since last report

The annual impact of perinatal lamb mortalities has increased substantially due to higher commodity prices. Costs have increased too, largely in line with CPI. Most assumptions used are similar to those of the 2015 report.

Peri-natal Mortalities was ranked 1st in this report. The original 2015 ranking was also 1st.

4.5.2 Internal parasites

The disease

Gastrointestinal parasites and lungworm occur in all sheep-producing regions of Australia. The amount and distribution of rainfall determines which parasites predominate and their financial impact, both from lost production and from costs of treatment and control. Infections are more problematic in high-rainfall areas (an annual rainfall of >450 mm). The effects of parasitism are more severe in young animals and late pregnant and lactating ewes, especially in maiden and older ewes.

Previous studies ranked gastro-intestinal parasites as one of the costliest animal health conditions (McLeod, 1995; Sackett *et al.*, 2006; Lane *et al.*, 2015) in Australia and that most of the costs were attributable to lost production rather than to treatment costs.

The overwhelming conclusion, supported by past on-farm demonstration studies (Kahn, Larsen and Woodgate, 2007; Kahn *et al.*, 2015; Kirk *et al.*, 2021) is that internal parasites are a major constraint on production in Australian sheep flocks. Production losses in the animal occur primarily as a result of reduced food intake, but also accrue from poor nutrient utilisation and redistribution of protein for tissue repair (L. Symons and Steel, 1978; Sykes and Coop, 2001). Less obviously, there may be substantial indirect costs associated with internal parasites. For example, the stocking rate, flock structure and grazing management on farms in high-rainfall areas of Australia are often influenced by the producer's attitude to internal parasites (Lean, Vizard and Ware, 1997).

Young sheep are the most susceptible to internal parasite infections. Uncontrolled clinical infections in young sheep can result in mortality rates that approach 100%; but such severe losses are rare because most producers use some form of control. In contrast, sub-clinical infections are common and may reduce liveweight gains by about 20% and wool growth by up to 30% in both young and adult sheep (Barger, 1982).

There have been changes in the distribution and population of the national sheep flock, additionally, the relative value of sheep meat and wool production has also changed, along with the cost of treatments.

Anthelmintic resistance is a serious constraint to sheep production in many properties within the high rainfall areas. There is some evidence that farms in the high winter rainfall zone are able to manage effective worm control programs that use strategically-timed drench treatments which are integrated with other control options, such as testing for drench resistance, monitoring worm egg counts, grazing management and the selection of sheep with enhanced immunity to internal parasites (see WormBoss 2014), (Larsen *et al.*, 2006; Wormboss, 2014). Anthelmintic resistance is potentially more serious in uniform and summer dominant rainfall areas, where barber's pole worm (*Haemonchus contortus*) is consistently present, as populations can increase rapidly and cause significant mortalities in both ewes and lambs. Effective long-term control strategies seek to minimise the impact of parasites but also reduce the rate of development of anthelmintic resistance. This is done typically by reducing the number of treatments and integrating these treatments with other control options as mentioned above (Besier and Love, 2003; Larsen, 2014).

Nevertheless, some production loss is inevitable even when relatively immune sheep are exposed to infection. Losses include 3-5% lower bodyweights and 10% less wool production in both Merinos and prime-lamb breeds (Barger and Southcott, 1975; Kahn, Larsen and Woodgate, 2007; Kahn *et al.*, 2015). Decreased growth rates also occur in rapidly growing prime lambs, although these effects can be contained when the amount and quality of pasture offered is good. For example, prime lambs kept free of internal parasites by continuous suppressive treatment with ivermectin capsules gained 1.6 kg more than untreated lambs (Carmichael, O'Callaghan and Martin, 2005). Similar, but less consistent, differences were observed in a project comparing untreated lambs with a cohort treated with long-acting moxidectin injections in four regions of eastern Australia (Kahn *et al.*, 2015). Kirk (Kirk *et al.*, 2021) also found ewes were more vulnerable to parasitism when immature, twin-bearing or were under nutritional stress. The effects of parasitism were reduced when peri-parturient ewes were held in optimal body condition score and grazed adequate pastures.

In winter and uniform rainfall areas the accumulation of 'dag' on breech wool was associated with substantially increased costs. This is predominantly due to 'hypersensitivity scouring' in adult sheep, which is an immune response by certain sheep following challenge with worm larvae (Larsen *et al.*, 1994). In addition to direct costs associated with crutching, dag is also a major risk factor for breech strike in these areas (Tyrell, Larsen and Anderson, 2014).

	Unknown aetiology									*Known aetiology*
2015										X
2022										X

Prevention

Effective long-term control strategies seek to minimise the impact of parasites but also to reduce the rate of anthelmintic resistance development. Prevention is based on a combination of strategic treatment, monitoring to determine the timing and need for additional treatments, monitoring effectiveness of drenches and integrating these with other control options, such as grazing management and selection for sheep with enhanced immunity to internal parasites to reduce the reliance on anthelmintics.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015							X			
2022							X			

Treatment

Treatment in the face of high worm burdens is considered part of prevention programs. The main limitation on the efficacy of anthelmintics is the widespread nature of drench resistance and the limited extent of resistance testing by sheep producers. An inevitable increase in drench resistance is expected for the future arising from a lack of new treatment chemicals and the recent withdrawal of long-acting capsules treatment options. Integrated parasite management tools will need to be progressively adopted by industry.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015								X		
2022							X			

Distribution

The distribution is stable although, with intensification of production systems, worm problems may increase if effective control programs are not implemented. The occurrence of severe outbreaks may increase in some areas, and the distribution of certain parasites, such as Haemonchus, may be slowly expanding due to increased stock movements and long-term effects of climate change.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022						X				

Prevalence

Prevalence is variable between years depending on (changing) climatic conditions. Prevalence may increase in the long term unless there is greater uptake of continual monitoring of drench resistance by industry as ongoing use of products with suboptimal efficacy will increase parasite burdens and challenge.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: Internal parasites

Table 86: Assumptions: internal parasites in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Distribution Australia wide, though problems are more serious in higher rainfall regions particularly above 450mm rainfall.	-	***
% Flocks affected	All flocks affected though with differing levels. Different risk zones are considered: High rainfall high risk (41%), Wheat sheep zone medium risk (47%) and Pastoral zone low risk (12%).	All flocks affected though with differing levels. Different risk zones are considered: High rainfall high risk (41%), Wheat sheep zone medium risk (51%) and Pastoral zone low risk (8%).	***
Mortalities	Merinos High rainfall: Weaners: 3.5%, Adults: 1.7%	High rainfall: weaners 2.5, adults 1.5% Wheat sheep: weaners 1.4%	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	Summer rainfall: Weaners: 6.4%, Adults: 3.2% Wheat sheep: Weaners: 1.4%, Adults: 0.4% Pastoral: Weaners: 0.2%, Adults: 0.05% *Prime lambs: 30% of Merino enterprises*	All else similar	
Weight loss	<u>Temporary kg BW loss</u> High rainfall: Weaners: 0.8, Adults: 1.7 Summer rainfall: Weaners: 0.8, Adults: 1.7 Wheat sheep: Weaners: 0.3, Adults: 1.0 Pastoral: Weaners: 0.1, Adults: 0 <u>Permanent kg BW loss</u> High rainfall: Weaners: 0.8, Adults: 1.7 Summer rainfall: Weaners: 0.8, Adults: 1.7 Wheat sheep: Weaners: 0.3, Adults: 1.0 Pastoral: Weaners: 0.1, Adults: 0 *Prime lambs: 80% of Merino enterprises* (Barger and Southcott, 1975; Carmichael, O'Callaghan and Martin, 2005; Kahn, Larsen and Woodgate, 2007; Kahn *et al.*, 2015)	-	**
Fertility decline	1.5% per kg bodyweight loss	-	**
Fleece weight loss %	<u>Merinos</u> High rainfall: Weaners: 6.1%, Adults: 6.1% Summer rainfall: Weaners: 6%, Adults: 6% Wheat sheep: Weaners: 2.7%, Adults: 2.7% Pastoral: Weaners: 0.5%, Adults: 0% *Prime lambs: 2/3rd of Merino enterprises* (Barger and Southcott, 1975; Kahn, Larsen and Woodgate, 2007; Kahn *et al.*, 2015)	-	**
Staple strength	<u>Merinos</u> High rainfall: Weaners: 8.5, Adults: 8	3% discount on fleece value merino only	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
discount N/kTex	Summer rainfall: Weaners: 8, Adults: 7 Wheat sheep: Weaners: 3.5, Adults: 0 Pastoral: Weaners: 0, Adults: 0 *Prime lambs: nil* (Sackett *et al.*, 2006)		
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Considered as part of prevention program	-	***
Prevention	<u>Drench frequency (per year)</u> (Weaners / Maiden ewes / Adult ewes / Wethers) High rainfall: 3 / 2.2 / 2.7 / 1.8 Summer rainfall: 5 / 4 / 5.6 / 4.0 Wheat sheep: 2.5 / 1.8 / 1.5 / 1.3 Pastoral: 0.8 / 0.3 / 0.2 / 0 Note ~ 3% capsule & 10% long-acting use in HRZ Cost of drench including labour & adjusted for long acting: $0.45/dose adults, $0.38/weaner <u>Monitoring frequency WEC (per year)</u> (Weaners / Ewes / Wethers) High rainfall: 0.6 / 0.8 / 0.5 Summer rainfall: 0.6 / 1 / 1 Wheat sheep: 0.3 / 0.7 / 0.4	Similar drench frequency assumed as previous 2015 (Sloan, 2019; Colvin, Reeve, Peachey, *et al.*, 2021) 3% capsule use and 5% long acting injectable in HRZ Cost of drench including labour & adjusted for long acting: $0.51/dose adults, $0.43/weaner Drench frequency similar costs per monitor $0.14/sheep Drench resistance trial cost $680, 3.7% flocks	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	Pastoral 0.1 0 0 Cost per sheep per monitor: $0.12/sheep Drench resistance testing: FECRT cost: $600 1% flocks/annum (Reeve and Walkenden-Brown, 2014)	test/annum mostly in HRZ and part wheat sheep zone (Colvin, Reeve, Peachey, *et al.*, 2021)	
Dags	Proportion with dags due to worms |	Weaners	Adults	Reduction in fleece value | High rainfall: 38% 35% $0.34 Summer rainfall: 9% 5% $0.09 Wheat sheep: 14% 14% $0.15 Pastoral 0% 0% $0.00 (Larsen *et al.* 1994) Part crutching cost (of $1.40) allocated to dag management in wheat/sheep (10%) and high rainfall zone (25%)	Reduction in fleece value due to dags - HRZ $0.53 - Summer rainfall $0.14 - Wheat sheep: $0.24 - Pastoral $0.00	**

Based on these assumptions the annual cost of internal parasites in sheep in Australia is estimated at $665M (Table 87). The 2015 estimate was $436M (equivalent to $494.9M in 2022).

Table 87: Economic cost of internal parasites in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$2.07	$1.22	$0.27	$12.64	$5.80	$0.37	**$14.72**	**$7.03**	**$0.64**
Per Flock	$0	$0	$0	$4,462	$2,635	$574	$27.316	$12,534	$806	**$31,788**	**$15,169**	**$1,379**
Total	**$0M**			**$102.5M**			**$562.5M**			**$665.4M**		

If the severity of internal parasites is reduced by 50% before extra costs are considered, then the gain to the industry would be $278M.

Changes since last report

The main changes in the annual cost of internal parasites are due to increased commodity prices for both meat and wool even though the size of the sheep industry has reduced. Small changes to the base assumptions had a small impact on the annual cost of internal parasites. Cost increases by CPI since the last report in 2015 were applied.

Internal parasites in sheep were ranked 2nd in this report. The original 2015 ranking was also 2nd.

4.5.3 Dystocia

The disease

The causes of dystocia in sheep are complex and most associated with foeto-pelvic disproportion, uterine inertia, failure of the cervix to fully dilate, malpresentation and disease or congenital defects in lambs. Risk factors include breed, nutrition, age of dam, metabolic problems such as hypocalcaemia and pregnancy toxaemia, pasture toxicity (such as clover disease) and gender of lamb. There is a clear genetic component and evidence for stress and environmental risk factors impacting dystocia. The cost of dystocia arises from increased peri-natal mortality, ewe mortality and extra supervision associated with lambing. Apart from the direct loss of lambs from dystocia, up to 80% of lambs that die within a few days of birth due to starvation-mismothering-exposure have brain injuries arising from a difficult birth (G. N. Hinch and Brien, 2013b). Dystocia is a risk in all climatic zones.

	Unknown aetiology									*Known aetiology*
2015							X			
2022							X			

Prevention

Prevention of dystocia is largely related to management including nutrition of ewes, avoiding them being too fat or too light (BCS 3-3.5 target). Controlling metabolic disease is important, as is avoiding ewe exposure to toxic pastures. The provision of adequate feed, shelter and smaller mob size during lambing will help reduce the risk of dystocia. Dystocia has low heritability, but genetic selection for reduced dystocia and for some indicator traits such as lambing ease can provide long-term improvements. Breed selection provides another avenue to reduce dystocia.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015							X			
2022							X			

Treatment

Treatment of dystocia largely relates to supervision of lambing ewes. Intensive supervision must be balanced with minimising interruption of lambing ewes where problems are of low risk.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015								X		
2022								X		

Distribution

Distribution is stable.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

Prevalence is generally constant – but influenced by season. With the trend towards more meat-breed sheep, dystocia will likely increase in the interim as a higher proportion of the merino flock is mated to meat-breed sires. However, the long-term trend should be towards reduced dystocia as more of the national flock converts to meat breeds and away from Merinos. A recent review summarised a large number of investigations since the 1990's and found the average lamb mortality attributable to dystocia was 53% (Bruce *et al.*, 2021).

	Prevalence decreasing									*Prevalence increasing*
2015						X				
2022						X				

Economics

Assumptions: Dystocia

Table 88: Assumptions: dystocia in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	All regions	-	***
% flocks affected	Peri-natal lamb losses due to dystocia based on ewe flock include: - Merino X Merino: 5.3% - Dual purpose: 8.4% - Specialist prime lamb (first cross ewes by terminal): 5.0% (Holst, Fogarty and Stanley, 2002b; Victorian Department of Environment and Primary Industries, 2012; K. G. Geenty *et al.*, 2013)	Peri-natal lamb losses due to dystocia have been adjusted since the last analysis, based on an extensive review of by Bruce (Bruce *et al.*, 2021). - Merino X Merino: 11.3% - Dual Purpose 10.8% - Prime lamb 7.8%	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Mortalities	Mortality rates in ewes due to dystocia are assumed to be: - Merino X Merino: 0.26% - Dual purpose: 0.49% - Specialist prime lamb - (first cross ewes by terminal and other): 0.29% - Typical dystocia rates assisted birth: 3.6% (Victorian Department of Environment and Primary Industries, 2012; S. R. McGrath, Lievaart and Friend, 2013)	Recent studies indicate that mortality rates in ewes due to dystocia are higher than previously indicated contributing to about 35% of mortalities over lambing or 0.9% of total ewe numbers (Bruce et al., 2021). The proportion of ewe mortalities due to dystocia is similar (38%) of ewe deaths in the peri-natal period. ((Glanville *et al.*, 2022)	**
Weight loss	Ewes that fail to rear lambs are 6% heavier in summer (Lee *et al.*1995) resulting in a subsequent fertility benefit of 4.5%. No other production losses are attributed to dystocia including impact on flock stocking rate or age structure.	-	***
Fleece	Ewes that lose lambs should produce about 6% more wool due to no lactation (Lee and Atkins, 1995b).	-	***
Wool	Ewes that do not rear lambs will produce slightly broader fleece but their fleece has lower staple strength (2 N/kTex) resulting in a 1% discount in fleece value (Scrivener and Vizard, 1997).	0.25% discount on wool value-	**
Fertility	4.5% more lambs produced in following year	-	**
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	There is no treatment apart from assisting ewes with dystocia.	-	***

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Prevention	Supervision of flocks to reduce ewe losses with dystocia is adopted widely. On average 80% of specialist prime lamb flocks and dual-purpose flocks supervise lambing with 50% of Merino flocks supervising lambing at a cost of $0.05/ewe day for 6 weeks. Further prevention relates to genetic improvement and nutritional management which should be undertaken to optimise flock reproductive performance. The cost of nutrition was not considered as part of this syndrome apart from a small cost of allocation of ewes to paddocks for lambing ($0.30/ewe).	Costs increased by CPI 13.6% Supervision: $0.057/ewe/day for 7 weeks	**

Based on these assumptions the annual cost of dystocia in Australia is estimated at $529M (Table 89). The 2015 estimate was $219M (equivalent to 248.6M in 2022).

Reducing dystocia rates by 50% will produce a gain to the industry of $154M before considering extra costs to achieve the benefit. Note that dystocia is a sub-set of peri-natal lamb mortalities with additional loss from the mortality of ewes included.

Table 89: Economic cost of dystocia in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$1.33	$0	$0	$6.72	$0	$0.	**$8.06**	**$0**	**$0**
Per Flock	$0	$0	$0	$2,742	$0	$0	$13,855	$0	$0	**$19,325**	**$0**	**$0**
Total	**$0M**			**$87.4M**			**$441.4M**			**$528.7M**		

<u>Changes since last report</u>

The annual cost of dystocia to the Australian sheep industry has increased due to higher commodity prices, primarily due to higher livestock values. In addition, assumed dystocia rates have increase due to inclusion of all indirect dystocia cases including stillbirth. The three classes of dystocia include A: dystocia, B: stillborn, C: birth injury.

Dystocia was ranked 3rd in this report. The original 2015 ranking was also 3rd.

4.5.4 Flystrike

The disease

Flystrike is an important disease of sheep with two main presentations: breech strike and body strike. Other sites include pizzle, poll and wound strikes. Breech, body and pizzle strike are considered here. *L. cuprina* is the most important fly species, accounting for at least 90% of all strikes. There are several important risk factors including:

- Susceptible sheep: for breech strike, urine and faecal staining caused by scouring (mostly associated with internal parasites, enteritis and pasture). Less wrinkle and more breech-bare skin area reduces risk, as does mulesing. Sheep that develop fleece rot and dermatophilosis especially in wet conditions are most at risk of body strike. Pizzle strike is associated with urine staining of the belly wool. Sheep genetic change will reduce sheep susceptibility to flystrike over the long term.
- Weather and climate: moist and warm weather is a risk factor for flystrike. Prolonged wet conditions with susceptible sheep often results in flystrike outbreaks.
- Farm management: several management factors impact risk of flystrike. These include time of shearing, crutching, chemical prevention, mulesing, tail docking, control of scouring, paddock selection for susceptible sheep, control of fly numbers and sheep genetics.

The economic cost associated with flystrike arises from mortalities, production losses of lost wool and reduced wool growth and value, weight loss, impaired reproduction in affected animals, treatment and prevention costs.

	Unknown aetiology									*Known aetiology*
2015									X	
2022									X	

Prevention

An integrated approach to flystrike control can be very effective. Controls include reducing sheep susceptibility through chemical control, genetic selection and management and by reducing fly populations in high-risk periods (De Cat, Larsen and Anderson, 2012; Larsen, Tyrell and Anderson, 2012; Lucas and Horton, 2013). Flystrike challenge is expected to increase as the reduction in use of mulesing within the Australian sheep flock continues (mulesing has been an effective preventive for breech strike, especially in merino sheep). An additional challenge for effective flystrike prevention is the increasing emergence of chemical resistance within treatment chemicals. The first signs of chemical resistance in a flock is a shortened chemical protection periods and subsequent increase in the frequency of flystrike.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015								X		
2022							X			

Treatment

Treatment of individual struck sheep is effective, especially if implemented early. Several effective and safe chemicals are available to kill fly larvae in association with the removal of flystrike-affected wool. Clipping and chemical treatment of flystrike-affected regions on sheep is well adopted by industry. Treatment of severe flystrike cases with antibiotics and anti-inflammatory therapeutics will further improve survival rates. The primary limitation to effective flock treatment is the high labour requirement for effective supervision and early intervention. Emergence of chemical resistance to common flystrike chemicals will make the delivery of effective treatment more challenging.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015									X	
2022								X		

Distribution

Distribution is mostly stable, though varies widely with seasonal conditions, which are increasingly variable. Climate change in the long term may increase the potential flystrike risk period with increasing temperature although this may be tempered by lower predicted rainfall. Outbreak years may be less frequent but potentially more severe.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022						X				

Prevalence

Prevalence is generally constant – but influenced greatly by season. This is highlighted by a recent survey (Colvin *et al.*, 2020) that estimated the incidence of breech and body strike in ewes was 2.7% and 2.1% respectively, whereas in 2003 these estimates were 2.2% and 1.0% respectively, and in 2011 (a wet year) were 4.1% and 5.5% respectively. The risk of flystrike will potentially increase if effective preventive treatments are not adopted to offset the decline in mulesing. Managing flystrike will become more difficult with increasing *L. cuprina* chemical resistance.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022						X				

<u>Economics</u>

Assumptions: Flystrike

Table 90: Assumptions: flystrike in sheep

<table>
<tr><th>Variable</th><th>2015 Assumptions</th><th>2022 Assumption Changes</th><th>Confidence</th></tr>
<tr><td>Regional Extent</td><td>High rainfall; wheat-sheep; and pastoral zones are considered as high, medium and low risk respectively.</td><td>-</td><td>***</td></tr>
<tr><td>% flocks infected</td><td>Average flystrike prevalence per property (Sackett et al., 2006)
<table>
<tr><th></th><th>High rain-fall</th><th>Wheat sheep</th><th>Pastoral</th></tr>
<tr><td><u>Ewes</u></td><td></td><td></td><td></td></tr>
<tr><td>body</td><td>2.1%</td><td>1.5%</td><td>2.3%</td></tr>
<tr><td>breech</td><td>2.4%</td><td>2.3%</td><td>2.1%</td></tr>
<tr><td><u>Weaners</u></td><td></td><td></td><td></td></tr>
<tr><td>body</td><td>3.4%</td><td>2.9%</td><td>3.9%</td></tr>
<tr><td>breech</td><td>2.8%</td><td>2.5%</td><td>2.4%</td></tr>
<tr><td>pizzle</td><td>0.5%</td><td>0.9%</td><td>0.2%</td></tr>
<tr><td><u>Wethers</u></td><td></td><td></td><td></td></tr>
<tr><td>body</td><td>1.5%</td><td>1.6%</td><td>2.8%</td></tr>
<tr><td>breech</td><td>0.9%</td><td>1.3%</td><td>2.1%</td></tr>
<tr><td>pizzle</td><td>0.6%</td><td>0.8%</td><td>1.6%</td></tr>
</table>
Note: It is assumed 40-60% of producers jet at strategic times, 30-40% at high-risk times and 20% when fly strike detected. 35% of producers only treat individual struck sheep. 30% cross over between breech and body strike</td><td>Average flystrike prevalence per property (Sackett et al., 2006), Also includes previous benchmarking surveys (Reeve and Walkenden-Brown, 2014; Colvin et al., 2020; Colvin, Reeve, Thompson, et al., 2021)
<table>
<tr><th></th><th>High rainfall</th><th>Wheat sheep</th><th>Pastor</th></tr>
<tr><td><u>Ewes</u></td><td></td><td></td><td></td></tr>
<tr><td>body</td><td>2.1%</td><td>1.8%</td><td>2.8%</td></tr>
<tr><td>breech</td><td>2.7%</td><td>2.0%</td><td>2.3%</td></tr>
<tr><td><u>Weaners</u></td><td></td><td></td><td></td></tr>
<tr><td>body</td><td>3.1%</td><td>3.7%</td><td>3.9%</td></tr>
<tr><td>breech</td><td>3.0%</td><td>2.6%</td><td>2.4%</td></tr>
<tr><td>pizzle</td><td>0.5%</td><td>0.9%</td><td>0.2%</td></tr>
<tr><td><u>Wethers</u></td><td></td><td></td><td></td></tr>
<tr><td>body</td><td>2.3%</td><td>1.7%</td><td>2.8%</td></tr>
<tr><td>breech</td><td>1.4%</td><td>2.2%</td><td>2.1%</td></tr>
<tr><td>pizzle</td><td>0.6%</td><td>0.8%</td><td>1.6%</td></tr>
</table>
Note: It is assumed 40-60% of producers jet at strategic times, 30-40% at high-risk times and 20% when fly strike detected. 35% of producers only treat individual struck sheep. 30% cross over between breech and body strike
-</td><td>**</td></tr>
<tr><td>Mortalities</td><td>10% for adults; 20% for hoggets - averaged across body, breach and pizzle strikes (Sackett et al., 2006; Lucas and Horton, 2013)</td><td>-</td><td>**</td></tr>
<tr><td>Weight loss</td><td>12% for body, breach and pizzle strike (Lucas and Horton, 2013)</td><td>-</td><td>***</td></tr>
<tr><td>Fleece</td><td>Clean fleece weight reduction of 8%</td><td>-</td><td>***</td></tr>
<tr><td>Wool</td><td>Fibre diameter penalty of 1.5 micron/kg cfw loss; staple strength reduction 18 N/KTex for 100% of affected sheep (Colditz et al., 2005; Sackett et al., 2006;</td><td>-</td><td>***</td></tr>
</table>

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	Lucas and Horton, 2013) Wool price discount (%) as per below (Norton, 2012). *Staple strength N/kTex* | *Superfine* | *Fine* 28-38 | 5 | 2 21-28 | 9 | 5 14-21 | 16 | 9 <14 | 18 | 11		
Fertility	1.5% per kg body weight for 50% of body weight loss	-	**
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Clip wool and apply chemical to affected sheep ($5.05/sheep mostly labour - 10 minutes/sheep @ $30/hour), 1% treated with antibiotics @$5.00/sheep. 80% of affected pastoral sheep treated; 90% of wheat-sheep and high rainfall affected sheep are treated.	Clip wool and apply chemical to affected sheep ($5.75/sheep mostly labour - 10 minutes/sheep @ $34/hour), 1% treated with antibiotics @$5.00/sheep. 80% of affected pastoral sheep treated; 90% of wheat-sheep and high rainfall affected sheep are treated.	**
Prevention	Between 40-60% of producers jet at strategic times, 30-40% at high-risk times and 20% when fly strike detected. 35% of producers only treat individual struck sheep. 30% cross over between breech and body strike (Reeve and Walkenden-Brown, 2014). *Chemical group (FlyBoss, 2014)* | *Cost c/sheep crutch & body* Clik | 143 Cyromazine jet | 30 Cyromazine spray | 59 Spinosad | 53 ML | 47	Between 40-60% of producers jet at strategic times, 30-40% at high-risk times and 20% when fly strike detected. 35% of producers only treat individual struck sheep. 30% cross over between breech and body strike. *(Reeve and Walkenden-Brown, 2014; Colvin et al., 2020)* *Chemical group (FlyBoss, 2022)* | *Cost c/sheep crutch & body* Clik | 140 Cyromazine jet | 30 Cyromazine spray | 65 Spinosad | 60-170 ML | 30 Avenge | 120	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	<u>Labour costs:</u> Shortwool backliner: $0.20 Long wool hand jetting: $0.50 Long wool backliner: $0.30 Jetting race: $0.10 Mulesing: $0.90 (excluding lamb marking cost, include Clik) (48% producers mulesing 70% for Merinos 20% for self-replacing meat sheep) Trisolvin: $0.75 (60% use) Crutch: assume 50% of crutch cost allocated to flystrike at $1.40/animal = $0.70	<u>Labour costs:</u> Shortwool backliner: $0.23 Long wool hand jetting: $0.56 Long wool backliner: $0.34 Jetting race: $0.12 Mulesing: $1.10 (excluding lamb marking cost, include Clik) (mulesing 70% for Merinos 12% for self-replacing meat sheep) (Colvin *et al.*, 2020) Trisolvin: $0.72 (87% use) Crutch: assume 50% of crutch cost allocated to flystrike at $2.00/animal = $1.00. Unmulesed Merinos given extra crutch in high rainfall regions	

Based on these assumptions the annual cost of flystrike in sheep in Australia is estimated at $324M (Table 91). The 2015 estimate as $173M (equivalent to $196.4M in 2022). This figure will vary widely in individual years depending on climatic conditions.

Table 91: Economic cost of flystrike in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0.19	$0.15	$0.17	$1.18	$0.96	$0.88	$3.21	$2.95	$3.21	**$4.58**	**$4.23**	**$4.25**
Per Flock	$319	$258	$287	$1,991	$1,626	$1,480	$5,417	$4,972	$5,412	**$7,724**	**$7,147**	**$7,180**
Total	**$12.5M**			**$83.8M**			**$227.4M**			**$323.7M**		

Reducing the prevalence of flystrike by 50% before considering extra costs will reduce the cost of flystrike to the industry by $66M.

<u>Changes since last report</u>

The annual cost of flystrike in sheep in Australia has increased partly due to losses associated with high commodity prices. In addition, most control costs have increased even though fly prevention activities are similar apart from the number of producers that are mulesing sheep has reduced but costs have increased with the high adoption rate of pain relief and with more un-mulesed sheep extra crutching has been adopted, especially in high rainfall regions to help control breech strike. There is no evidence that the frequency of chemical control has increased much since the last farm management surveys, except anecdotal evidence in the wet summer of 2021-22 although assumptions were not changed.

Flystrike was ranked 4th in this report. The original 2015 ranking was 5th.

4.5.5 Weaner illthrift and mortality

The disease

Weaner illthrift describes the syndrome of young sheep failing to thrive when other stock classes on the farm are in satisfactory health. It is manifested by poor growth and wool production, increased susceptibility to disease and excessive mortality in young sheep in the first year after weaning. It has multiple, concurrent causes, many of which are related to nutrition and husbandry. Increased post-weaning mortality is a component of the weaner illthrift syndrome and an important contributor to the adverse production and animal welfare aspects of the condition. Note that several disease syndromes contribute to weaner illthrift and mortality including internal parasites, liver fluke, footrot, perennial ryegrass toxicosis, pneumonia, mastitis and flystrike.

Prevention

Recent studies have concentrated on factors that reduce weaner mortality, with nutrition having a significant effect. Improving weaner bodyweight and growth rates profoundly reduces post-weaning mortality. It is likely that strategies to improve survival would reduce illthrift in general, as would specific preventives for components of the illthrift syndrome such as strategic worm control and blowfly strike control.

A national survey of weaner management (Campbell *et al.*, 2013) identified that 'excessive' (> 4%) mortality was less likely on farms that subdivided weaner mobs based on body weight or condition score, presumably because this allows lightweight, high-mortality-risk weaners to receive differential management or improved access to feed. The same study showed that offering high-protein supplementary feeds, such as lupins, improved weaner survival.

A recent study showed that weight-corrected weaner survival was antagonistically genetically correlated with fleece weight — so using popular MerinoSelect indexes will also potentially lead to small reductions in weaner survival. To prevent this decline, weaner survival should be recorded and included in merino breeding objectives (Walkom *et al.*, 2019).

The key barrier to these various strategies, effectively reducing weaner illthrift, remains the failure to effectively extend the key control information to farmers and in encouraging them to monitor risk factors such as body weight and growth rate and to adjust nutritional management and husbandry accordingly.

Treatment

Treatment for specific factors contributing to weaner illthrift, including nutrition, timing of management events, gastrointestinal parasitism and blowfly strike, exist and are discussed elsewhere in this review.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015								X		
2022								X		

Distribution

Distribution of weaner mortalities is widespread across climatic zones, though more severe in the pastoral zone and in Merinos compared with Merino-cross weaners.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

Based on a single year's survey in 2008 (Campbell *et al.*, 2013), weaner mortality was found to be highest in the pastoral zone (average annual post-weaning mortality 7.7%) compared to the wheat-sheep zone (4.4%) and the high rainfall zone (4.6%). Average weaner mortality was greatest in Queensland (6.1%), Western Australia (5.8%) and Tasmania (5.2%) compared to New South Wales or Victoria (both 4.4%) or South Australia (3.5%). Greater mortality was reported in Merino enterprises (5.2%) than crossbred flocks (4.6%). Similar results were observed in 2009 and 2010 Wool Desk surveys (K. Curtis, unpublished).

These figures were self-reported by farmers during a telephone survey and are likely to have some biases; actual weaner mortality rates are likely higher than those reported. For example, average weaner mortality has been reported at 11% in Victoria (Mackinnon Project, unpublished, reported in (Campbell, Vizard and Larsen, 2009)), 7% Central Tablelands of NSW (Hatcher *et al.* 2010), 15% Yass (Hatcher *et al.* 2008) and 6–9% in South Australia (Hocking-Edwards, Gould and Copping, 2008).

It is difficult to estimate the prevalence of illthrift, above that of actual weaner mortality. Since post-weaning mortality represents an extreme form of weaner illthrift, it is reasonable to estimate that the additional prevalence of illthrifty weaners is 1–2 times the actual weaner mortality for a flock.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

<u>**Economics**</u>

Assumptions: Weaner illthrift and mortality

Table 92: Assumptions: weaner illthrift and mortality in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Regional differences are based on climatic zones with highest risk pastoral zone (12% of the sheep flock), moderate risk high rainfall zone (41% of the sheep flock) and lowest risk in the wheat sheep zone with (47% of the sheep flock)	Regional differences are based on climatic zones with highest risk pastoral zone (8% of the sheep flock), moderate risk high rainfall zone (41% of the sheep flock) and lowest risk in the wheat sheep zone with (51% of the sheep flock) -	***
% Flocks affected	*Weaners affected with illthrift* *High rainfall zone: Merino 9.8%; Dual purpose 7.4%* *Wheat sheep zone: Merino 9.7%; Dual purpose 6.4%* *Pastoral zone Merino: 17.0%, Dual purpose 12.0%* Prime lamb flocks not affected	-	***
Mortalities	50% mortality in affected weaners (only ewe weaners for dual purpose as wether weaners sold)	-	**
Weight loss	Temporary weight loss of 5 kg in affected weaners (Merino); 3 kg for crossbred lambs in dual purpose flocks	-	**
Fertility	3.75% Merino, 3% dual purpose for maiden ewes previously affected by illthrift	-	*
Fleece weight	13% reduction in Merinos, 7% reduction in dual purpose	-	**
Wool price	7% reduction in price for Merino weaner wool due to lower staple strength	3% reduction in price for Merino weaner wool due to lower staple strength -	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Considered in specific diseases	-	**
Prevention	50% flocks in high rainfall and wheat sheep zones adopt grain feeding at a cost including labour of $4.03/animal (2.5 kg/month for 5 months)	70-80% flocks in high rainfall and wheat sheep zones adopt grain feeding (or fodder crop equivalent) at a cost including labour of $4.58/animal (2.5 kg/month for 5 months)	*

Based on these assumptions the annual cost of weaner illthrift and mortality in sheep in Australia is estimated at 225.0M (Table 93). The 2015 estimate was $188M (equivalent to $213.4M in 2022).

Table 93: Economic cost of weaner illthrift and mortality in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$0.27	$1.07	$0.90	$3.89	$2.28	$2.18	**$4.16**	**$3.35**	**$3.08**
Per Flock	$0	$0	$0	$578	$2,311	$1,935	$8,381	$4,910	$4,701	**$8,958**	**$7,221**	**$6,636**
Total	**$0M**			**$63.1M**			**$161.9M**			**$225.0M**		

Note that this syndrome includes several diseases, including gastrointestinal parasitism. Hence, when considering the financial cost of weaner mortality and illthrift, it is not in total addition to the cost estimates for these other diseases, such as gastrointestinal parasitism.

The net gain from moving all flocks to below an industry standard of 4% mortality rate is estimated at $29.2M.

<u>Changes since last report</u>

The cost of weaner illthrift has increased due to higher commodity prices and higher costs of preventive management adjusted for inflation and a higher proportion of flocks implementing preventive management. This has been balanced with lower stock numbers. Another adjustment included reducing the carryover fertility adjustment for maiden merino ewes previously impacted with illthrift.

Weaner illthrift and mortality was ranked 5th in this report. The original 2015 ranking was 4^{th}.

4.5.6 Lice

The disease

Lice infestation caused by *Bovicola ovis* is an important disease of the Australian sheep flock causing significant economic loss through reduction in fleece values, lower bodyweight and control and prevention costs. The most recent survey (Colvin *et al.*, 2022) indicates that in the five years preceding and including 2018, 13.9% of producers Australia-wide reported seeing live lice in their flocks and 17.2% reported seeing lice in 2018, with 16.5% of producers reporting some sheep rubbing and 69.5% reporting no evidence of lice. The survey found the prevalence of lice decreased from 18.6% in the five years preceding and including 2011 and the number of flocks reporting no evidence of lice increased from 59.3% in 2011 to 69.5% in 2018.

Currently, there are effective chemicals available to control and eradicate lice, so the prevalence is expected to remain stable. Chemical resistance in lice is expected to increase with the continued use of the same chemicals. The number of producers reporting not treating sheep has remained stable at 26.7%.

Ongoing poor chemical application technique and poor biosecurity against straying and purchased sheep are important industry issues. The emergence of exotic breeds, especially in pastoral areas, is expected to increase the prevalence of lice because of the perception that treatment of these breeds is not necessary. These breeds readily breach conventional fencing making the maintenance of flock isolation more challenging. The increased use of meat breeds is promoting the trading of breeding stock, and this will potentially increase transmission and spread of lice.

	Unknown aetiology									*Known aetiology*
2015										X
2022										X

Prevention

There are effective strategies to prevent lice entering a flock including on-farm biosecurity such as quarantining introduced sheep, maintaining secure boundary fences and proper use of available lice chemicals. Flocks that rely primarily on chemical control will promote development of chemical resistance, resulting in reduced efficacy. Biosecurity is an important adjunct to treatment.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015								X		
2022								X		

Treatment

There are effective chemicals to control lice however effectiveness is often reduced following poor application. This also promotes development of chemical resistance and reduced efficacy of control.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015							X			
2022							X			

Distribution

The distribution is stable; potentially increasing in pastoral areas as more producers change to non-woolled breeds, which are more challenging to control for lice than Merinos.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015						X				
2022						X				

Prevalence

Prevalence has reduced slightly, possibly due to the use of more effective chemicals; there has been reduced use of insect growth regulator chemicals (IGRs), which lice have widespread resistance. The prevalence of lice is generally regarded to be stable, but detection of lice is difficult by inspecting sheep or by presuming sheep have lice if they have evidence of rubbing. The prevalence may increase in the future with increasing chemical resistance.

	Prevalence decreasing									*Prevalence increasing*
2015						X				
2022						X				

Economics

Assumptions: Lice

Table 94: Assumptions: lice in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	All sheep regions	-	***
% flocks infected	Prevalence 43% (pastoral zone) and 29% (wheat/sheep and high rainfall zones) (Reeve and Walkenden-Brown, 2014).	Prevalence 43% (pastoral zone) and 29% (wheat/sheep and high rainfall zones) ((Reeve and Walkenden-Brown, 2014; Colvin *et al.*, 2022).-	***
Mortalities	Nil	-	***
Weight loss	No reduction in bodyweight	-	**
Fleece weight	Reduction in clean fleece weight of between 2% – 18% (Wilkinson, De Chaneet and Beetson, 1982; Wilkinson, 1988)	-	***
Wool price	Wool price discount average 2% in pastoral zone and 1% in wheat sheep and high rainfall zones). Discount on cotting range from 0.1	Similar discounts used in 2022	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	for soft cotts to 17% for severe cotting, depending on micron (Nolan, 2012). No fibre diameter discount (Wilkinson, De Chaneet and Beetson, 1982; Wilkinson, 1988).		
Fertility	Nil	-	***
Market avoidance	Nil	$0.20/head biosecurity costs fencing-	***
Movement restrictions	Notifiable disease in some states restricts selling opportunities until infestation controlled, although no price discount on sale sheep considered.	-	**
Treatment	Range of different treatment methods varying from off-shears back lining, short wool dip and long wool back lining. Average treatment cost of $1.42/adult (Liceboss, 2014) with 28%, 10% and 8% treated to control lice in long wool for pastoral, wheat/sheep and high rainfall zone respectively.	Range of different treatment methods varying from off-shears back-lining, short wool dip and long wool back lining. Average treatment cost of $1.61/adult with 20%, 8% and 7% treated to control lice in long wool for pastoral, wheat/sheep and high rainfall zone respectively. Less treatment with shedding breeds (Reeve and Walkenden-Brown, 2014; Colvin *et al.*, 2022)	***
Prevention	Similar to treatment but effectiveness of lice prevention is restricted due to poor on farm biosecurity and poor application of chemicals to eradicate lice. Average prevention cost of $0.85/adult (Liceboss, 2014) with 68%, 66% and 52% treated for control and eradication after shearing in pastoral, wheat/sheep and high rainfall zone respectively.	Similar to treatment but effectiveness of lice prevention is restricted due to poor on farm biosecurity and poor application of chemicals to eradicate lice. Average prevention cost of $1.37/adult with 80%, 66% and 65% treated for control and eradication after shearing in pastoral, wheat/sheep and high rainfall zone respectively (Reeve and Walkenden-Brown, 2014; Colvin *et al.*, 2022).	***

Based on these assumptions the annual cost of lice in sheep in Australia is estimated at $107.5M (Table 95). The 2015 estimate was $81M (equivalent to $91.9M in 2022). The modest increase in cost of lice is consistent with higher sheep values but reduced sheep numbers in Australia.

Table 95: Economic cost of lice in sheep

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0.17	$0.04	$0.03	$1.01	$0.85	$0.83	$0.86	$0.37	$0.37	**$2.04**	**$1.25**	**$1.24**
Per Flock	$368	$84	$73	$2,216	$1,850	$1,824	$1,922	$818	$818	**$4,501**	**$2,752**	**$2,716**
Total	**$3.3M**			**$59.5M**			**$28.9M**			**$107.5M**		

The net gain of moving all flocks to a flock prevalence of 29% where only infected flocks are treated and 7% of flocks treated in long wool is estimated at $30.0M.

<u>Changes since last report</u>

The annual cost of lice increased due to higher wool prices and higher treatment costs, but lower sheep numbers compared to 2015 has held the increase somewhat. In addition, lice prevalence reduced marginally.

Lice was ranked 6th in this report. The original 2015 ranking was 7th.

4.5.7 Mastitis

The disease

Sheep mastitis in the Australian sheep flock is present in several forms. More severe forms, leading to peracute gangrenous mastitis, is predominantly caused by *Mannheimia sp.* and *Staphylococcus aureus*. Several other bacterial species produce more chronic forms of clinical mastitis resulting in changes to milk quality, quantity and udder appearance. Sub-clinical mastitis is caused predominantly by *Staphylococci* and *Streptococci* and is also common in some breeds which can result in reduced lamb growth during infection. Mastitis can result in death of ewes and/or their lambs or may only reduce ewe and/or lamb bodyweight, lamb weaning rate or lamb and ewe survival. Whilst clinical mastitis is fairly obvious with between 2-4% of ewes normally affected, recent research identified around 15% of ewes are affected with subclinical mastitis (Barber, 2017).

	Unknown aetiology									*Known aetiology*
2015							X			
2022							X			

Prevention

There are currently no preventive strategies available for sheep producers, although some vaccine development work was undertaken in the 1990s with some autogenous vaccines demonstrating efficacy, but no products are commercially available. Flay (Flay, Ridler and Kenyon, 2020) found that udder palpation prior to joining was useful in identifying and prioritise culling of ewes with (palpable) udder defects. Ewes with palpable defects weaned 21–28% less lambs, and their lambs weighed 25–33% lighter than lambs from ewes with normal udder palpations. Prevention therefore relies upon culling ewes with poor udder conformation.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015	X									
2022		X								

Treatment

Treatment of clinical cases of mastitis is limited to use of injectable antibiotics. The primary problem with this treatment is in identifying ewes before there are significant health or production impacts on the ewe or their lambs. It is common in per-acute cases for both the ewe and lamb to die within a few days of infection, leaving minimal time for diagnosis and treatment by the farmer and/or veterinarian. More commonly ewes with less severe mastitis reduce milk yield resulting in lambs with poor growth and a higher risk of dying.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015						X				
2022						X				

Distribution

Mastitis of sheep is spread widely across all sheep-producing areas. There is a lack of survey data so there is no good reference point to determine if the incidence is changing. Another difficulty is that mastitis rates vary considerably between years due to seasonal and environmental factors, hence longitudinal surveys will be required to identify long-term trends.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

The prevalence of mastitis is likely to be increasing as more ewes are bred to produce prime lambs. These ewes tend to have higher milk production than Merinos and higher rates of twinning, hence are more likely to develop mastitis.

	Prevalence decreasing									*Prevalence increasing*
2015							X			
2022							X			

Economics

Assumptions: Mastitis

Table 96: Assumptions: mastitis in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Generally restricted to high rainfall and sheep/wheat zones	-	**
% Flocks affected	Clinical mastitis in British Breeds - 5% (such as pure Poll Dorsets hence serious problem in seed stock enterprises) Clinical mastitis in prime lamb maternals - 2.5% Clinical mastitis in Merino - 1% Sub-clinical mastitis in British Breeds - 30% Sub-clinical mastitis in prime lamb maternals - 15% Sub-clinical mastitis in Merino - 7% (Omaleki et al., 2011)	Clinical mastitis in British Breeds - 5% (such as pure Poll Dorsets hence serious problem in seed stock enterprises) Clinical mastitis in prime lamb maternals - 2.5% Clinical mastitis in Merino - 1% Sub-clinical mastitis in British Breeds - 30% Sub-clinical mastitis in prime lamb maternals - 15% Sub-clinical mastitis in Merino - 7% (Omaleki *et al.*, 2011; Barber, 2017)	*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Mortalities	40% of clinical cases die. Ratio of twin to single dams in this is generally 2:1 with most (80%) lambs dying (Omaleki *et al.*, 2011).	With higher estimated rate of clinical mastitis mortality rate of affected ewes reduced to 20% 50% of progeny with clinical mastitis die.	**
Weight loss	Significant weight loss in clinically affected ewes (if they survive) estimated at 5kg temporary. Many clinically affected ewes that survive will be culled. Lambs that survive from clinically affected ewes are assumed to be 15% lighter. Sub-clinical mastitis - reduced weaning weight of lambs by 9%. This may have more importance in survivability for Merino lambs due to lower weaning weights (De Olives *et al.*, 2013).		**
Fertility	*Ewes with clinical mastitis produce 4% fewer lambs in the following year*	-	*
Fleece weight %	Estimate 5% less for clinical cases that survive.	-	*
Wool price discounts	Large reduction in tensile strength in clinical cases, though not documented (estimate at 15 N/kTex). Presumably some reduction in subclinical but minimal though not documented.	4% reduction in merino fleece value due to low staple strength -	**
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Available, but limited due to low detection rates. Assume	Available, but limited due to low detection rates. Assume	*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	10% clinical cases treated with antibiotics - $10/case.	10% clinical cases treated with antibiotics - $13.60/case.	
Prevention	Nil available	-	**
Other costs		-	

Based on these assumptions the annual cost of mastitis in sheep in Australia is estimated at $104.1M (Table 97). The 2015 estimate was $52M (equivalent to $59.0M in 2022).

This estimate has high uncertainty, due to lack of information on the prevalence of disease within breeds and over time, and the uncertain impact of subclinical mastitis. Part of the cost of mastitis is a subset of peri-natal mortalities.

Table 97: Economic cost of mastitis in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0.01	$0	$0	$0	$0	$0	$1.69	$0	$0	**$1.70**	**$0**	**$0**
Per Flock	$13.2	$0	$0	$0	$0	$0	$3,540	$0	$0	**$3,553**	**$0**	**$0**
Total	**$0.4M**			**$0M**			**$103.8M**			**$104.1M**		

The net gain from reducing the prevalence of mastitis by 50% is estimated at $52.1M before extra costs of prevention and treatment are considered.

<u>Changes since last report</u>

The cost of mastitis has increased due to higher commodity prices, both livestock and to a small extent wool prices. The increased cost mastitis also increased due to an assumed increase in the prevalence of clinical mastitis based on research in both Australia and New Zealand.

Mastitis was ranked 7th in this report. The original 2015 ranking was 8th.

4.5.8 Arthritis

The Disease

Arthritis is a common problem of lambs and occasionally older sheep. There are several major causative agents producing arthritis including *Erysipelothrix rhusiopathiae*, *Chlamydia pecorum*, *Streptococcus spp,* a range of pyogenic bacteria, and other bacteria causing sporadic arthritis (Paton *et al.*, 2003a; Farquharson, 2007; Lloyd *et al.*, 2016; *Arthritis*, no date). Erysipelas and Chlamydia polyarthritis are the most common causes, though many laboratory submissions fail to diagnose any underlying agent cause. In one study, *Fusobacterium necrophorum* was the most important cause of post-mulesing arthritis in western NSW (Curran 2012, Watt 2010). There are a variety of risk factors, depending to some extent on the timing of infection including marking, tail length, mulesing, shearing, dipping, grass-seed infestation and any procedure that damages the skin. Poor hygiene and wet muddy conditions are important risk factors. Poor nutrition leading to low colostrum production by ewes can result in high levels of neonatal arthritis in lambs.

The epidemiology of Chlamydia polyarthritis is not well known. Prevalence rates vary but range between 0.6–3.1% (Farquharson, 2007) One investigation showed chlamydia percorum infected 6.1% of abnormal joints and *Erysipelothrix rhusiopathiae* infected 13.8% of abnormal joints (Lloyd *et al.*, 2017). Paton (Paton *et al.*, 2003a) reported a high correlation between mulesing and shearing and the incidence of arthritis, which is more likely to occur in merino lambs. In contrast, Farquharson (Farquharson, 2007) reported Chlamydia polyarthritis to be more common in rapidly growing lambs, especially in meat breeds, though disease still occurs in merino lambs growing at lower rates. Economic losses arise from mortality, lower production of surviving lambs, treatment and prevention costs and post farm gate, trimming and condemnation of carcases.

	Unknown aetiology									*Known aetiology*
2015						X				
2022							X			

Prevention

An effective vaccine is available to prevent erysipelas arthritis (Eryvac™), though adoption rates are not high. This is probably due to lack of awareness of the specific disease within their flocks by producers; clearly other (non-erysipelas) causes of arthritis are prevented by this vaccine. Increased in the use of Eryvac™ will reduce the prevalence of erysipelas arthritis. General hygiene at marking, mulesing or dipping and other management procedures are undertaken to reduce incidence. Correct tail length at docking (Lloyd *et al.*, 2016), minimising shearing of terminal lambs, and the gradual decline in mulesing will reduce the incidence of arthritis (Paton *et al.*, 2003a). Management of grass seed infestation will reduce arthritis in exposed lambs and sheep.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015					X					
2022						X				

Treatment

Early treatment of arthritis with parenteral antibiotics is moderately effective in early cases. Many cases are often not treated until disease is well advanced when mobs are mustered for other reasons.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015					X					
2022					X					

Distribution

Distribution is stable.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

Good on farm data to determine the prevalence of arthritis is limited. On farm data which is available almost certainly under-estimates the true prevalence because many lambs die without the causative agent identified. Prevalence will vary between seasons and regional effects are also evident. Abattoir surveillance provides good information about the prevalence of arthritis in slaughter sheep, but alone cannot identify any causative agent.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: Arthritis

Table 98: Assumptions: Arthritis in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Widespread across all regions and climatic zones	-	***
% flocks infected	Average prevalence of lambs/weaners 2%; adults 1% (Paton *et al.*, 2003a; Farquharson, 2007; Lloyd, Schröder and Rutley, 2018)	Average prevalence of lambs/weaners 2% in merino and 1.2% in prime lamb flocks; adults 1% (Paton *et al.*, 2003a; Farquharson, 2007; Lloyd, Schröder and Rutley, 2018) Merino flocks' higher prevalence than prime lamb flocks	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
		-	
Mortalities	50% of lambs affected	65% of affected merino lambs, 50% crossbred lambs die, 30% adults affected (includes lambs with no commercial value (Paton *et al.*, 2003a; Lloyd *et al.*, 2016; Dal Grande *et al.*, 2021)	*
Weight loss	3kg, 4kg and 4.5kg for affected Merino, dual purpose and prime lambs (Farquharson, 2007)	Merino lambs weight loss 2 kg, dual purpose 3 kg and prime lamb 4 kg weight loss based on reports 3kg, 4kg and 4.5kg for affected Merino, dual purpose and prime lambs (Farquharson, 2007) Lambs Av. 2.7kg weight loss (Lloyd, Schröder and Rutley, 2018)	**
Fleece	Nil	5% weight loss of carryover lambs shorn	*
Wool	Nil	-	*
Fertility	Nil	-	*
Market avoidance	0.018% carcases condemned; 0.07% carcases trimmed. Average 3kg/affected carcase (Farquharson, 2007)	0.016% carcases condemned; 0.7% carcases trimmed. Average 0.1-4.5kg/affected carcase (Farquharson, 2007; Lloyd, Schröder and Rutley, 2018; Mazoudier *et al.*, 2020; *National Sheep Health Monitoring Project*, no date)	**
Movement restrictions	Nil	-	***
Treatment	12% of affected lambs treated with antibiotics at a cost of $8.00/lamb (Farquharson, 2007)	12% of affected lambs treated with antibiotics at a cost of $9.09/lamb (Farquharson, 2007)	*
Prevention	16% of 2 yo ewes vaccinated twice and 8% of adult ewes vaccinated once with Eyrvac at a cost of $0.87/dose including labour	17% of 2 yo ewes vaccinated twice and 20% of adult ewes vaccinated once with Eyrvac or equivalent at a cost of $1.20/dose including labour	***

Based on the adopted prevalence and impacts of the disease on the classes of animals affected, GHD has calculated the annual cost of Arthritis in sheep in Australia at $97.2M (Table 99). The 2015 estimate was $39M (equivalent to $44.3M in 2022).

Table 99: Economic cost of Arthritis in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0.01	$0	$0	$0.23	$0	$0	$1.18	$0	$0	**$1.42**	**$0**	**$0**
Per Flock	$22	$0	$0	$488	$0	$0	$2,541	$0	$0	**$3,051**	**$0**	**$0**
Total	**$0.7M**			**$15.6M**			**$81.0M**			**$97.2M**		

The net gain from moving all flocks experiencing arthritis to 50% of current disease prevalence is estimated at $48.6M before considering extra costs of prevention.

Changes since last report

The main change to the cost of arthritis from the previous report is the large increases to commodity prices, which has increased production losses. Weight loss in affected lambs decreased as new information on this component came to hand. The prevalence of arthritis was increased slightly in crossbred sheep and there was a small increase in mortality rates in merinos. Trimming losses were increased from low levels to 0.7% of lambs, though the trim weight was reduced to average 0.7 kg/carcase. The use of Erysipelas vaccines doubled all other costs, which were CPI adjusted for this report.

Arthritis was ranked 8th in this report. The original 2015 ranking was 10th.

4.5.9 Perennial rye grass toxicosis

The disease

Perennial ryegrass (PRG) pastures infected with the wild-type (WT) endophyte *Neotyphodium lolii* produces several classes of alkaloids which, when ingested by livestock, cause perennial ryegrass toxicosis (PRGT). The effects of PRGT are potentially severe, with serious outbreaks causing considerable production losses, animal welfare problems and further indirect costs and subclinical losses resulting in considerable economic losses. Fungal endophytes in ryegrass act in a symbiotic relationship providing resistance to insect pests and thus confer agronomic advantages which enhance the persistence and productivity of ryegrass (Leury *et al.*, 2014).

The two main alkaloids that cause toxicosis of livestock include Lolitrem B and Ergovaline. Lolitrem B, a neurotoxin that affects muscle activity, has widespread impact on the respiratory, cardiovascular and digestive systems. It causes tremors and has profound effects on smooth muscle, altering gut motility and severely disrupting digestion. Ergot alkaloids interact with dopamine receptors leading to peripheral vaso-constriction, disruption of thermoregulation and endocrine dysfunction. Reduction of blood circulation to glands, skin and extremities raises blood pressure, temperature and respiration rate causing heat stress, reduced food intake and serum prolactin, and potentially impaired reproductive efficiency (Reed *et al.*, 2005a).

It is estimated that six million hectares are sown to PRG in Australia, predominantly in Victoria, Tasmania southern South Australia and Western Australia and parts of the high rainfall regions of New South Wales. Old PRG sward populations often have a frequency of *N. lolii* infection of 80-90% (Reed *et al.*, 2005b).

The concentration of toxic alkaloids peaks in the summer to autumn period. Clinical signs vary between years depending on environmental conditions (and consequent pasture growth) and composition of pastures. Symptoms are usually more severe in years when late spring rain provide carryover feed late into summer, followed by summer rain that triggers some growth, which is then followed by dry and hot conditions in late summer and autumn that subsequently stress the plants. This triggers the overgrowth *N. lolii* and the subsequent production of toxins. Severe outbreaks tend to occur approximately every five years, although in high-risk regions some toxicity events occur every year with additional ongoing subclinical effects occurring well after staggers has diminished.

Economic losses are caused by mortalities (misadventure, drowning, chronic recumbency and hyperthermia, as well as secondary consequences due to flystrike and parasitism), production losses associated with lower weight gain, poor reproductive performance, increased dags and reduced fleece values. In outbreak years, substantial labour resources must be diverted to provide husbandry and management of the welfare of affected sheep. Many indirect impacts of PRGT arise from this interference with farm workflow and regular farm husbandry procedures, such as worm control and fly control, further exacerbating production losses and death rates. From a social perspective, a severe PRGT event can be overwhelming and produce substantial stress on managers of affected sheep flocks (and cattle herds).

There are several important strategies to minimise the impact of outbreaks and ongoing production losses. In the first instance, supervision of recumbent stock and removal of at-risk mobs from toxic to safe pastures will minimise losses. If no safe pastures are available, either supplementing to dilute toxic pastures or, if severe, removal from pasture and feedlotting may be necessary. Novel alkaloid detoxifying agents such as Elitox® or Mycofix® supplemented in a lick appear to reduce the impact of PRGT.

In the long term, replacement of PRG pastures infested with wild-type endophytes with safe pastures is the best solution, if replacement pastures can be successfully established. These newer cultivars often are more persistent and more productive (Leury *et al.*, 2014). Safe pastures include alternative pasture species (such as phalaris, fescues and cocksfoot), PRG with novel endophytes (such as AR37, Endo 5, AR1, NEA) that are less toxic to stock and still protect against insect attack. Many persistent cultivars and species of pastures are available that are more productive than PRG infected with wild type endophyte. Some endophyte-free cultivars of PRG are commercially available but poor persistence is an issue. The main limitation to adoption of whole scale replacement of toxic pasture is the cost, risk of failure, concern about persistence of new pasture, concern that new pasture will be re-invaded with wild-type PRG, and the long timeframe to achieve an adequate return on investment.

The cause of PRGT is well known though some of the physiological effects and production impacts of toxic alkaloids are not clear. In addition, the importance of alkaloids apart from Lolitrem B and Ergovaline are not as clear.

Unknown aetiology — *Known aetiology*

2015									X	
2022									X	

Prevention

Prevention relies on removal of stock from toxic to safe pastures, diluting the effects of toxic pastures and by supplementary feeding or feedlotting during severe outbreaks. Alkaloid detoxifying agents are commercially available however the full benefits of compounds available are not well documented. In the long term, permanent replacement of toxic pastures with safe pasture is economically viable if replacement pastures persistent and are more productive. The main challenge with replacement of toxic pasture is to ensure new pastures are persistent. Producers that invest in high fertiliser rates help persistence of new pasture species but naturally favour re-invasion of perennial rye grass infected with wild type or standard endophytes that are toxic to livestock.

Low efficacy/ unproven preventives available — *Effective preventives available*

2015								X		
2022								X		

Treatment

No therapeutic compound is available to treat PRGT. The only option to treat clinically affected stock is to remove them from toxic pasture and provide supportive husbandry (food and water) whilst they recover. There has been some promise that potassium bromide helps reduce the toxic effects of lolitrem B (Combs *et al.*, 2019). However, no commercial product is available at this stage.

Low efficacy/ unproven treatments available — *Effective treatments available*

2015		X								
2022		X								

Distribution

The distribution of PRGT is limited to high rainfall regions (>600 mm) where PRG with wild-type endophyte is grown. PRG with wild-type endophyte is grown on at least six million hectares in southern Australia, particularly in Victoria and Tasmania but also NSW, southern South Australia and southern Western Australia. Increased fertiliser application encourages PRG hence potentially increasing the severity of outbreaks over time. Producers that have previously experienced severe outbreaks of PRGT are actively replacing toxic PRG pasture, though the extent of this is relatively small. In the long-term climate change may reduce the distribution of perennial rye grass, but potentially make outbreaks more severe, although at this stage there is no strong evidence of any major changes in distribution although widespread outbreaks have not occurred in the last decade.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022				X						

Prevalence

The prevalence of PRGT varies from season to season. Historically, in high-risk regions severe outbreaks occur in about 20% of years and moderate impact in 40% of years. In moderate risk regions, outbreaks occur about 30% of the time and in low-risk regions outbreaks occur about 10% of the time (Sackett and Francis, 2006). Weaners are more at risk than adult sheep and Merinos appear more susceptible than crossbred sheep and meat breeds. Prevalence has reduced since the mid-2000s for reasons that are uncertain but may relate to an increased frequency of dry periods or through the replacement of previously toxic pastures on severely affected properties. As a result, the average severity of outbreaks is assumed to be half the previous report level.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022				X						

Economics

Assumptions: PRGT

Table 100: Assumptions: PRGT in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Conf.
Regional Extent	About 11.2% of Australia's sheep flock is exposed to a high risk of PRGT, about 3.5% to a medium risk and 9.2% to a low risk of PRGT. The remainder of the sheep population is not exposed to PRGT. PRGT is highest risk in higher rainfall regions of Victoria and Tasmania.	-	***
% Flocks affected	High risk flocks are exposed to a severe impact in 20% of years, a moderate impact in 40%, a low impact in 20% and no risk in 20% of years. Moderate risk flocks are exposed to a moderate impact in 30% years and	High risk flocks are exposed to a severe impact in 10% of years, a moderate impact in 20%, a low impact in 10% and no risk in 40% of years. Moderate risk flocks are exposed to a moderate impact in 15% years and low impact 5% of years. Low risk flocks are exposed to	**

Variable	2015 Assumptions	2022 Assumption Changes	Conf.
	low impact 10% of years. Low risk flocks are exposed to a low impact in 10% of years.	a low impact in 10% of years. Flock impact reduced by 50% on high and medium risk flocks based on experience of last 10 years compared to previous 10 years -	
Mort.	No accurate published data is available but based on experience and surveys, the following estimates are used: *Weaners* / *Adults* High impact: 12% / 7% Moderate impact: 3% / 2% Low impact: 1% / 0%	-	**
Weight loss	Weight loss data is highly variable between trials and regions though a best estimate of the temporary weight loss attributed to PRGT is: Weaners / Adults High impact: 2 kg / 2 kg Moderate impact: 1 kg / 1 kg Low impact: 0 / 0	-	**
Fertility	The impact of PRGT on reproductive performance is highly variable. Based on experience and trials the following estimates have been used (the impact is likely to be due to the direct effects of PRGT and the secondary impacts on lower bodyweight): High impact - 12% reduction; moderate impact - 6%; low impact - 2%.	-	*
Fleece weight %	Little data is available on the effects on wool growth, however in some longer-term trials in NZ reduced wool growth has been experienced as is the case in Australia in outbreak years. Fleece weight reductions are assumed to be: *10% for high impact, 4% for moderate and 0.5% for low impact scenarios.*	-	**
Wool price discounts	Staple strength reduced by 5 N/kTex in high-risk situations.	0.5% reduction in fleece value due to lower staple strength in severe impact situations	*
Market avoid.	No information is available, although timing of sales is often restricted due to inability to transport staggering stock. 5% of stock sales are assumed to be delayed by 2 months.	-	**
Movmnt restrictns	Nil	-	**
Treat.	*Labour[1]* / *Supplementary feed (amount & cost)[2]* / *Extra drenching[3]* *Wean.* / *Adult* / *Wean.* / *Adult*	*Labour[1]* / *Supplementary feed (amount & cost)[2]* / *Extra drenching[3]* *Wean.* / *Adult* / *Wean.* / *Adult*	**

<table>
<tr><th>Variable</th><th>2015 Assumptions</th><th>2022 Assumption Changes</th><th>Conf.</th></tr>
<tr><td></td><td>
<table>
<tr><td>High Impact</td><td>$2400</td><td>10 kg $2.50</td><td>5 kg $1.25</td><td>1</td><td>0.5</td></tr>
<tr><td>Moderate Impact</td><td>$1200</td><td>5 kg $1.25</td><td>2 kg $0.50</td><td>0.5</td><td>0</td></tr>
<tr><td>Low Impact</td><td>$400</td><td>3 kg $0.75</td><td>0</td><td>0</td><td>0</td></tr>
</table>
1. The total extra cost of labour to manage a high impact, moderate and low-cost scenario ($/flock).
2. Supplementary feeding required over an outbreak at a cost of $250/t ($/head).
3. Likely extra drenching undertaken due to poor timing of drenches and producer response to extra dags. Cost of drenching $0.45/dose adults, $0.38/weaner.
</td><td>
<table>
<tr><td>High Impact</td><td>$2,726</td><td>10 kg $2.84</td><td>5 kg $1.42</td><td>1</td><td>0.5</td></tr>
<tr><td>Moderate Impact</td><td>$1,363</td><td>5 kg $1.42</td><td>2 kg $0.57</td><td>0.5</td><td>0</td></tr>
<tr><td>Low Impact</td><td>$544</td><td>3 kg $0.85</td><td>0</td><td>0</td><td>0</td></tr>
</table>
1. The total extra cost of labour to manage a high impact, moderate and low-cost scenario ($/flock).
2. Supplementary feeding required over an outbreak at a cost of $284/t ($/head).
3. Likely extra drenching undertaken due to poor timing of drenches and producer response to extra dags. Cost of drenching $0.51/dose adults, $0.43/weaner.
</td><td></td></tr>
<tr><td>Prev.</td><td>No cost considered although pasture renovation costs may be substantial.</td><td>-</td><td>**</td></tr>
<tr><td>Other costs and prodn losses</td><td>
Additional costs associated with PRGT

<u>Increased dags</u>

PRGT increases dag in sheep. The cost associated with this is reduced wool value due to faecal soiling and extra crutching costs
<table>
<tr><td></td><td><u>Weaners</u></td><td><u>Adults</u></td></tr>
<tr><td>High impact</td><td>1 ($0.54)</td><td>1 ($0.54)</td></tr>
<tr><td>Moderate impact</td><td>0.5 ($0.43)</td><td>0.5 ($0.43)</td></tr>
<tr><td>Low impact</td><td>0</td><td>0</td></tr>
</table>
<u>Other production losses associated with PRGT</u>
<u>Reduced milk production:</u> 13% lower in sheep in high risk flocks resulting in 2.4 kg/lamb decrease in weight; 6.5% lower in moderate impact scenarios 1.2 kg/lamb decrease in weight.

<u>Lower bodyweights:</u> Adult sheep with consistently lower bodyweight when grazing toxic pastures even when clinical staggers is not apparent. This has several potential effects including:

Lower bodyweight of adult sheep so lower sale value (~2 kg high, ~ 1kg moderate) and lower reproduction (3%)
Lifetime wool impact of ewes consistently in lower body condition estimated to produce progeny that have fleeces that have 0.1 kg clean less wool but the fleece is 0.3 micron higher fibre diameter.

</td><td>
Additional costs associated with PRGT

<u>Increased dags</u>

PRGT increases dag in sheep. The cost associated with this is reduced wool value due to faecal soiling and extra crutching costs
<table>
<tr><td></td><td><u>Weaners</u></td><td><u>Adults</u></td></tr>
<tr><td>High impact</td><td>1 ($0.61)</td><td>1 ($0.61)</td></tr>
<tr><td>Moderate impact</td><td>0.5 ($0.49)</td><td>0.5 ($0.49)</td></tr>
<tr><td>Low impact</td><td>0</td><td>0</td></tr>
</table>
All other production impacts similar to 2015 analysis
</td><td>**</td></tr>
</table>

Based on these assumptions the annual cost of PRGT in sheep in Australia is estimated at $89M (Table 101). The 2015 estimate was $105M (equivalent to $119.2M in 2022).

Table 101: Economic cost of PRGT in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$0.88	$0.31	$0.03	$8.65	$3.24	$1.08	**$9.53**	**$3.55**	**$1.11**
Per Flock	$0	$0	$0	$1,900	$667	$66	$18,687	$6,996	$2,328	**$20,588**	**$7,663**	**$2,394**
Total	**$0M**			**$6.0M**			**$99.1M**			**$89.0M**		

If the area of land affected with PRGT is reduced by 50% before extra costs are considered, then the cost to industry would reduce by $44.5M.

<u>Changes since last report</u>

The annual cost of PRGT has reduced substantially even with higher commodity prices as the frequency of high and medium impact events has reduced compared with the previous decade partly due to climatic conditions and in part due to several farms previously severely affected changing their pasture composition to lower risk pastures.

PRGT was ranked 9th in this report. The original 2015 ranking was 6th.

4.5.10 Footrot

The disease

Footrot is a complex disease caused by the bacteria *Dichelobacter nodosus*. Footrot causes a spectrum of clinical disease ranging from benign footrot, which is widespread and usually causes mild disease, to virulent footrot which can cause severe disease and substantial economic loss if left uncontrolled. Intermediate footrot is sometimes described. This refers to strains situated between benign and virulent strains and whose clinical expression is dependent on several factors including the strain or strains of *D nodosus* present, the local environment (specifically moisture availability, temperature and pasture conditions), the resistance of sheep to footrot and effectiveness of controls. Some controls only restrict clinical expression of the disease. All these factors must be considered when diagnosing the strain of footrot present. In most states virulent footrot is a notifiable disease. Diagnosis is usually based on clinical expression although, depending on individual state regulations, additional laboratory tests may be used to classify the strain. Direct polymerase chain reaction (PCR) testing of foot swabs is more sensitive than culture-dependent sero-grouping (Dhungyel, McPherson and Whittington, 2017), but does not provide any indication of virulence. However, there are serious limitations on the ability of laboratory tests to classify the strains (Allworth, 2014).

Production losses associated with footrot depend on the strain of footrot, breed of sheep, local environment and control measures adopted. The impact of footrot is less severe in years with short growing seasons and low rainfall compared with years of high rainfall and extended growing seasons where in wetter years more sheep become infected, and sheep develop more severe lesions and are affected (and shed) for longer periods. The clinical expression of some intermediate-type strains is benign under lower rainfall conditions but more virulent in high rainfall regions. The analysis in this report is based on clinical appearance of footrot.

Virulent footrot is very costly if not adequately controlled when endemic, with the cost of eradication exceeding $10/sheep (Allworth, 1990). In addition, eradication of clinically mild strains is more difficult regardless of laboratory testing (Allworth and Egerton, 2018). Indirect costs can exceed the direct costs of the disease with management distracted by the need to reduce stocking rates or delay other critical management events resulting in increased animal health problems such as worms or flystrike. In contrast, benign footrot has a relatively minor impact on production and control measures are not as expensive.

	Unknown aetiology									*Known aetiology*
2015									X	
2022									X	

Prevention

Biosecurity measures to prevent introduction of footrot include limiting the purchase of new sheep, inspection and quarantine of new sheep, and ensuring boundary fences prevent the introduction of stray sheep. Control of footrot depends on the strain present, the local environment and management skills. Control is largely based on the use of footbathing (usually with zinc sulphate) during spread periods to limit the severity of existing lesions and slow the development of new lesions. The multivalent vaccine (Footvax®) was reintroduced to the market in 2020, though its use may be regulated in some states. Even though it only offers a short period of protection of up to 12-16 weeks, its use in high challenge environments will be cost effective so offers another option for control footrot control. A targeted serogroup-specific mono/bivalent vaccine (McPherson, Whittington and Dhungyel, 2020) offers very effective control footrot of footrot, though is dependent upon successful isolation, serogrouping and virulence testing of the infecting *D. nodosus* strain(s). The serogroup specific mono/bivalent vaccine is not currently available to sheep producers. Eradication of footrot is achieved by inspection and culling of infected sheep during non-spread periods or total destocking.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015								X		
2022								X		

Treatment

Treatment of footrot is mostly based on footbathing using zinc sulphate, particularly during wet periods when the disease is progressing. The efficacy of footbathing is limited by the intensive labour required, particularly with virulent strains where regular footbathing is required. There is also the difficulty of footbathing during lambing if this coincides with spread periods. During dry periods, parenteral antibiotics are commonly used to salvage severely affected sheep. This may also be used within a footrot eradication program to cure infected sheep thereby reducing numbers of sheep for culling.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015								X		
2022								X		

Distribution

The distribution of footrot is relatively stable following an intensive period of state-based footrot eradication programs. These programs successfully reduced the level of virulent footrot, but the distribution of less virulent forms footrot remains stable. Benign footrot is widespread across all high rainfall regions of Australia. Virulent footrot is widespread in Tasmania and to a lesser degree in the high rainfall regions of Victoria. Intermediate strains are widespread in Victoria and to a lesser degree in southern New South Wales where conditions are less conducive to their expression due to shorter growing seasons. In Tasmania, the widespread distribution of virulent footrot probably overwhelms intermediate strains, which are less common.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

The prevalence of footrot depends on the strain of footrot present on farm, local environmental and climatic conditions, and control measures adopted. The prevalence of footrot lesions in sheep on a farm can range from very low (<5%) in drought years to over 80% in wet years with extended growing seasons.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: Footrot

Note that economic costs are calculated separately for benign footrot and for virulent/intermediate footrot

Table 102: Assumptions: footrot in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Conf.
Regional Extent	Distribution of virulent footrot predominantly in high rainfall regions of Victoria and Tasmania. Benign footrot (clinical) widely distributed across high rainfall zone of Australia.	-	**
% Flocks affected	Based on state reports and surveys: *State* — *Benign >450mm^* — *Virulent (intermediate)* NSW — 40% — 0.4%* (5% intermediate in HRZ) Tasmania — 40% — 25% (15%) Victoria — 50% — 4% (10%) SA — 20% — 0.6%* mostly intermediate (3% in south-east SA) WA — 30% — 0.6%* mostly intermediate ^ Benign footrot of limited consequence in low rainfall zone	Based on state reports and surveys: *State* — *Benign >450mm^* — *Virulent (intermediate)* NSW — 60% — 1.0% (5% intermediate in HRZ) Tasmania — 40% — 25% (15%) Victoria — 50% — 5% (10%) SA — 30% — 3%* mostly intermediate WA — 30% — 2.6%* mostly intermediate ^ Benign footrot of limited consequence in low rainfall zone * Based mostly on reports consulting State Departments (State prevalence of virulent footrot assumed to be double reported prevalence)	

Variable	2015 Assumptions	2022 Assumption Changes	Conf.
	* Based mostly on state reports at national footrot workshop (Anon 2012) - reported figures doubled	Nationwide prevalence of virulent footrot assumed to be 2.9%. intermediate footrot 5.5% and benign footrot 45.2%.	
Mortalities	No published data. Estimate 1% higher in flocks with virulent footrot (mostly due to flystrike, weaner illthrift and delayed management). Note: Marshall (Marshall *et al.*, 1991) indicated 4.5% higher mortality in mobs with uncontrolled virulent strain vs. mobs with footrot controlled but not directly related to footrot.	- No published data. Estimate 1% higher (0.2% IFR) in flocks with virulent footrot (mostly due to flystrike, weaner illthrift and delayed management). Note: Marshall (Marshall *et al.*, 1991) indicated 4.5% higher mortality in mobs with uncontrolled virulent strain vs. mobs with footrot controlled but not directly related to footrot.	**
Weight loss	Average across Merino flocks and climatic zones and years considering control programs implemented: <u>Benign</u>: Temporary BW loss 0.5% <u>Intermediate:</u> Temporary kg BW loss 1.25%; Permanent 1.25% <u>Virulent:</u> Temporary kg BW loss 2.5%; Permanent 2.5% *Meat breeds: 50% of impact of Merinos* (L. E. A. Symons and Steel, 1978; Stewart *et al.*, 1986; Cummins, Thompson and Roycroft, 1991; Marshall *et al.*, 1991; Glynn, 1993)	-	**
Fertility	1.5% per kg bodyweight loss	-	**
Fleece weight %	Average across flocks and climatic zones and years considering control programs implemented: Benign footrot: 0.5% Intermediate Footrot: 2% Virulent footrot: 3% (L. E. A. Symons and Steel, 1978; Stewart *et al.*, 1986; Cummins, Thompson and Roycroft, 1991; Marshall *et al.*, 1991; Glynn, 1993; Abbott, 2000)	-	**
Wool price discounts	None considered, though wool produced is finer in affected sheep due to weight loss	-	**

Variable	2015 Assumptions	2022 Assumption Changes	Conf.
Market avoidance	Nil	-	***
Movement restrictns	Footrot is a notifiable disease in most states that restrict sales: assume $5/sheep discount due to sale restriction on properties with virulent footrot (except Tasmania).	Footrot is a notifiable disease in most states that restrict sales: assume $10/sheep discount due to sale restriction on properties with virulent footrot (except Tasmania).	**
Treatment	Considered as part of prevention program	-	***
Prevention	Footbathing for control ($0.15/sheep incl labour) Benign footrot: 50% footbath 1 time per year Intermediate footrot: Footbath 3 times per year Virulent footrot: Footbath 5 times per year Salvage antibiotics: ($1.00/sheep plus $1.00 labour) Intermediate footrot: 5% of affected flocks treat 5% sheep Virulent footrot: 10% affected flocks treat 10% sheep Eradication: 120 flocks annually. Annual cost of inspections and 20% salvage treatment with antibiotics (3 inspections @ $1.50 per inspection antibiotics $1.00/animal, additional labour $1.03/animal assisting with inspections) Biosecurity shared maintenance of fencing (shared with OJD, Lice and footrot) $0.20/animal 100% properties	Footbathing for control ($0.17/sheep incl labour) Benign footrot: 50% footbath 2 time per year Intermediate footrot: Footbath 4 times per year Virulent footrot: Footbath 5 times per year Vaccination: Vaccination cost: $2.20 ($2.00 +$0.20 labour) 25% flocks with virulent footrot Salvage antibiotics: ($1.44/sheep plus $1.14 labour) Intermediate footrot: 5% of affected flocks treat 5% sheep Virulent footrot: 100% affected flocks treat 10% sheep Eradication: 120 flocks annually. Annual cost of inspections and 20% salvage treatment with antibiotics (3 inspections @ $1.70 per inspection antibiotics $1.44/animal, additional	**

Variable	2015 Assumptions	2022 Assumption Changes	Conf.
	3.8% of all properties footbath introduced sheep average 75 sheep (Reeve and Walkenden-Brown, 2014)	labour $1.17/animal assisting with inspections) Biosecurity shared maintenance of fencing (shared with OJD, Lice and footrot) $0.23/animal 100% properties 3.8% of all properties footbath introduced sheep average 75 sheep (Reeve and Walkenden-Brown, 2014)	
Other costs	2% additional sheep treated for flystrike (intermediate and virulent footrot (Allworth, 1990) Supplementary feed cost considered with weight loss Additional labour costs associated with husbandry $0.25/sheep ($240/1000 sheep) Other indirect costs such as impact of delayed management, such as drenching or lower stocking rate not considered though may be substantial on individual farms	2% additional sheep treated for flystrike (intermediate and virulent footrot (Allworth, 1990) Supplementary feed cost considered with weight loss Additional labour costs associated with husbandry $0.28/sheep ($270/1000 sheep) Other indirect costs such as impact of delayed management, such as drenching or lower stocking rate not considered though may be substantial on individual farms -	**

Based on these assumptions the annual cost of virulent and benign footrot in sheep in Australia is estimated at $82.2M (Table 103). The 2015 estimate of virulent and benign footrot combined was $44.4M (equivalent to $51.0M in 2022). In addition, the cost of benign footrot alone is calculated to be $23.7M in sheep in Australia (Table 104). The 2015 estimate was $12.1M (equivalent to $13.7M in 2022)

Table 103: Economic cost of Virulent and benign footrot in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0.02	$0.01	$0	$3.22	$0.73	$.39	$13.96	$3.66	$0.69	**$16.21**	**$4.39**	**$1.08**
Per flock	$49	$12	$0	$6,916	$1,570	$836	$27,849	$7,880	$1,490	**$34,813**	**$19,462**	**$2,326**
Total	**$0.1M**			**$21.2M**			**$61.0M**			**$83.4M**		

The net gain from moving all flocks experiencing virulent footrot to benign footrot is estimated at $59.7M.

Table 104: Economic cost of benign footrot in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$0	$0	$0.39	$0	$0	$0.38	**$0**	**$0**	**$0.76**
Per flock	$0	$0	$0	$0	$0	$834	$0	$0	$814	**$0**	**$0**	**$1,648**
Total	**$0M**			**$12.0M**			**$11.7M**			**$23.7M**		

With current technology no value is placed on eliminating benign footrot as the cost of eradication is greater than the cost of living with the disease.

Changes since last report

The cost of footrot has increased due to higher reported prevalence of virulent footrot in most states and higher value of livestock and wool prices. All cost increased with inflation and there has been high adoption of footrot vaccine use in flock with virulent footrot in Victoria and Tasmania. Other costs increases were indexed with inflation. In addition, the control cost of managing benign footrot were slightly increased.

Footrot was ranked 10th in this report. The original 2015 ranking was 9th.

4.5.11 Ovine Johne's disease

The Disease

Ovine Johne's disease (OJD) caused by the sheep strain of *Mycobacterium avium subsp. Paratuberculosis* is a chronic wasting disease of sheep resulting in high case death rates in adult sheep, which can extend to over 10% of the adult flock in uncontrolled situations, lost production and historical restrictions on trade (Abbott, Whittington and McGregor, 2004; Bush *et al.*, 2008). Historically, the disease spread from a focus in the central tablelands of NSW in the early 1980s to become widespread from the mid-1990s in most southern medium- to high-rainfall regions of eastern and western Australia. Attempted eradication in some regions failed, but with the subsequent advent of vaccination and a better understanding on management of the disease, OJD appears now to be under control. Vaccination has reduced mortalities to low levels. Vaccination, on-farm management strategies, risk-based trading and biosecurity measures are the main strategies to control OJD. Vaccination is widespread. Vaccinated flocks benefit from reduced clinical disease and adult death rates.

Abattoir surveillance data (Animal Health Australia, 2014b) shows the percentage of lines infected with OJD peaked in 2010–11 (4.8%), reducing to 1.5% in 2014. However, this data is skewed as not all abattoirs participate in surveillance and OJD is not routinely assessed in the NSHMP except if producers request feedback. Abattoir surveillance data has not been reported at all on an industry wide basis in recent years for OJD has not been reported in recent years with

Apart from the obvious impact of mortalities many producers cull advanced cases of OJD (no commercial value). Early clinical cases have a reduction in fleece weight and lower body weight with potential reproduction consequences (Abbott, Whittington and McGregor, 2004; McGregor, Abbott and Whittington, 2015). The main prevention cost now is flock vaccination, with biosecurity measures also contributing to farmer outlay. Some regulatory costs are associated with flocks in the Sheep MAP (Animal Health Australia, 2014a). In addition, other losses arise from carcase trimming (due to vaccination lesions) and condemnation of offal (Hernandez-Jover *et al.*, 2013).

	Unknown aetiology									*Known aetiology*
2015										X
2022										X

Prevention

The main strategy to prevent OJD is to vaccinate lambs from infected sheep flocks with Gudair™ vaccine when less than 16 weeks of age (Windsor *et al.*, 2014). If effective vaccination programs are applied the shedding of bacteria is substantially reduced and subsequently clinical disease is reduced over time to very low levels. Limitations to the effectiveness of vaccination programs include poor vaccination techniques, partial flock vaccination and introducing unvaccinated sheep. Other strategies to manage OJD are to adopt property and regional biosecurity strategies to minimise the risk of introduction of OJD into flocks.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015								X		
2022								X		

Treatment

No treatment is available to treat clinical OJD cases. OJD in clinically affected sheep is uniformly fatal.

Low efficacy/ unproven treatments available — *Effective treatments available*

2015	X									
2022	X									

Distribution

Distribution of OJD appears to be stable, though current surveillance regimes are somewhat limited.

Distribution contracting — *Distribution stable* — *Distribution increasing*

2015					X					
2022					X					

Prevalence

Prevalence appears to be stable to reducing. There are now fewer farms impacted by major mortality issues with widespread use of vaccination. Farms with a long history of vaccination still experience low levels of mortalities and some farms with no history of OJD and not vaccinating have become infected some with initial high mortality rates but then commence vaccination that subsequently reduces mortality and financial impact. There are no recent surveys reporting industry prevalence rates but are assumed to be similar to the previous reporting period.

Prevalence decreasing — *Prevalence increasing*

2015				X						
2022				X						

Economics

Assumptions: OJD

Table 105: Assumptions: OJD in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Generally restricted to high rainfall and sheep/wheat zones	-	***
% flocks infected	Prevalence regions were broken down in the regions previously used until 2012 with prevalence based on current abattoir monitoring data assuming ~50% sensitivity (70% multibacillary 30% sensitivity paucibacillary)	-	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	(Bradley et al 2005). Assumptions for Merinos as follows: - High prevalence: 29% of sheep population, 50% prevalence, 1% mortality in infected flocks - Medium prevalence: 29% of sheep population, 10% prevalence, 0.5% mortality in infected flocks - Low prevalence: 42% of sheep population, 0.2% prevalence, 0.2% mortality in infected flocks Prime lamb mortality rate 50% of Merinos		
Mortalities	See above	-	**
Weight loss	Production losses 4% body weight loss 8 months prior to death, 11% 6 months prior to death (Abbott, Whittington and McGregor, 2004).	Similar reduction also (McGregor, Abbott and Whittington, 2015)	***
Fleece weight	Reduction in clean fleece weight of between 2% – 18%. Assumed 6% fleece weight loss in year prior to death (Abbott, Whittington and McGregor, 2004).	-	***
Wool quality	No impact	-	*
Fertility	Body weight loss leads to reduced reproduction rate 1.5%/1 kg BW	-	***
Market avoidance	0.5%, 0.25%, 0.1% suffer $10 loss of sale value in high, medium, low prevalence areas respectively. OJD trimming costs 1% in vaccinated lines 0.74kg CW trim (Hernandez-Jover *et al.*, 2013)). Approx $60K offal condemned	0.5%, 0.25%, 0.1% suffer $14 loss of sale value in high, medium, low prevalence areas respectively. OJD trimming costs 1.3% (NSHMP 2021) 0.74kg CW trim. Approx. $70K offal condemned	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Movement restrictions	No consideration of cost of livestock trading restrictions due to regulation though could potentially be substantial and devastating for studs in some states	-	**
Treatment	There is no treatment available	-	***
Prevention	Vaccination costs $2.50/animal including labour. 5.6 million doses annually	Vaccination costs $2.84/animal including labour. 8.3 million doses annually	***
Regional control	426 flocks in SheepMAP annual costs $600/flock. $0.20 per animal biosecurity (fencing) cost (shared with lice and footrot).	$0.23 per animal biosecurity (fencing) cost (shared with lice and footrot).	**

Based on these assumptions the annual cost of OJD in sheep in Australia is estimated at $52.7M (Table 106). The 2015 estimate was $35M (equivalent to $39.7M in 2022).

Table 106: Economic cost of OJD in sheep

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$0.67	$0.47	$0.03	$0.79	$0.33	$0.23	**$1.46**	**$0.80**	**$0.26**
Per Flock	$0	$0	$0	$1,449	$1,026	$69	$1,707	$705	$494	**$3,156**	**$1,731**	**$563**
Total	**$0M**			**$23.8M**			**$28.9M**			**$52.7M**		

The net gain from moving all flocks experiencing OJD to the lowest level of disease, though with current levels of vaccination is estimated at $13.2M.

<u>Changes since last report</u>

The annual cost of Ovine Johne's Disease increased in line with higher livestock prices in addition to vaccination rates increasing by 50%. Direct costs increased in line with inflation.

OJD was ranked 11th in this report. The original 2015 ranking was 11th.

4.5.12 Hypocalcaemia

The disease

Hypocalcaemia is a sporadic disease that occasionally causes substantial losses. Ewes mobilise skeletal calcium reserves to meet the foetal demands during late pregnancy so are particularly susceptible to hypocalcaemia when their intake or absorption of calcium decreases. The young lamb will maintain its plasma calcium concentration at the expense of bone structure when dietary calcium intake is inadequate during their rapid growth period. Young lambs are unable to absorb sufficient calcium from pasture. Milk intakes that result in growth rates greater than 150 g/day during the first six weeks are necessary to prevent osteoporosis by the time lambs are weaned at 12 weeks of age (Caple *et al.*, 1988).

Hypocalcaemia has several underlying causes and syndromes (Caple *et al.*, 1988; *Hypocalcaemia conundrums*, no date):

- Hypocalcaemia is regularly encountered in sheep (especially ewes and weaners) that have been supplemented for a long period of time (usually greater than 2-3 months) with cereal grain, which is naturally low in calcium, or when grazing dual-purpose cereal crops such as oats during winter.
- Perhaps the most common syndrome is observed in late pregnant ewes grazing lush grass-dominant pasture, short feed or cereal crops. Older ewes carrying multiple lambs are at greatest risk. Outbreaks are more severe in ewes that have been fed grain for extended periods such as during droughts. Handling ewes in late pregnancy exacerbates risk. Hypocalcaemia in lactating ewes is more common in northern regions (Watt B pers com).
- Dove (Dove et al., 2016) reported significant growth responses to combination(s) of calcium, magnesium and sodium licks when grazing cereals, especially wheat.
- A short interruption to food supply at critical times, such as in a severe weather event, or being held off feed such as for shearing or transport is an important risk factor for hypocalcaemia. Late pregnant ewes are most at risk. Conditions such as foot abscess can lead to anorexia with secondary hypocalcaemia.
- Hypocalcaemia is common in weaner sheep when associated with underlying osteoporosis. Osteoporosis in young sheep has many causes but is commonly associated with malnutrition, poor milk supply, calcium, copper or vitamin D deficiency and gastro intestinal parasitism (Caple *et al.*, 1988).
- Whilst hypocalcaemia is widespread there are few detailed reports or surveys describing the prevalence of hypocalcaemia in ewes and lambs.
- Occasionally hypocalcaemia is induced in sheep grazing pastures such as soursob (*Oxalis spp.*) or sorrel which are high in oxalates that bind calcium and thereby can induce hypocalcaemia.

Early treatment is important, particularly in pregnant ewes, as delayed therapy often results in complications such as pregnancy toxaemia.

	Unknown aetiology									*Known aetiology*
2015								X		
2022								X		

Prevention

Prevention is based on ensuring young sheep do not suffer malnutrition by receiving adequate milk supply from their dams and preventing nutritional deficiencies that can increase risk of hypocalcaemia and osteoporosis. Dietary management is the most important control for preventing hypocalcaemia in ewes and lambs. The highest risk groups are older twin- and triplet-bearing ewes and poorly grown weaners up to 15 months of age in southern states.

Providing adequate nutrition to ewes to ensure lambs have growth rates above 150 g/day is necessary to prevent hypocalcaemia. Limestone supplements for ewes fed grain (especially wheat) for extended periods and licks of calcium, magnesium and sodium for ewes and weaners grazing cereal crops are recommended. Other preventives include avoiding removing heavily pregnant ewes from pasture for extended periods.

Low efficacy/ unproven preventives available — *Effective preventives available*

2015							X			
2022							X			

Treatment

Treatment requires immediate administration of calcium by injection. Recovery after early treatment is typical, if not complicated by pregnancy toxaemia.

Low efficacy/ unproven treatments available — *Effective treatments available*

2015									X	
2022									X	

Distribution

The distribution varies between years, and is often more common in drought-affected regions (Larsen, Constable and Napthine, 1986). The distribution may be increasing with the trend towards high-fertility breeds of Merinos and conversion of flocks from wool to meat sheep breeds, alongside the wider adoption of grazing cereals. The increased use of highly productive pastures may paradoxically enhance risk of metabolic syndromes because the concomitant increase in stocking rates may increase risk of feed shortages during droughts.

Distribution contracting — *Distribution stable* — *Distribution increasing*

2015						X				
2022							X			

Prevalence

The prevalence of hypocalcaemia is mostly stable but may have increased slightly with the general trend towards more maternal prime lamb genetics (with intrinsically higher reproductive and growth rates) or use of Merino genetics with higher growth and reproductive rates. Ewes with superior growth and reproduction genetics and grazing high quality, lush pastures in winter have higher calcium requirements. These highly productive pastures have a high DCAD, very low calcium-to-phosphorous (Ca:P) ratios and low vitamin D, which together results in limitations to calcium uptake and bone calcium mobilisation (Lean, Vizard and Ware, 1997). Edwards (Edwards *et al.*, 2018) found approximately 20% of pregnant ewes had low blood calcium and magnesium levels, although not responsive to treatment indicates that their potentially vulnerable status. Glanville (Glanville *et al.*, 2022) found 16% of meat-breed ewes died around the time of lambing due to hypocalcaemia.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022						X				

Economics

Assumptions: Hypocalcaemia

Table 107: Assumptions: hypocalcaemia in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Highest risk in high rainfall zone, moderate in wheat sheep and lowest risk in pastoral zone.	-	**
% flocks infected	a. Ewes HRZ Merinos 0.3% (0.1% for 9 in 10 years, 2% 1 in 10 years), meat breeds 0.4%, all weaners 0.4% b. Ewes Wheat-sheep 0.24% (0.14% for 9 in 10 years, 2% 1 in 10 years), meat breeds 0.3%, all weaners 0.2% c. Ewes Pastoral 0.2%, weaners 0.2% (Larsen, Constable and Napthine, 1986; Victorian Department of Environment and Primary Industries, 2012; S. R. McGrath, Lievaart and Friend, 2013)	Glanville (Glanville et al., 2022) found 0.4% of ewes autopsied in the perinatal period died with hypocalcaemia. Hypocalcaemia assumed to affect 1% of mature ewes.	*
Mortalities	A 40% mortality rate has been assumed for hypocalcaemia (untreated cases). Note that pregnancy toxaemia is	Prime lamb enterprise ewe mortality rate increased to 0.4% of mature ewes	*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	considered separately with the underlying cause likely to be hypocalcaemia in many cases.		
Weight loss	No weight loss, fertility or other production effects are assumed; all production losses are due to deaths	-	**
Fleece	Nil	-	***
Wool	Nil	-	***
Fertility	Nil	-	*
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Treatment by administering injectable calcium. The cost of calcium injections and labour is $10.00/ewe. 60% of ewes with clinical hypocalcaemia treated.	Treatment by administering injectable calcium. The cost of calcium injections and labour is $13.60/ewe. 60% of ewes with clinical hypocalcaemia treated.	*
Prevention	Prevention is by provision of adequate dietary nutrients (no cost allocated). About 30% of producers supply lime at 1.5% of diet in drought years (1 in 10 years @$0.60) and 5% of producers provide a supplement in an average year ($0.30). A survey of producers *(S. McGrath, Lievaart and Friend, 2013)* in the wheat-sheep zone of southern NSW grazing dual purpose crops found 40% of producers graze cereals. Across Australia this is estimated to be 20% overall. An estimated 55% of producers supplemented with calcium and roughage. Cost of lick supplement 2c/day for 28 days = $0.56/ewe and weaner. In addition, roughage costs were	Prevention is by provision of adequate dietary nutrients (no cost allocated). About 30% of producers supply lime at 1.5% of diet in drought years (1 in 10 years @$0.69) and 5% of producers provide a supplement in an average year ($0.45). A survey of producers (McGrath et al. 2013) in the wheat-sheep zone of southern NSW grazing dual purpose crops found 40% of producers graze cereals. Across Australia this is estimated to be 25% overall. An estimated 55% of producers supplemented with calcium and roughage. Cost of lick supplement 3c/day for 28 days = $0.64/ewe and weaner. In addition, roughage costs were estimated to be $0.48/ewe and weaner. Preventive strategies	*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	estimated to be $0.42/ewe and weaner. Preventive strategies such as Unimix™ or Vitamin D are adopted in such a low level they are not considered.	such as Unimix™ or Vitamin D are adopted in such a low level they are not considered.	

Based on these assumptions the annual cost of hypocalcaemia in sheep in Australia is estimated at $44.4M. The 2015 estimate was $11.16M (equivalent to $13.2M in 2022).

Table 108: Economics of hypocalcaemia in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0.05	$0.05	$0.02	$0.18	$0.29	$0.00	$0.43	$0.39	$0.13	**$0.66**	**$0.73**	**$0.14**
Per Flock	$112	$101	$33	$378	$625	$0	$917	$828	$269	**$1,406**	**$1,553**	**$301**
Total	**$3.2M**			**$15.1M**			**$26.1M**			**$44.4M**		

If the prevalence of hypocalcaemia in mature ewes was reduced to half the assumed level, the saving for the sheep industry would be approximately $14.6M.

<u>Changes since last report</u>

The annual cost of hypocalcaemia in sheep in Australia has increased substantially primarily due to increased livestock prices and a higher hypocalcaemia mortality rate in mature ewes. Lower growth rates of young sheep grazing at risk cereals was not included due to the uncertainty in the number of sheep grazing these high-risk crops, although lost production of the order of 10% of total cost of hypocalcaemia to the Australian sheep flock is feasible.

Hypocalcaemia was ranked 12th in this report. The original 2015 ranking was 17th.

4.5.13 Caseous lymphadenitis

The Disease

Caseous lymphadenitis (CLA), commonly called cheesy gland, is caused by *Corynebacterium psuedotuberculosis* infection. Infected sheep develop abscesses in lymph nodes and organs including the lungs and liver. Wool production may be affected as abscesses develop (Paton *et al.*, 1988). CLA is widespread, affecting sheep in all climatic zones. Initial infection is thought most common at first or second shearing. Infection is mostly via shearing cuts. Transmission is increased when sheep are in close contact (as at shearing) and enhanced by post-shearing dipping. Infection can occur several months after bacterial transmission where the bacteria may pass through intact skin (Paton *et al.*, 1994, 1988, 2003b).

The prevalence of cheesy gland in the sheep flock is estimated at 29% in unvaccinated flocks, whereas the prevalence in fully vaccinated flocks (receiving an annual booster) is 3%. Flocks that are only vaccinated as lambs had a similar prevalence to unvaccinated flocks. In one study, 95% of 223 flocks had CLA (Paton *et al.*, 2003b). Pointon (Pointon, Kiermeier and Hamilton, 2017) found the prevalence of CLA lesions in abattoirs was 7.7% of carcases. This is a substantial reduction in prevalence estimates from the 1990s and suggests that increased adoption of CLA vaccine has reduced disease prevalence (Windsor and Bush, 2016). The economic effects of CLA arise from reduced wool production (that occurs in the year of infection, presumably due to the sheep mounting an immune response) and the cost of vaccination. Post-farm-gate costs include condemnation of between 0.3% of adult carcases and carcase downgrade and trim costs.

	Unknown aetiology									*Known aetiology*
2015										X
2022										X

Prevention

Vaccination with CLA vaccine is the most effective strategy to prevent CLA. Hygiene at shearing, the shearing of younger sheep first and avoiding handling of freshly shorn sheep are recommended. The effectiveness of CLA vaccine is less than optimal, arising from restricted or inappropriate vaccine usage and a common perception that the vaccine is not cost effective.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015							X			
2022							X			

Treatment

There is no known treatment for CLA.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015	X									
2022	X									

Distribution

Distribution remains stable, perhaps slightly decreasing as the number of mature wethers in the industry continues to decline.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

Prevalence is generally stable or slightly decreasing due to vaccination and a reduction in use of wet dips for lice control (which is a risk factor for CLA).

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: CLA

Table 109: Assumptions: CLA in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	22% flocks high risk with no vaccination, 58% moderate risk with partial vaccination and 20% low risk with full vaccination program	20% flocks high risk with no vaccination, 44% moderate risk with partial vaccination and 36% low risk with full vaccination program -	**
% flocks infected	Prevalence segregated based on vaccine program adopted (Paton *et al.*, 2003b): 22% of sheep flocks: no vaccination, prevalence of 29% in adults. 58% of sheep flocks: non-effective vaccination program, prevalence of 28% in adults 20% of sheep flocks: effective vaccination program, prevalence of 3% in adults	Prevalence segregated based on vaccine program adopted (Paton *et al.*, 2003b; Windsor and Bush, 2016): 20% of sheep flocks: no vaccination, prevalence of 29% in adults. 44% of sheep flocks: non-effective vaccination program, prevalence of 20% in adults 36% of sheep flocks: effective vaccination program, prevalence of 3% in adults	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
		-	
Mortalities	Nil	-	***
Weight loss	Nil	-	***
Fleece weight	5% reduction in clean fleece weight in year of infection with resulting reduction in fibre diameter (Paton *et al.*, 1988)	-	***
Wool quality	Slight reduction in FD	-	**
Fertility	Nil	-	***
Market avoidance	0.3% of adult carcases sold condemned, 3% of offal sets condemned and 3% carcases trimmed (0.6kg) (Paton *et al.*, 2003b; Fontaine and Baird, 2008; GHD, 2011)	-	**
Movement restrictions	Nil	-	***
Treatment	Nil	-	***
Prevention	Prevention is by vaccination with CLA vaccine. Marginal cost of $0.12/dose (cost above clostridial vaccine component) with 50% of labour cost $0.12/dose	Prevention is by vaccination with CLA vaccine. Marginal cost of $0.16/dose (cost above clostridial vaccine component) with 50% of labour cost $0.15/dose. Vaccination rates increased with higher adoption of vaccination.	**

Based on these assumptions the annual cost of CLA in sheep in Australia is estimated at $23.1M as shown (Table 110). The 2015 estimate was $17.8M (equivalent to $20.2M in 2022).

Table 110: Economic cost of CLA in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$0	$0.11	$0.34	$0.30	$0.21	$0.03	**$0.30**	**$0.32**	**$0.37**
Per Flock	$0	$0	$0	$0	$235	$733	$651	$458	$72	**$651**	**$694**	**$804**
Total	**$0M**			**$11.7M**			**$11.4M**			**$23.1M**		

There is no apparent net gain from moving all flocks to the lowest level of disease. Vaccination against CLA is already widely adopted. In fact, if vaccination was adopted across the remainder of the industry, the cost of moving all flocks to the lowest risk would be -$2.53M.

Changes since last report

The cost of CLA increased slightly over the 2015 estimate due to higher commodity prices for wool and carcase values, but partly offset by reduced sheep numbers. Prevention costs increased with increased vaccination rates. Trim and carcase condemnation reduced with the CLA prevalence decline within the sheep industry.

CLA was ranked 13th in this report. The original 2015 ranking was 15th.

4.5.14 Liver fluke

The disease

Liver fluke (*Fasciola hepatica*) is an important disease of sheep in regions where the parasite occurs. Liver fluke can infect many species in addition to sheep and cattle (including wildlife such as kangaroos). Fluke is most common in regions with an average annual rainfall of 600 mm or greater, although fluke can occur from time to time in regions with lower rainfall and on irrigated and swampy ground. Adult fluke live in the bile ducts of the liver and pass eggs into the faeces. The intermediate stages infect snails, most commonly, *Austropeple tomentosa,* but potentially, *Austropeplea viridis* and *Pseudosuccinea columella* which have a wider range (Boray, Jackson and Strong, 1985). The fluke intermediate stages multiply in the host snail and infective stages leave the snail to attach to pasture. Sheep become reinfected from grazing pasture infested with infective metacercariae. Acute fluke infection follows ingestion of large number of metacercariae and infection causes severe disease and often death. Chronic liver fluke infection is more common, and this results in production losses, anaemia and bottle jaw. Rarely, black disease caused by *Clostridium novyi* in association with larval fluke migrating through the liver, results in sudden death. Black disease is prevented by clostridial vaccine (e.g. 5-in-1 vaccination).

Production losses associated with liver fluke include mortality, weight loss, reduced wool growth, and reduced reproductive performance (arising from reduced ewe body weight). Post farm gate offal condemnation losses at abattoirs are common and substantial for that sector. Control is based on strategic and tactical drenching of sheep with flukicides, exclusion fencing of swampy high-risk areas, improved drainage (especially in irrigation areas) and strategic grazing management to avoid high-risk animals grazing high-risk paddocks.

	Unknown aetiology									*Known aetiology*
2015										X
2022										X

Prevention

Long-term control relies on the strategic use of flukicides that kill immature and adult fluke populations in sheep. Strategic drenching both minimises production losses and reduces pasture contamination. Specific timing of drenching depends on the level of fluke challenge and the regional climatic conditions. Monitoring of fluke burdens is useful to fine-tune strategic drenching programs. Additional control can be achieved by fencing off swampy areas or grazing with adult cattle that are less susceptible to fluke. The development of resistance to Triclabendazole, the most used and effective flukicide, will make fluke control more difficult if not managed (Kelley *et al.*, 2016).

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015							X			
2022						X				

Treatment

Treatment in the face of high fluke burdens is considered part of prevention programs. The main limitation on the efficacy of anthelmintics is the likely widespread nature of drench resistance and the limited extent of resistance testing amongst sheep producers.

Low efficacy/ unproven treatments available *Effective treatments available*

2015								X		
2022							X			

Distribution

The introduction of new snail species (*Austropeplea viridis* and *Pseudosuccinea columella*) that can survive a wider range of climatic zones and environments may increase the distribution of fluke in future, including in Western Australia where currently no fluke is present. The distribution of liver fluke may be enhanced by climate change, with warmer winters for survival on pasture balanced with higher mortality with hot temperatures.

Distribution contracting *Distribution stable* *Distribution increasing*

2015						X				
2022						X				

Prevalence

Prevalence is generally stable, though the prevalence increases in wet years. Resistance to Triclabendazole will potentially reduce the efficacy of control programs and increase the severity of fluke. The National Sheep Health Monitoring Project (NSHMP) survey data suggests there has been a decline over the past few years to 0.5% animals infected from approx. 8.89 million inspected carcasses. Tasmania recording the highest prevalence of Fluke with 25% of properties affected. The prolonged dry across NSW, Victoria and southern QLD may have influenced the recent downward trend in these states' prevalence through abattoirs.

Prevalence decreasing *Prevalence increasing*

2015					X					
2022					X					

Economics

Assumptions: Liver fluke

Table 111: Assumptions: liver fluke in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Distribution predominantly in NSW, Victoria, Southern QLD and Tasmania, rare in South Australia, exotic to Western Australia. More common above 600 mm rainfall and	-	***

<table>
<tr><th>Variable</th><th>2015 Assumptions</th><th>2022 Assumption Changes</th><th>Confidence</th></tr>
<tr><td></td><td>irrigated pasture outside the high rainfall regions. 13.6% sheep flocks considered high risk, 2.1% moderate risk and 84.3% low to nil risk.</td><td></td><td></td></tr>
<tr><td>% Flocks affected</td><td>Based on abattoir surveillance (Animal Health Australia, 2014b)
<table>
<tr><th>State</th><th>% farms</th><th>% sheep with fluke</th></tr>
<tr><td>NSW</td><td>34%</td><td>9.25%</td></tr>
<tr><td>QLD</td><td>13%</td><td>2.56%</td></tr>
<tr><td>Tasmania</td><td>15%</td><td>3.38%</td></tr>
<tr><td>Victoria</td><td>10%</td><td>0.97%</td></tr>
<tr><td>SA</td><td>0.4%</td><td>0.06%</td></tr>
</table>
A survey of NSW and Victoria (Hort, 1998) indicated 33% of properties had positive FEC tests.</td><td>Based on abattoir surveillance (Animal Health Australia, 2021)
<table>
<tr><th>State</th><th>% farms</th><th>% sheep with fluke</th></tr>
<tr><td>NSW</td><td>8%</td><td>0.74%</td></tr>
<tr><td>QLD</td><td>2%</td><td>0.02%</td></tr>
<tr><td>Tasmania</td><td>25%</td><td>3.86%</td></tr>
<tr><td>Victoria</td><td>2%</td><td>0.18%</td></tr>
<tr><td>SA</td><td>0.2%</td><td>0.02%</td></tr>
</table>
A survey of NSW and Victoria (Hort, 1998) indicated 33% of properties had positive FEC tests.</td><td>**</td></tr>
<tr><td>Mortalities</td><td>No published data. Estimate 0.25% in affected flocks.</td><td>-</td><td>*</td></tr>
<tr><td>Weight loss</td><td>In affected sheep:
Temporary weight loss: 5.5% in high-risk flocks, 3% mod risk
Permanent weight loss: 5.5% high risk, 3% mod risk</td><td>-</td><td>*</td></tr>
<tr><td>Fertility</td><td>1.5% per kg bodyweight</td><td>-</td><td>**</td></tr>
<tr><td>Fleece weight %</td><td>In affected sheep, wool production penalty 14% in high-risk flocks, 7% mod risk</td><td>-</td><td>*</td></tr>
<tr><td>Wool price discounts</td><td>Due to reduction in staple strength of 8 N/kTex</td><td>2% discount on wool value with due to staple strength discount</td><td>*</td></tr>
<tr><td>Market avoidance</td><td>0.01302% adult offal (Liver) condemned (GHD, 2011)</td><td>0.5% of sheep affected with liver fluke (Liver) condemned (NSHMP 2020-21)</td><td>**</td></tr>
</table>

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	0.00326% lamb offal (Liver) condemned Average value $0.81/liver	Average value $1.65/liver	
Movement restrictns	Nil	-	***
Treatment	Considered as part of prevention program	-	**
Prevention	Cost of drench: $0.40/dose including labour Drench frequency: 1.45 drenches per year (Hort, 1998) Monitoring costs: $0.12/sheep, 0.25 times per year	Cost of drench: $0.45/dose including labour Drench frequency: 1.45 drenches per year Monitoring costs: $1.65/sheep, 0.25 times per year	**

Total cost of disease

Based on these assumptions the annual cost of liver fluke in sheep in Australia is estimated at $38.2M (Table 112). The 2015 estimate was $25M (equivalent to $28.4M in 2022).

Table 112: Economic cost of liver fluke in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$0.14	$0.03	$0	$3.85	$0.56	$0	**$3.99**	**$0.59**	**$0**
Per Flock	$0	$0	$0	$308	$65	$0	$8,301	$1,212	$6	**$8,609**	**$1,277**	**$0**
Total	**$0M**			**$1.4M**			**$36.8M**			**$38.2M**		

If the severity of Liver fluke is reduced by 50% before extra costs are considered, the cost to industry would reduce by $18.4M.

Changes since last report

The annual cost of liver fluke in sheep in Australia has increased substantially since the last report in 2015 primarily due to higher commodity price for meat and wool. In addition, expenses have all increased by CPI. Base assumptions are similar except the prevalence has reduced due to drought conditions although this is assumed to be a short-term issue rather than a permanent change to the cost of Liver fluke.

Liver fluke was ranked 14th in this report. The original 2015 ranking was 13th.

4.5.15 Clostridial disease

The disease

The most common clostridial disease of sheep is enterotoxaemia (*C. perfringens* type D). Others include occasional tetanus (*C. tetani*) and less commonly recognised malignant oedema (*C. septicum*), blackleg (*C. chauvoei*), and black disease (*C. novyi*). Clostridia bacteria are widespread and can survive in the environment for long periods. Enterotoxaemia (or pulpy kidney) is commonly encountered with young sheep grazing lush pasture or in feedlot situations. Sheep on a diet high in carbohydrate which is not completely broken down in the rumen pass into the small intestine where clostridia bacteria rapidly multiply and produce toxins that precipitate disease (Farquharson, 1994). Poor hygiene at lamb marking will very occasionally produce tetanus outbreaks. Disease is invariably fatal, however highly effective and cheap vaccines exist against the major clostridial diseases.

Enterotoxaemia is often blamed for sudden deaths, however, in many situations sudden death resulting in rapid carcass autolysis may be caused by many diseases so the prevalence of clostridial diseases may be over-estimated.

	Unknown aetiology									*Known aetiology*
2015								X		
2022								X		

Prevention

Effective combination vaccines are available and are widely used as various trade names (e.g. “5-in-1”, “3-in-1” or “6-in-1”) or in combination with drenches. This prevents most disease. In high-risk situations, more frequent vaccination for enterotoxaemia may be necessary. Black disease is often associated with liver fluke infestations — but fluke areas are generally well known and preventive measures (against fluke and black disease) are typically applied. Recent surveys indicate that adoption of vaccination is higher than previously assumed so effective prevention.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015								X		
2022									X	

Treatment

Treatment is generally not effective within broad-acre livestock industries; affected sheep are rarely identified in time.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015	X									
2022	X									

Distribution

The distribution of clostridial diseases is widespread but stable.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

Clostridial diseases are an ever-present risk, though risk is often elevated when lush pasture or intensive feeding is present.

	Prevalence decreasing									*Prevalence increasing*
2015							X			
2022							X			

Economics

Assumptions: Clostridial diseases

Table 113: Assumptions: clostridial diseases in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	All sheep flocks are at risk of clostridial disease. About 75-80% use effective vaccination in ewes and 50% in lambs	All sheep flocks are at risk of clostridial disease. About 96% of producers use clostridial vaccine and 80% use effective vaccination in ewes and 75-85% effective vaccine protocol (2 doses) in lambs (Kopp *et al.*, 2020)	**
% Flocks affected	- 1% of flocks experience large-scale outbreaks (generally arising from failure to vaccinate or incorrect vaccine administration/storage). 2% of young stock and 0.25% of adults affected. - 19% of flocks experience moderate outbreak (again due to inadequate vaccination). Up to 0.5% of young stock and 0.1% of adults affected.	Use 2015 assumptions – note a recent New Zealand report showed about lamb mortalities were 1.6% higher from previously unvaccinated ewes where lambs were not vaccinated compared lambs that did receive 2 vaccinations from marking (Bingham and Hodge, 2022).	*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	- 80% of flocks experience no disease		
Mortalities	100% of clinical cases	-	***
Weight loss	Nil	-	***
Fertility	*Nil*	-	***
Fleece weight %	Nil	-	***
Wool price discounts	Nil	-	***
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Nil	-	***
Prevention	Prevention is by vaccination. A dose is estimated to cost $0.30 (vaccine plus labour). Few estimates are available regarding vaccine use. Based on a recent survey of 1600 producers (2011), 44% of producers vaccinated once at marking, 54% twice to lambs, 77% vaccinated ewes annually, 21% wethers annually and 55% rams annually. This is probably a reasonable estimate of industry practice.	Prevention is by vaccination. A dose is estimated to cost $0.34 (vaccine plus labour). Few estimates are available regarding vaccine use. Previous surveys of 1600 producers (2011), 44% of producers vaccinated once at marking, 54% twice to lambs, 77% vaccinated ewes annually, 21% wethers annually and 55% rams annually. Recent surveys (Kopp *et al.*, 2020) showed 79% of merino producers vaccinate ewes prelambing and 80-90% vaccinated meat breed ewes. About 17% of merino lambs were vaccinated just once and 23% of crossbred lambs were vaccinated once. This is probably a reasonable estimate of industry practice.	**
Other costs		-	

Based on these assumptions the annual cost of clostridial diseases in sheep in Australia is estimated at $37.4M (Table 114). This estimate has uncertainty due to lack of data on prevalence of disease. The 2015 estimate was $31.7M (equivalent to $36.0M in 2022).

Table 114: Economic cost of clostridial diseases in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$0	$0.20	$0.51	$1.93	$0.55	$0	**$1.93**	**$0.75**	**$0.51**
Per Flock	$0	$0	$0	$0	$420	$1,087	$4,078	$1,156	$0	**$4,078**	**$1,576**	**$1,087**
Total	**$0M**			**$31.0M**			**$6.3M**			**$37.4M**		

The net gain from moving all flocks to the lowest level of clostridial diseases is $2.7M if all flocks followed recommended vaccination protocols so losses due to clostridial disease were negligible but extra vaccination would increase prevention costs.

Changes since last report

The cost of clostridial diseases in sheep has increased slightly due to higher livestock prices and small increases in adoption rates and the cost of vaccine.

Clostridial diseases were ranked 15th in this report. The original 2015 ranking was 12th.

4.5.16 Pregnancy toxaemia

The disease

Pregnancy toxaemia is a common metabolic disease of sheep. Pregnancy toxaemia usually occurs towards the end of the final trimester of pregnancy in ewes carrying multiple pregnancies, with very fat or very thin ewes most at risk, particularly older ewes. Twin-bearing ewes require 180% of the energy required by single-bearing ewes. The condition results from the inability of ewes to consume enough dry matter and energy such that the energy demand outstrips the ewe's ability to supply. Negative energy balance results in mobilisation of fatty acids from body reserves when the liver is unable to produce enough glucose to meet demand. The liver then becomes saturated with fatty acids and the subsequent production of ketones results in ketosis, or pregnancy toxaemia. Other risk factors include dietary change, sudden feed restriction (e.g. as caused by yarding), and concurrent diseases, especially foot abscess and hypocalcaemia.

Early intervention and treatment can be moderately effective, but late treatment is successful for around half of cases. Untreated ewes generally die. Prevention depends upon ensuring adequate supply of pasture or, if not available, supplementary feed. Separation of twin-bearing and triplet-bearing ewes from single-bearing ewes with differential feeding will reduce the risk of disease in these high-risk cohorts. Controlling concurrent diseases such as hypocalcaemia and foot abscess will further reduce risk of pregnancy toxaemia.

Pregnancy toxaemia is present in all climatic zones, though good prevalence data is not available. In the Victorian sentinel flock project (DEPI 2012), 13% of ewe deaths over a three-year period were caused by metabolic problems of which 80% were attributed to pregnancy toxaemia. Metabolic disease was more commonly diagnosed as the cause of death in ewes in prime lamb flocks (15.5%) compared to dual purpose (8.7%) and Merino (3.7%) flocks. Surveys in South Australia, Victoria and New South Wales all identified pregnancy toxaemia as an important cause of death in late pregnant ewes (Harris and Nowara, 1995; S. R. McGrath, Lievaart and Friend, 2013; Watt, Eppleston and Dhand, 2021). A recent investigation into ewe mortality during lambing identified that Pregnancy Toxaemia accounted for 2% and 1% of ewe mortalities over the lambing period over two years where 2.5% and 1.98% of total mortalities over lambing occurred in the two years (McQuillan *et al.*, 2021). This is likely to be an under-estimated of losses caused by Pregnancy Toxaemia as most losses occur in the pre-lambing period.

	Unknown aetiology									*Known aetiology*
2015									X	
2022									X	

Prevention

Prevention depends upon adequate supply of energy — from pasture and/or supplementary feed. Separation of twin-bearing and triplet-bearing ewes from single-bearing ewes and differential feeding of high-risk cohorts will reduce risk. Controlling concurrent diseases such as hypocalcaemia and foot abscess will reduce the risk of pregnancy toxaemia. Plan handling operations to occur prior to the last month of pregnancy, if handling is necessary, handle with care for short periods and be flexible with the order (i.e. older, twinning ewes first).

Low efficacy/ unproven preventives available | *Effective preventives available*

2015							X			
2022							X			

Treatment

A variety of treatments are available, though none are effective if delivered late in the course of the disease.

Low efficacy/ unproven treatments available | *Effective treatments available*

2015				X						
2022				X						

Distribution

Distribution is stable.

Distribution contracting | *Distribution stable* | *Distribution increasing*

2015					X					
2022					X					

Prevalence

Prevalence is generally constant, but highly influenced by season. A trend towards meat breeds with high fecundity will increase prevalence of pregnancy toxaemia if nutrition is not well managed.

Prevalence decreasing | *Prevalence increasing*

2015						X				
2022						X				

Economics

Assumptions: Pregnancy toxaemia

Table 115: Assumptions: pregnancy toxaemia in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	The distribution of pregnancy toxaemia is widespread in all regions and sporadic in nature, with higher risk years being drought years and wet years associated with foot abscess.	-	**
% flocks infected	Pregnancy toxaemia is distributed across all climatic zones and regions with 0.5% of prime lamb flocks affected, 0.4%	-	*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	of dual-purpose flocks and 0.25% of Merino flocks with all cases in mature (>2 yo) ewes.		
Mortalities	A 80% mortality rate has been assumed for pregnancy toxaemia.	Mortality rate assumed to be 80% for clinical cases	**
Weight loss	Temporary weight loss of 2 kg.	-	*
Fleece weight	No reduction in fleece weight considered	-	**
Wool quality	Wool price discounts range from 1% - 18% depending on wool micron categories (Nolan, 2012). Surviving ewes have a reduction in staple strength of 15 N/kTex.	4% discount of merino fleece due to reduced staple strength	
Fertility	25% of surviving ewes fail to rear lambs	-	*
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	The most common treatment is supplied by providing oral or parenteral dextrose or glucose fluids and electrolytes. Providing additional supplementary feed will also help reduce the re-occurrence and prevent new cases. About 25% of cases are assumed to be treated with intensive therapy costing $15/ewe.	The most common treatment is supplied by providing oral or parenteral dextrose or glucose fluids, calcium borogluconate and electrolytes. Providing additional supplementary feed will also help reduce the re-occurrence and prevent new cases. About 25% of cases are assumed to be treated with intensive therapy costing $17/ewe.	*
Prevention	Prevention is by providing adequate pasture or supplementary feed and preventing concurrent disease. The value of supplementary feed is partially considered as it is supplied to ewes as normal farm management (assumed 1 kg/ewe		*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	extra for 4 weeks to 20% of mature ewes).		

Based on these assumptions the annual cost of pregnancy toxaemia in sheep in Australia is estimated at $30.3M (Table 116). The 2015 estimate was $16M (equivalent to $18.2M in 2022).

Table 116: Economic cost of pregnancy toxaemia in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0.01	$0	$0	$0.11	$0	$0	$0.33	$0.00	$0.00	**$0.44**	**$0**	**$0**
Per Flock	$17	$0	$0	$234	$0	$0	$699	$0	$0	**$950**	**$0**	**$0**
Total	**$0.5M**			**$7.5M**			**$22.3M**			**$30.3M**		

The net gain from halving mortality rate in all flocks experiencing pregnancy toxaemia is estimated to be $8.8M before the cost of effective treatment is considered.

<u>Changes since last report</u>

The assumed mortality rate of clinical cases was increased from the previous analysis. In addition, changes in the cost of the disease were also due to increases in livestock and wool prices and the cost of treatment increasing at CPI.

Pregnancy toxaemia was ranked 16th in this report. The original 2015 ranking was 16th.

4.5.17 Pneumonia

The disease

Pneumonia is typically a sporadic disease of sheep affecting both adults and lambs. There are a variety of causes including *Mannheimia haemolytica,* which is most commonly isolated (Watt *et al.* 2013), but other agents include *Arcanobacter pyogenes, Mycoplasma spp* and viruses such as Parainfluenza 3 virus (St George and Liefman, 1972). Lloyd (2019) tested 171 samples from 5 abattoirs of which 66% tested positive for *Mycoplasma ovipnuemoniae*. Numerous other bacteria have been implicated though none on a widespread basis. Pneumonia is linked to mortality, carcase condemnation, reduced liveweight gain, increased time to reach slaughter weight and reduced carcase quality (Lacasta *et al.*, 2019). Lungworm (*Dictyocaulis filaria, Meullerus capillaris and Protostrongylus rufescens*) was historically common, however use of broad-spectrum anthelmintics has made this a rare cause of pneumonia. In the context of this report Pleurisy is also included.

Whilst farm prevalence data is limited or non-existent, abattoir monitoring of conditions associated with pneumonia is widespread in Australia. The National Sheep Health Monitoring Program (NSHMP) data shows up to 50% of Australian sheep flocks have endemic pneumonia. The 2020–21 NSHMP data found approximately 0.3% and 1.2% of carcases had evidence of damage due to pneumonia and pleurisy respectively, with a higher proportion of lambs with evidence of pneumonia compared with sheep over 2 years of age. In contrast more adults had evidence of pleurisy compared with lambs. Lloyd (Lloyd, 2019) collected lamb pleurisy trim data during the MLA Project B.AHE.0238 and found 48.5% of affected carcasses required trimming, with an average of 1.0kg trim weight per carcass. Location, management or climatic and production differences influence the development of disease. Predisposing factors on individual farms are not always clear, but stress and weather change are often associated with outbreaks.

	Unknown aetiology									*Known aetiology*
2015							X			
2022							X			

Prevention

No control measures exist to prevent pneumonia. Lung worm is largely managed by anthelmintics for worm control and any cost is incidental to this. Vaccines are available for cattle and internationally for sheep though none are available in Australia. Management to reduce stress, crowding and dust, especially in intensive situation, in addition to improving shade and ventilation, careful introduction of feed to minimise the risk of acidosis are all beneficial

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015		X								
2022			X							

Treatment

Treatment is based upon antibiotics, usually long-acting oxytetracyclines. Individual animal treatments are not common, often only implemented in large outbreaks; most low-level outbreaks are not recognised. Treatment is moderately effective but typically outbreaks are well advanced before treatment is implemented.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015							X			
2022							X			

Distribution

Distribution seems to be widespread across sheep growing regions.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

Prevalence is generally constant although variable between years

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: Pneumonia

Table 117: Assumptions: Pneumonia in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Prevalence is assumed to be constant across regions.	-	*
% flocks infected	Based on abattoir surveillance, about 3.3% of lambs and 5.7% of adults show evidence of pneumonia (Watt, Barwell and Links, 2013; Department of Agriculture Forestry and Fisheries, 2014; National Sheep Health Monitoring Project, no date)	Based on NSHMP data 50% of flocks show evidence of pneumonia and pleurisy previous within flock prevalence rates used. Retain prevalence rates from previous analysis	*
Mortalities	10% of weaners and 5% of adults with clinical pneumonia	0.33% of weaners 0.2% of ewes die with pneumonia (assumes 10% of weaners die of pneumonia and 5% of adults with clinical disease)	*
Weight loss	Production loss data is limited. In New Zealand, Alley (2002) found that lambs with pneumonic	Temporary weight loss 23 days longer to finish affected sale lambs (Hickford et al., 2014)	*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	lesions had on average 1.5 kg lower carcase weight (3.3 kg liveweight) than control lambs. The penalty for lambs with minor lesions is small but lambs with more than 20% of their lungs affected had severe weight penalties. No penalty has been considered for weight loss in adults.		
Fleece weight	Nil	-	*
Wool quality	Nil	-	*
Fertility	Nil	-	*
Market avoidance	Carcase and offal condemnation: a. Condemnation: 0.016% of adults, 0.0013% lambs (DAFF 2014) b. Carcase trim and offal condemnation 0.49% of adults, 0.039% lambs average 1.1 kg cw/carcase (GHD, 2011; Hernandez-Jover et al., 2013) c. Offal value $0.61/offal condemnation	a. Condemnation: 0.016% of adults, 0.0013% lambs (DAFF 2014) b. Pneumonia: 0.03% adults 0.27% lambs. Pleurisy: 0.86% adults 0.38% lambs c. average 1.0kg cw/carcase (Lloyd, 2016) d. Offal value $0.70/offal condemnation	**
Movement restrictions	Nil	-	*
Treatment	Treatment is implemented by antibiotic therapy $10.00 per dose. Only lambs treated, assumed 1% of clinical cases treated	Treatment is implemented by antibiotic therapy $11.40 per dose. Only lambs treated, assumed 5% of clinical cases treated	*
Prevention	Prevention is not available	-	**

Based on these assumptions the annual cost of pneumonia in sheep in Australia is estimated at $26.0M (Table 118). The 2015 estimate was $20.4M (equivalent to $23.2M in 2022). This estimate has uncertainty due to lack of prevalence data and subsequent subclinical production losses.

Table 118: Economic cost of pneumonia in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0.02	$0	$0	$0	$0	$0	$0.73	$0	$0	**$0.76**	**$0**	**$0**
Per Flock	$50	$0	$0	$0	$0	$0	$1,560	$0	$0	**$1,629**	**$0**	**$0**
Total	**$0.8M**			**$0M**			**$25.2M**			**$26.0M**		

Reducing prevalence by 50% without extra costs considered would reduce the cost to industry by $13M. Note that no value on potential production losses has been included for adult sheep as they are unknown although probably reasonably significant.

Changes since last report

The annual cost of pneumonia to the sheep industry has increased due to higher livestock prices and increased costs of treatment that have been indexed to inflation.

Pneumonia was ranked 17th in this report. The original 2015 ranking was 14th.

4.5.18 Bacterial enteritis

The disease

Bacterial enteritis is a combination of several bacterial diseases of the intestinal tract commonly observed in high rainfall regions in weaned Merino lambs and hoggets and occasionally first-cross hoggets but is rarely seen in second-cross lambs. *Campylobacter spp.* and *Yersinia spp.* are bacterial agents most associated with this syndrome. Salmonellosis has been excluded from the economic analysis of this syndrome, which is far less common though can be very important on individual farms. Virulent *Yersinia enterocolitica* and *Yersinia pseudotuberculosis* are most common isolates from sheep with acute gastroenteritis. Campylobacter occurs more frequently during summer, especially when conditions are wet, and typically has fewer deaths than outbreaks of Yersiniosis. Shedding of *Y. pseudotuberculosis* occurs only during the winter, whereas *Y. enterocolitica* is shed throughout the year. Clinical disease in winter is therefore mostly produced by *Y. pseudotuberculosis* though recent research demonstrates that *Y. enterocolitica* can also cause significant disease (Stanger *et al.*, 2019). Risk factors for developing clinical disease are complicated. In winter disease is most often associated with gastrointestinal parasitism, cold and wet weather and nutritional stress. Affected animals are lethargic, scour profusely and rapidly dehydrate. Sheep less than 16 months of age are most commonly affected and during an outbreak, the prevalence of clinical disease and mortalities can exceed 30% and 10%, respectively (Stanger, McGregor and Larsen, 2018). The proportion of animals shedding each species varies between regions ranging from 0% to 75% for *Y. enterocolitica* and 0% to 55% for *Y. pseudotuberculosis* (Stanger *et al.*, 2019). The point prevalence of *Yersinia spp*. shedding in one flock was 90.6% post weaning (Yang *et al.*, 2016). Estimated morbidity rates range from 1–90% (18% average) and mortality 0–6.9% (1.8% average) due to unspecified *Yersinia spp.* Morbidity and mortality rates of the disease in summer are less well documented though likely to be significant. Antibiotic resistance has been identified with *Yersinia spp*. to sulphonamides which has implications for treatment given the widespread use of this antibiotic group for the treatment of bacterial enteritis (Stanger *et al.*, 2019). Weaner colitis in winter is usually caused by *Yersinia spp.* and is more understood than the disease in summer which seems to be mostly associated with *Campylobacter spp*.

	Unknown aetiology									*Known aetiology*
2015						X				
2022								X		

Prevention

No vaccines are available. General flock management to improve nutrition and reduce stress and control concurrent disease such as worms is recommended.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015				X						
2022					X					

Treatment

Antibiotic therapy focusing on injectable oxytetracyclines together with management interventions, such as improving nutrition and moving affected mobs onto uncontaminated pastures, can help control Yersinia outbreaks. Response to treatment of summer outbreaks of campylobacter do not seem to be as effective. Antibiotic resistance is widespread, and the use of sulphonamides is not recommended in flocks that have had a long-term history of outbreaks and (failed) treatment with sulphonamides for yersiniosis.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015							X			
2022						X				

Distribution

The disease predominantly occurs in high rainfall regions mostly affecting Merino weaners where 50% of flocks are considered at risk.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

Slee and Skilbeck (Slee and Skilbeck, 1992) estimated 5% of flocks (mostly in winter) have *Y. pseudotuberculosis* and 17% of flocks have *Y. enterocolitica* (present throughout the year). Stanger showed that the prevalence of faecal shedding within a flock is not a reliable means of predicting an outbreak of yersiniosis, because moderate to high shedding was not always associated with clinical disease outbreaks. Prevalence of clinical disease can fluctuate between regions and years and can exceed 30% with up to 10% mortalities (Stanger, McGregor and Larsen, 2018). Yersinia appears to be less severe in favourable years with good feed, whereas summer colitis is more severe in wet summers regardless of nutrition.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: Bacterial enteritis in sheep

Table 119: Assumptions: bacterial enteritis in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	50% of high rainfall zone is at risk	50% of merino flocks at risk 25% of dual purpose and 12.5% of prime lamb flocks at risk in the high rainfall zone	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
% Flocks affected	10% of Merino weaner mobs affected, 5% of first cross weaner mobs 40% of weaners have clinical disease: 10% severe, 30% mild.	30% of weaners have clinical disease in merino flocks, 25% in dual purpose and 20% in carry over prime lamb flocks	*
Mortalities	Average 3% of affected mob (K. Stanger pers com 2014)	2% carryover prime lamb	*
Weight loss	5 kg severe, 1kg mild (temporary)	Average 3 kg (temporary)	*
Fertility	*Nil*	-	**
Fleece weight %	5% lower severe, 1% lower mild	5% less in merino weaners, 2% in crossbred weaners	*
Wool price discounts	Reduction in FD associated with lower wool production. Staple strength 15 N/kTex lower severe, 10 N/kTex lower mild (Sackett *et al*. 2006).	8% discount (ICS 2022) on merino weaner wool value due to reduced staple strength of affected weaners	**
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	Antibiotic treatment to affected mob $0.70/sheep. 50% treat but 50% also drench for worms	Antibiotic treatment to affected mob $1.60-2.00/sheep. 50% treat but 50% also drench for worms	**
Prevention	Nil		***
Other costs	Additional crutching costs for 50% flocks @ $0.35/sheep. Loss of wool due to dags $0.25/sheep. Summer outbreak - jet for fly control (20%, cost $0.50/sheep)	Additional crutching costs for 50% flocks @ $1.00/sheep. Loss of wool due to dags $0.50/sheep (merino only). Summer outbreak - jet for fly control (20%, cost $0.60/sheep)	**

Based on these assumptions the annual cost of weaner bacterial enteritis in sheep in Australia is estimated at $19.8M (Table 120). The 2015 estimate was $10M (equivalent to $13.2M in 2022). This estimate has uncertainty due to lack of prevalence data and subsequent subclinical production losses.

Table 120: Economic cost of bacterial enteritis in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0.11	$0	$0	$0	$0	$0	$1.50	$0	$0	**$1.61**	**$0**	**$0**
Per Flock	$283	$0	$0	$0	$0	$0	$3,258	$0	$0	**$3,496**	**$0**	**$0**
Total	**$1.4M**			**$0M**			**$18.4M**			**$19.8M**		

The net gain from moving all flocks experiencing bacterial enteritis to the lowest level with adoption of vaccination is estimated to be $19.8M before the cost of vaccination is considered. This completely offsets the estimated cost of bacterial enteritis.

Changes since last report

The annual cost of bacterial enteritis has increased on the 2015 estimate primarily due to higher commodity prices for meat and wool. There has been an increase in the treatment cost of bacterial enteritis due to use of more expensive antibiotics. The assumed impact of bacterial enteritis has been reduced in dual-purpose and prime-lamb flocks.

Bacterial enteritis was ranked 18th in this report. The original 2015 ranking was 19th.

4.5.19 Foot abscess

The disease

Foot abscess is mostly caused by *Fusobacterium necrophorum*, although other bacterium such as *Arcanobacterium pyogenes* are considered to have a role (Roberts *et al.*, 1968; West, 1981; Egerton, Yong and Riffkin, 1989). The disease also includes heel abscess. Infection starts of the basal layers of the skin spread into subcutaneous tissue and can extend to the distal interphalangeal joint causing suppurative arthritis, swelling and severe pain. Abscesses may rupture producing a draining sinus. Heavily pregnant older ewes and rams on lush pasture in wet conditions are most at risk with dry sheep at much reduced risk. Toe abscess can occur in all classes of sheep, though most frequently in heavy sheep in wet conditions. Wet conditions and mechanical trauma and breakage of overgrown horn and shelly toe can result in infection of the sensitive lamina by bacteria resulting in severe pain.

The frequency and severity of foot abscess outbreaks vary from year to year. Lush, wet seasons can see outbreaks in which more than 10% of sheep are affected, with significant economic impact. Affected pregnant sheep are at risk of secondary pregnancy toxaemia and death. Affected sheep also produce less wool and typically develop a severe break in the wool resulting in lower fleece value. Affected sheep are often culled prematurely due to chronic lameness and foot deformities. The most effective treatment is parenteral antibiotics though response to treatment is often poor if infection is already well established. Resolution typically takes eight weeks. Prevalence data is not well documented in the Australian sheep flock (S. R. McGrath, Lievaart and Friend, 2013; Victorian Department of Environment and Primary Industries, 2013). Barwell et al, (2015) undertook a survey of sheep producers in central NSW in 2012 and found foot abscess occurred at rates between 0.03%-28%.

	Unknown aetiology									*Known aetiology*
2015								X		
2022								X		

Prevention

Strategies to effectively prevent foot abscess are not well defined. Risk factors are well known; older ewes that are heavily pregnant ewes in lush wet conditions are most at risk. Practical strategies to minimise the risk of foot abscess are difficult to adopt. Managing body weight of ewes must be balanced with reproductive performance and risk of pregnancy toxaemia. Apart from removing at risk mobs to dry paddocks, foot bathing has limited value and usually is not a practical solution and no vaccine is available. Barwell (Barwell *et al.*, 2015) and Watt (Watt, Eppleston and Dhand, 2021) reported major risk factors for foot abscess were lush pasture with more than 30% clover, older sheep and moving sheep during lambing so attention should be paid to managing these risks.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015				X						
2022				X						

Treatment

Early treatment of foot abscess with parenteral antibiotics, anti-inflammatory therapeutics and wound drainage are moderately effective in early cases, but the response is poor in more advanced cases. Footbathing with zinc sulphate in early stages is of uncertain value and may induce other unwanted issues associated with mustering and handling late pregnant ewes (Barwell *et al.*, 2015; Watt, Eppleston and Dhand, 2021). Draining waterlogged paddocks can assist but is rarely economically feasible or possible.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015					X					
2022					X					

Distribution

The distribution is stable and dependant on climatic conditions.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015						X				
2022						X				

Prevalence

The prevalence is generally stable. Intensification of pasture systems in high rainfall regions may, with time, increase the prevalence of foot abscess as could the expanded use of grazing cereals and fodder crops in medium- and high-rainfall regions. Increasing the Australian sheep flock's fecundity and body size will likely increase the risk of foot abscess. Exotic breeds run in high-rainfall regions appear to be of greatest risk of foot abscess. Good national prevalence data for foot abscess is not available; but there are some local surveys.

	Prevalence decreasing									*Prevalence increasing*
2015						X				
2022						X				

Economics

Assumptions: Foot abscess

Table 121: Assumptions: foot abscess in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	High risk in high rainfall zone 41% sheep, wheat-sheep moderate risk 47% sheep, pastoral zone low risk 12% sheep	High risk in high rainfall zone 41% sheep, wheat sheep moderate risk 51% sheep, pastoral zone low risk 8% sheep -	***

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
% flocks infected	| *Adult ewes* | *2 yo ewes* Pastoral low risk | 0.2% | 0% Wheat sheep medium risk | 1.5% | 0.3% HRZ high risk | 3% | 0.5% British breeds 67% of prevalence in Merinos. Rams 50% higher	-	*
Mortalities	5% of affected sheep	-	*
Weight loss	6.7% Merinos 5% meat breeds (Symons 1978)	-	*
Fleece	Fleece weigh reduction 2.5% Merinos, 1.7% meat breed (Symons, 1978)	-	*
Wool price	Due to staple strength declines: -15 N/kTex merinos, -10N/kTex meat breeds (Nolan, 2012)	4% discount on wool value for merino ewes due to reduced staple strength	**
Fertility	20% affected ewes fail to rear lamb	-	*
Market avoidance	Nil	3% of older affected sheep cannot be sold due to lameness	***
Movement restrictns	Nil	-	***
Treatment	25% affected ewes in high-risk zone and 20% in moderate risk zone @ $10/ewe	25% affected ewes in high-risk zone and 20% in moderate-risk zone @ $11.40/ewe	*
Prevention	Footbath 2% of flocks in high-risk zone @ $0.10/sheep	Footbath 2% of flocks in high-risk zone @ $0.13/sheep	*

Based on these assumptions the annual cost of foot abscess in sheep in Australia is estimated at $10.4M (Table 122). The 2015 estimate was $10M (equivalent to $13.2M in 2022). The annual cost of foot abscess to the sheep industry varies widely and could be three times higher in very wet years.

Table 122: Economic cost of foot abscess in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0.04	$0.02	$0	$0.01	$0	$0	$0.26	$0.17	$0.02	**$0.30**	**$0.19**	**$0.02**
Per Flock	$87	$46	$0.21	$5	$3	$0	$563	$370	$38	**$656**	**$419**	**$38**
Total	**$1.8M**			**$0.1M**			**$8.5M**			**$10.4M**		

Due to the sporadic nature of the disease the net gain from moving all flocks experiencing foot abscess to the lowest level of disease is difficult to calculate.

<u>Changes since last report</u>

The main changes to the annual cost of foot abscess in sheep is the increase in livestock prices. Treatment and prevention costs have been indexed to inflation too.

Foot abscess was ranked 19th in this report. The original 2015 ranking was 18th.

4.5.20 Infectious abortion

The disease

Infectious diseases contribute to ewe reproductive wastage through foetal reabsorption, abortion, stillbirths and birth of weak lambs that die soon after birth. *Campylobacter spp. (*32%), *listeria spp. (*25%) and *toxoplasma gondii* (9%) were the most common abortigenic pathogens identified where an aetiological diagnosis was made in ewe abortion investigations submitted to Australian veterinary diagnostic laboratories between 2000 and 2018 (Clune et al*,* 2021). About 14% cases of infectious abortions where a diagnosis was made were caused by a range of aetiological agents. The remaining 19% of abortion investigations where a diagnosis was made were due to non-infectious causes. Clune et al, (2021) reported that only 57% of abortion investigations achieved a diagnosis.

Campylobacteriosis (vibriosis) is the most common cause of abortion in sheep. It causes sporadic abortion within the high-rainfall regions of southern Australia, particularly Victoria and Tasmania but has been reported in all states except Queensland. The two major abortigenic campylobacter species are *Campylobacter fetus subsp fetus* (probably the most common) and *Campylobacter jejuni subsp jejuni* (Clough, 2003). Both campylobacter species are commensal organisms of the gastrointestinal tract. Susceptible ewes are infected by ingestion of pasture, water or feed that has been contaminated by infected aborted foetal fluids, foetuses, placenta or faeces. Carrier sheep are an important source of maintenance and transmission, but other animals including foxes, crows and other birds have been implicated in the spread of infection, although their importance is unclear compared to carrier ewes. Risk factors for spread include high stocking rates, rotational grazing where large numbers of stock are grazed together increasing the risk of contamination or feeding grain in a trail or confinement feeding that promotes heavy bacterial exposure.

Abortion storms in the last six weeks of pregnancy are the most obvious presentation. These typically affect 10–20% of ewes within a mob, although occasional up to 50% of ewes aborting are reported. Abortion storms typically occur every 5–7 years on endemic farms, reflecting the natural rise and fall in flock immunity after an outbreak (Clough, 2003). Maiden ewes and pregnant ewe lambs tend to be most at risk because they have lower immunity. Another risk factor is the introduction of naïve ewes onto a farm with circulating Campylobacter spp or ewes infected with *Campylobacter spp.* introduced to a farm with naïve ewes creating a risk of infection. In the absence of the use of vaccines, a common recommendation in endemically infected flocks was to ensure maidens ewes are combined with mature ewes well before mating to ensure they are exposed to campylobacter and develop immunity before pregnancy, thus reducing the risk of abortion storms. The introduction of a commercial vaccine Coopers Ovilis Campyvax™ has replaced the practice.

The extent of perinatal lamb losses from stillbirths and congenitally infected lambs that are weak and die within a day of birth is less clear. In New Zealand, Anderson (Anderson, 2001) demonstrated endemically infected flocks suffer ongoing perinatal lamb losses of 9-10% regardless of whether abortions are detected, with losses being reduced by vaccination. Very little evidence of this phenomenon exists in Australia although one trial (5 flocks only) using Guardian™ campylobacter vaccine resulted in a 6.8% increase in lamb marking percentage for vaccinated ewes (2011). Removing the one mob of adults in which no response was recorded from this trial result resulted in vaccination providing an increase to the lamb marking percentage of 8.6% across the four remaining maiden flocks (i.e. similar to the New Zealand experience).

The vaccine (Coopers Ovilis Campyvax™) protects against the most common strains of campylobacter present in Australia.

The Listeria species affecting Australian sheep include *L ivanovii,* which predominantly causes abortion and enteritis and *L monocytogenes* causing meningoencephalitis, abortion and enteritis. Clune et al, (2021) reported that *L ivanovii* caused the majority abortion outbreaks associated with Listeria spp. Compared to many other bacterial species, Listeria are found in a variety of environments including soil, water and decomposing vegetation. They are tolerant of a wide range of pH, temperature and salt conditions, the feeding of silage, particularly silage with a pH above 5.5, is often associated with outbreaks of listeriosis. The disease usually occurs under wet, muddy conditions and its occurrence is sporadic and unpredictable. Rajkumar (*Listeria abortion*, 2011)et reported abortion rates of between 3-10% in outbreaks of *L ivanovii*. Seargent (Sergeant, Love and McInnes, 1991) reported an abortion rate of 12% in an outbreak of *L ivanovii*.

Toxoplasma gondii is an obligate intracellular protozoan parasite. It has a two-stage asexual life cycle which can take place in warm blooded animals and a coccidian-type sexual life cycle which is confined to the intestines of members of the cat family. Wild rodents act as a reservoir of infection which is spread and enormously amplified by young cats.

Naïve pregnant ewes become infected after ingestion of feed or water contaminated with oocysts shed by a feline definitive host and remain so for life. The outcome of infection depends on the stage of pregnancy of the initial infection with few overt signs of disease seen by farmers. Infection early in pregnancy likely results in foetal resorption, mid-term infections are likely to result in foetal death, mummification and abortion. Late term infections result in the birth of normal lambs which may be infected or become immune.

Maiden and younger ewes are considered most at risk and the presence of breeding populations of feral and domestic cats clearly need to be considered as possible contaminants of water, pasture and conserved feed. In a recent study in primiparous ewe flocks across Southern Australia it was found that toxoplasma was not a significant contributor to foetal or lamb mortality between pregnancy scanning and marking. There was seroconversion in only 1% of primiparous ewes post joining that were confirmed pregnant but failed to raise a lamb (Clune *et al.*, 2022). The variable seropositivity seen on Australian farms suggests point source exposure to infective oocysts such as contaminated feed or water sources.

Once an outbreak has started there is very little that can be done apart from removing dead lambs and infected placenta. *Toxoplasma gondii* is susceptible to sulphonamides, but most ewes have been infected long before making a diagnosis. Sheep to sheep transmission is not thought to occur. Monensin fed during pregnancy has been shown to have some success as prophylaxis*,* this generally is not practical in our pasture-based systems.

No vaccine is available to control toxoplasma in Australia, in New Zealand Toxovax (MSD animal health) is available as a live attenuated vaccine.

	Unknown aetiology									*Known aetiology*
2015								X		
2022								X		

Prevention

There are two methods of prevention of campylobacter abortion in endemic flocks. The vaccine Coopers Ovilis Campyvax® which protects against *Campylobacter fetus subsp fetus* and *Campylobacter jejuni subsp jejuni* is most used in maiden ewes and pregnant ewe lambs. Producers can also reduce the risk of abortion storms by ensuring young ewes are mixed with older ewes well before mating, so they develop immunity before they become pregnant, although this strategy is not widely adopted now. Other factors that may reduce the risk of exposure are to avoid intense stocking rate rotational grazing systems (this may not be practical or cost effective) with late-pregnant ewes and avoid grain feeding on the same trial, especially with containment to minimise bacterial contamination.

Removal of the aborted foetuses and placental membranes is recommended as this material is a potential source of infection for the rest of the flock. Feed poor quality silage to pregnant ewes is a risk factor for listeriosis and in wet years care has to be taken if the is a large amount of decomposing feed available in the paddocks where pregnant ewes are grazing. Control of feral and domestic cat populations that can potentially contaminate conserved feed, water sources and pasture with toxoplasma oocyst.

Low efficacy/ unproven preventives available — *Effective preventives available*

2015							X			
2022							X			

Treatment

In the face of abortion outbreaks, antibiotic therapy for exposed pregnant ewes is the only option to reduce the impact, though the efficacy of this procedure is not clear, and in any case, rarely adopted. No proven treatment is available.

Toxoplasmosis is susceptible to sulphonamides, usually well past effective treatment window when diagnosis of abortion occurs.

Low efficacy/ unproven treatments available — *Effective treatments available*

2015	X									
2022	X									

Distribution

The distribution of infectious abortion appears stable. Campylobacter, Listeria and Toxoplasma abortion is observed in all southern states. Campylobacter is more common most in high rainfall regions, especially cool, moist climates such as Tasmania and southern Victoria, and has been observed in the pastoral zone under intensive feeding conditions.

Distribution contracting — *Distribution stable* — *Distribution increasing*

2015					X					
2022					X					

Prevalence

There is no good data on the prevalence of campylobacter abortion. Clough (Clough, 2003) summarised five surveys investigating causes of abortion and perinatal lamb loss and found 13% of farms were positive to campylobacter and of samples submitted from eight surveys, 15% were positive to campylobacter. A survey of 6000 ewes in 550 flocks found 69% of flocks were positive for

Campylobacter fetus subsp fetus and 66% were positive for *Campylobacter jejuni subsp jejuni* (Coopers Animal Health, 2020). The high positive rate does not indicate that all flocks have clinical disease but does show that *Campylobacter spp.* is common in sheep flocks.

In the wider industry there are no estimates of the prevalence of campylobacter, however, industry expert opinion estimates believe 5% of Tasmanian flocks have noticeable abortions due to campylobacter and 1% of flocks in high rainfall regions in New South Wales, Victoria, South Australia and Western Australia have outbreaks, with an estimated 10% of maidens/ewe lambs and 5% of adults aborting. No estimates are available of subclinical losses. Examination of 529 investigations on abortion or stillbirth between 2000 and 2018 from four State Veterinary Laboratories and found 32%, 25% and 9% of abortion investigations were positive for *Campylobacter spp, Listeria spp* and *Toxoplasma* respectively (T Clune *et al.*, 2021; Thomas Clune *et al.*, 2021). Whilst serological evidence of Toxoplasma was found on 16 of 28 farm this significance is considered low. Other infectious causes of abortion such as *Leptospirosis*, *Chlamydia pecorum, Salmonella spp and others, whilst contributing to a 14% of diognoses have relatively minor impact*

Prevalence is stable, although with widespread industry recommendations that promote rotational grazing and mating of ewe lambs, the prevalence of campylobacter abortion will almost certainly increase. Widespread use of Coopers Ovilis Campyvax™ vaccine will likely contain further spread.

	Prevalence decreasing									*Prevalence increasing*
2015							X			
2022							X			

<u>Economics</u>

Assumptions: Infectious abortion

Table 123: Assumptions: infectious abortion in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Tasmania is considered the highest risk region (3.2% sheep), followed by high rainfall regions of mainland states excluding Queensland (37.2% sheep). The wheat sheep zone is low risk (45.9% sheep).	Tasmania is considered the highest risk region (3.4% sheep), followed by moderate risk high rainfall regions of mainland states (37.3% sheep). About 51.4% of sheep in the wheat sheep zone is low risk.	**
% Flocks affected	*High risk: 5% flocks* *Moderate risk: 1.5% flocks* *Low risk: 0.5% flocks*	*High risk: 12.5% flocks* *Moderate risk: 3.75% flocks* *Low risk: 1.25% flocks*	*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Mortalities	Ewes aborting – Maidens – Adults High risk: 15% 5% Moderate impact: 12% 2.5% Low impact: 5% 0%	Ewes aborting – Maidens – Adults High risk 8.6% 2.6% Moderate impact 8% 2% Low impact 2.9% 0.9%	*
Weight loss	*Nil*	-	***
Fertility	Ewes that abort produce 3% more lambs the following year as they are heavier at joining	-	**
Fleece weight %	Ewes that abort produce 5% more wool	-	***
Wool price discounts	Staple strength reduced: 1% clean discount.	-	**
Market avoidance	Nil	-	***
Movement restrictions	Nil	-	***
Treatment	*Nil*	-	***
Prevention	1% at risk flocks vaccinate maidens with *Ovilis Campyvax* in high risk and moderate risk zones and 0.2% adults vaccinated	35- 60% of high-risk maidens and 5-20% adults 30-50% moderate risk maidens and 3-15% adults Cost of vaccine including labour $1.60/dose	*
Other costs	Nil	-	

Based on these assumptions the annual cost of infectious abortion in sheep in Australia is estimated at $12.7M (Table 124). The 2015 estimate was $1.6M (equivalent to $1.8M in 2022).

This estimate is highly uncertain due to lack of data on prevalence both in terms of frequency of abortion storms and impact of subclinical perinatal lamb loss associated with infectious abortion.

Table 124: Economic cost of infectious abortion in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$0.32	$0.28	$0	$0.56	$0.14	$0.02	**$0.87**	**$0.40**	**$0.02**
Per Flock	$0	$0	$0	$677	$539	$0	$1,184	$366	$39	**$1,862**	**$846**	**$39**
Total	**$0M**			**$7.1M**			**$5.6M**			**$12.7M**		

The net gain from moving all flocks experiencing infectious abortion to the lowest level will not reduce cost as further vaccination will likely cost more than the production losses of the disease.

Changes since last report

The cost of infectious abortion with the inclusion of all major causes of infectious abortion in sheep. The previous report only included campylobacter abortion. In addition, the advent of campylobacter vaccination has been well adopted in high-risk regions. The cost of vaccination has increased marginally, and livestock prices have increased.

Infectious abortion was ranked 20th in this report. The original 2015 ranking for camplyobacterial abortion was 22nd.

4.5.21 Pyrrolizidine alkaloidosis

The disease

Sheep are very sensitive to poisoning by pyrrolizidine alkaloids (PA). Two plants, heliotrope (*Heliotropium europaeum*) and Paterson's curse (*Echium plantagineum*), are the most common sources of PA toxicity in sheep, with *Senecio spp* and other plants containing PA's providing rare poisonings. PA's are hepatotoxins but can also damage the brain, kidney and lungs (Salmon, 2011). Two disease syndromes are common, being liver failure and copper poisoning when stored copper is suddenly released from the liver. In a review undertaken by Seaman (Seaman, 1987), heliotrope and Paterson's curse were equally important causes of liver failure whereas Paterson's curse was a more common cause of copper poisoning. However, Salmon (Salmon, 2011) reported that heliotrope was more important overall in causing disease. Liver damage occurs within weeks of ingestion of toxic pasture and is cumulative and irreversible. Chronic copper poisoning usually occurs after several years of ingesting toxin, particularly in clover-dominant pastures towards the end of spring when pastures are senescing, and copper becomes more available from the plant.

The disease is most common in southern NSW and along the northern fringe of Victoria but is present in all regions where heliotrope and Paterson's curse and other plants that contain PA grow. Seaman (Seaman, 1987) reported mortality rates of 2.4% from PA poisoning and 2.5% from chronic copper poisoning across seven-year period between 1978–84. At this time in New South Wales, 64% of sheep were Merinos, 27% crossbred and 9% other breeds, but 25% of losses were in Merinos and 52% in crossbreds. Merinos appear more resistant to disease and crossbred sheep more likely to eat heliotrope. Dorpers readily eat heliotrope, though their resistance to PA is unknown.

There is no treatment of affected sheep. Weed control is the primary method for minimising impact. In recent years the release of several biological control agents has shrunk the distribution of Paterson's curse. In addition, heliotrope is better controlled on cropping properties applying a more strategic use of herbicides aimed at preserving moisture over summer fallows. Perennials such as lucerne compete well with both weeds in permanent pastures. The successful removal of stored copper from the liver of high-risk sheep has been achieved using a loose lick (or drench) of sodium molybdite and sodium sulphate.

	Unknown aetiology									*Known aetiology*
2015						X				
2022						X				

Prevention

Prevention is best achieved by preventing livestock having access to toxic plants. Herbicide control in cropping land is primarily to preserve moisture for cropping has had heliotrope control benefits. Biological control of Paterson's curse is reducing the prevalence of this weed. Supplying licks containing sodium molybdate and sodium sulphate to at-risk sheep reduces the risk of chronic copper poisoning. Heliotrope is so widespread that it continues to produce PA poisoning despite these effective preventive measures being readily available.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015							X			
2022							X			

Treatment

No treatment of affected animals is available; the peracute nature of the disease renders treatment ineffective.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015	X									
2022	X									

Distribution

The distribution of PA poisoning mirrors the distribution of toxic weeds. PA poisoning is most common in central and southern New South Wales and the northern border of Victoria, though is present across most of the wheat-sheep zone.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

PA risk is highest through the wheat sheep regions of Southern Australia where heliotrope and Paterson's curse are most common.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: Pyrrolizidine alkaloidosis

Table 125: Assumptions: pyrrolizidine alkaloidosis in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	The high-risk regions include southern NSW and northern Victoria (14% sheep), moderate risk includes remaining wheat-sheep zones and adjoining regions (46% sheep) with remaining regions considered low/nil risk	-	**
% Flocks affected	High risk: 10% flocks, 10% of sheep affected Moderate impact: 1% flocks, 2% of sheep affected	-	*

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	Double clinical cases in prime lamb flocks		
Mortalities	50% of clinical cases	-	*
Weight loss	5 kg permanent weight loss of clinical cases adults and 2 kg for weaner sheep.	-	**
Fertility	1.5% decline per kg bodyweight loss	-	**
Fleece weight %	5.5% decline for adults affected and 2% for weaners	-	**
Wool price discounts	Nil	-	**
Market avoidance	Approximately 0.03% of sheep condemned due to jaundice	-	**
Movement restrictions	Nil	-	***
Treatment	Nil	-	***
Prevention	1% flocks provide sodium molybdate and sodium sulphate to reduce the risk of chronic copper poisoning at a cost of $1/sheep	0.5% flocks provide sodium molybdate and sodium sulphate to reduce the risk of chronic copper poisoning at a cost of $1.14/sheep	*
Other costs		-	

Based on these assumptions the annual cost of pyrrolizidine alkaloidosis in sheep in Australia is estimated at $11.3M (Table 126). The 2015 estimate was $6.8M (equivalent to $7.7M in 2022).

Table 126: Economic cost of pyrrolizidine alkaloidosis in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$0	$0	$0	$1.11	$0.02	$0	**$1.11**	**$0.02**	**$0**
Per Flock	$0	$0	$0	$7	$0	$0	$3,273	$48	$0	**$2,380**	**$48**	**$0**
Total	**$0.0M**			**$0.0M**			**$11.3M**			**$11.3M**		

The net gain from moving all flocks to the lowest level of pyrrolizidine alkaloidosis disease is estimated to be $11.3M.

Changes since last report

The cost of pyrrolizidine alkaloidosis in sheep in Australia has increased primarily due to increased livestock and wool prices even with slightly lower stock numbers. The prevalence of disease is assumed similar to that used in the previous report.

Pyrrolizidine alkaloidosis was ranked 21st in this report. The original 2015 ranking was 20th.

4.5.22 Sheep measles (*Taenia ovis*)

The disease

Sheep measles is caused by the intermediate stage of *Taenia ovis*, a tapeworm that infects dogs. Sheep grazing contaminated pasture ingest eggs that then hatch, and the tapeworm larvae migrate into muscle tissue to encyst. The most affected sites are heart, diaphragm and skeletal muscles. Cysts in tissue are subsequently eaten by dogs (or foxes) and develop into adult tapeworms (Jenkins, 2014). In infected sheep, cysts can die and develop into small pus-filled abscesses that eventually become mineralised nodules that are not acceptable in meat for human consumption. The financial impact of sheep measles relates to offal (primarily heart) condemnation, carcase trim and condemnation. There are no health or production impacts in dogs or sheep. Based on abattoir monitoring by the National Sheep Health Monitoring Project (NSHMP), sheep measles was detected in 1.3% of carcases Australia wide (Primary Industries and Regions South Australia, 2021).

	Unknown aetiology									*Known aetiology*
2015										X
2022										X

Prevention

An effective vaccine to prevent sheep measles has been developed, though is not yet registered in Australia. The only controls at present are to avoid dogs gaining access to uncooked sheep meat and to undertake regularly worming of dogs against tapeworm (preferably monthly) with praziquantel. This is not an option for fox or wild dog control, but control of foxes and wild dogs will presumably reduce exposure to sheep. Farmer surveys suggest most do not treat dogs regularly and many dogs have access to uncooked sheep meat (Jenkins, 2014).

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015							X			
2022							X			

Treatment

The only treatment available is to treat dogs to control tapeworms monthly with praziquantel.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015	X									
2022	X									

Distribution

Distribution seems to be widespread and stable across sheep growing regions.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

Prevalence

Prevalence appears constant to slightly decreasing with time. The NSHMP data records all states having <2% of sheep affected, except Tasmania which records 6.4% of carcasses impacted through the abattoir surveillance program.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022					X					

Economics

Assumptions: Sheep measles

Table 127: Assumptions: sheep measles

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Distributed across all sheep rearing regions of Australia.	-	***
% flocks infected	Based on abattoir surveillance (NSHMP) about 3.65% of sheep were infected with sheep measles. Prevalence appears to be slightly higher in southern regions though is averaged across all sheep growing regions.	-	***
Mortalities	Nil	-	***
Weight loss	Nil	-	***
Fleece	Nil	-	***
Wool	Nil	-	***
Fertility	Nil	-	***
Market avoidance	Carcase condemnation: a. Condemnation: 0.019% of adults, 0.012% lambs *(Animal Health Australia, 2014b; Department of Agriculture Forestry and Fisheries, 2014)* *b.* Carcase trim and offal condemnation 0.58% of adults, 0.35% lambs average 0.4 kg cw/carcase *(GHD, 2011; Hernandez-Jover et al., 2013)*	a. Carcase trim and offal condemnation 1.3% of carcases average 0.4 kg cw/carcase *(GHD, 2011; Hernandez-Jover et al., 2013)*(GHD 2009, Hernandez-Jover M et al. 2013) NSHMP 2021 *b.* Offal value $0.70/offal condemnation	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	c. Offal value $0.61/offal condemnation *(GHD, 2011; Hernandez-Jover et al., 2013)*		
Movement restrictions	Nil		***
Treatment	No treatment is available. However, the cost of tapeworm treatment of dogs is considered. On average dogs are treated twice yearly. Assume 3 dogs/farm treated with Droncit @ $12/dog (cost split with hydatids control).	No treatment is available. However, the cost of tapeworm treatment of dogs is considered. On average dogs are treated twice yearly on 93% of properties. (Jenkins, 2014) Assume 4.8 dogs/farm treated (Jenkins, 2014) with Droncit @ $13.6/dog (cost split with hydatids control).	*
Prevention	As for treatment of dogs		***

Based on these assumptions the annual cost of sheep measles in sheep in Australia is estimated at $4.8M (Table 128). The 2015 estimate was $2.4M (equivalent to $2.7M in 2022).

Table 128: Economic cost of sheep measles

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$0.03	$0	$0	$0.04	$0	$0	**$0.07**	**$0**	**$0**
Per Flock	$0	$0	$0	$60	$0	$0	$90	$0	$0	**$150**	**$0**	**$0**
Total	**$0M**			**$1.9M**			**$2.9M**			**$4.8M**		

Reducing prevalence by 50% without extra costs considered would reduce the cost to industry by $1.4M before extra costs of control are considered.

<u>Changes since last report</u>

The increase in the cost of Sheep Measles is due to higher value of livestock and an assumed increase in the use of praziquantel to control tapeworms in dogs.

Sheep Measles was ranked 22nd in this report. The original 2015 ranking was 21st.

5. Conclusion

5.1 Cattle summary

The estimated costs of treatment, prevention/control and production for the key diseases of the beef cattle industry for all Australia, the northern industry and the southern industry are presented in Figure 12, Figure 14 and Figure 16 respectively and the achievable gains from improved control in Figure 13, Figure 15 and Figure 17 respectively.

Parasitism dominates the cattle diseases with buffalo fly, cattle tick and internal parasites each costing much more than $100M per annum. These diseases also offer greatest potential gain from improved management.

Estimated gains from better control of disease are disease specific; some diseases with moderate to high costs do not have readily applied solutions for many farmers. Diseases such a neonatal mortality have few herd-level controls that can be applied to reduce the prevalence of disease. Diseases such as clostridia in southern cattle have minimal impact due to the high rates of vaccination such that these (effective) prevention costs dominate the residual cost of disease in the industry. Whilst this suggest there is little, if anything, to be gained from extra clostridial controls, it does not imply that reducing controls will increase farm profit — disease is optimally controlled by industry under the current settings.

Diseases such as BVDV (pestivirus) offer modest returns from improved control when compared to the total cost of disease. This is because for most herds in most seasons, the presence of virus results in few losses and these losses approximately equal the control costs. However, an outbreak of BVDV in a naïve herd is potentially business threatening and so for most producers the average cost-benefit (as presented here) may be insufficient information alone to determine if extra control is warranted. Risk and impact are not effectively captured in cost-benefit type analyses.

Figure 12: Estimated treatment, prevention and production costs of key endemic diseases of the beef industry

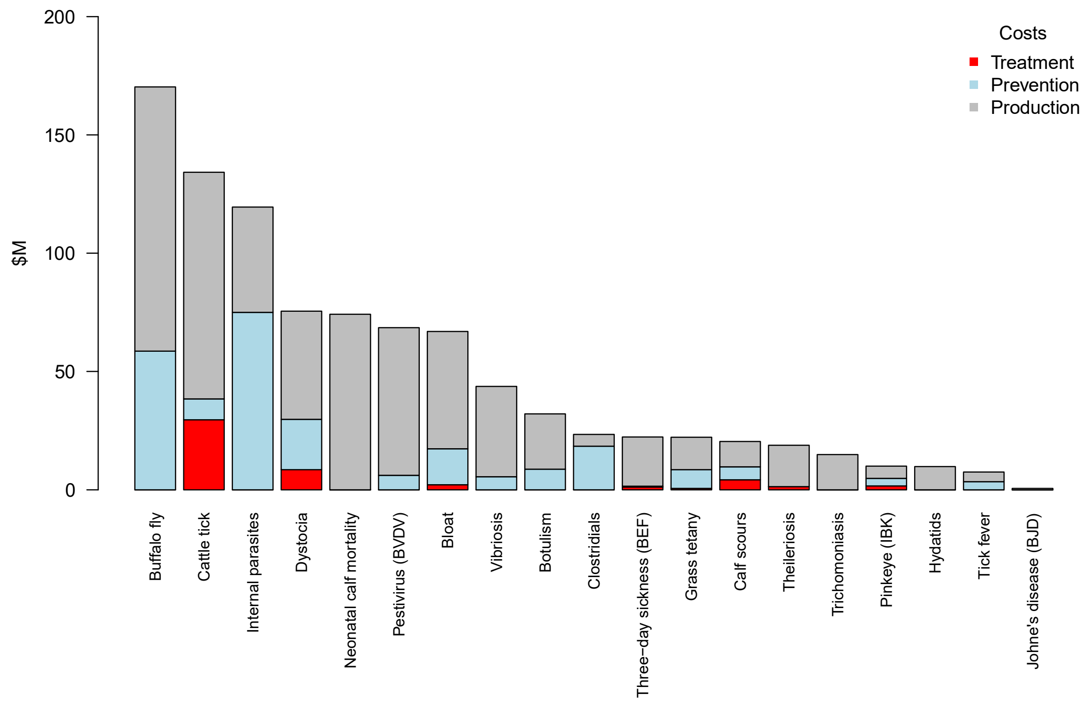


Figure 13: Total cost and achievable gain from better control of key endemic diseases of the beef industry

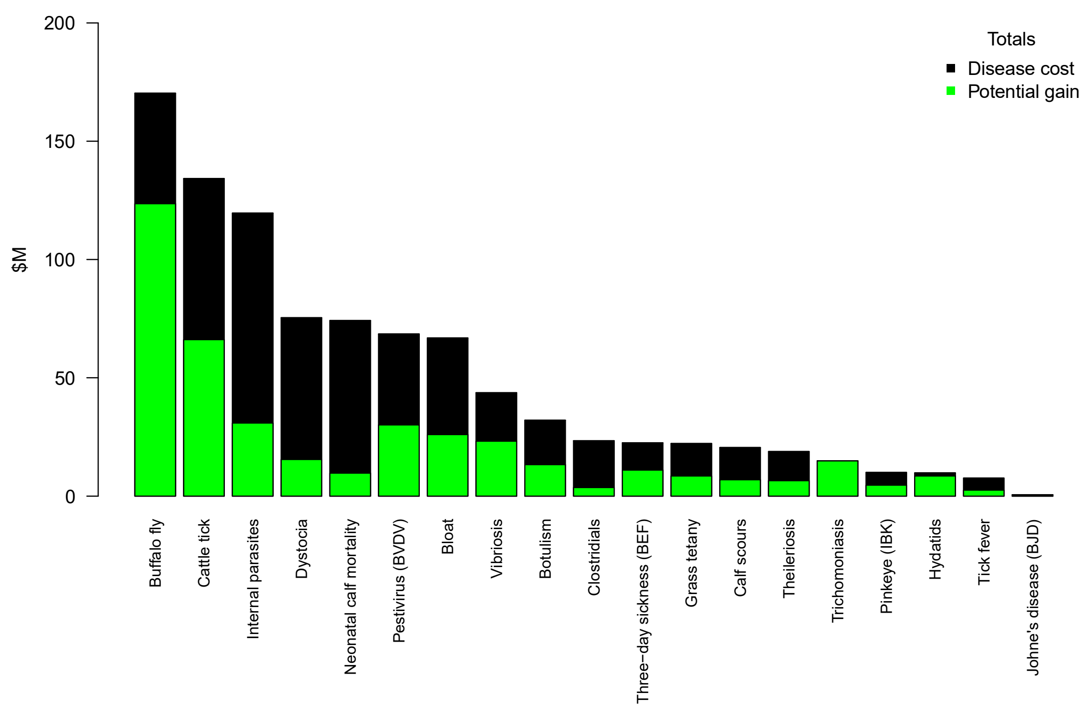


Figure 14: Estimated treatment, prevention and production costs of key endemic diseases of the northern beef industry

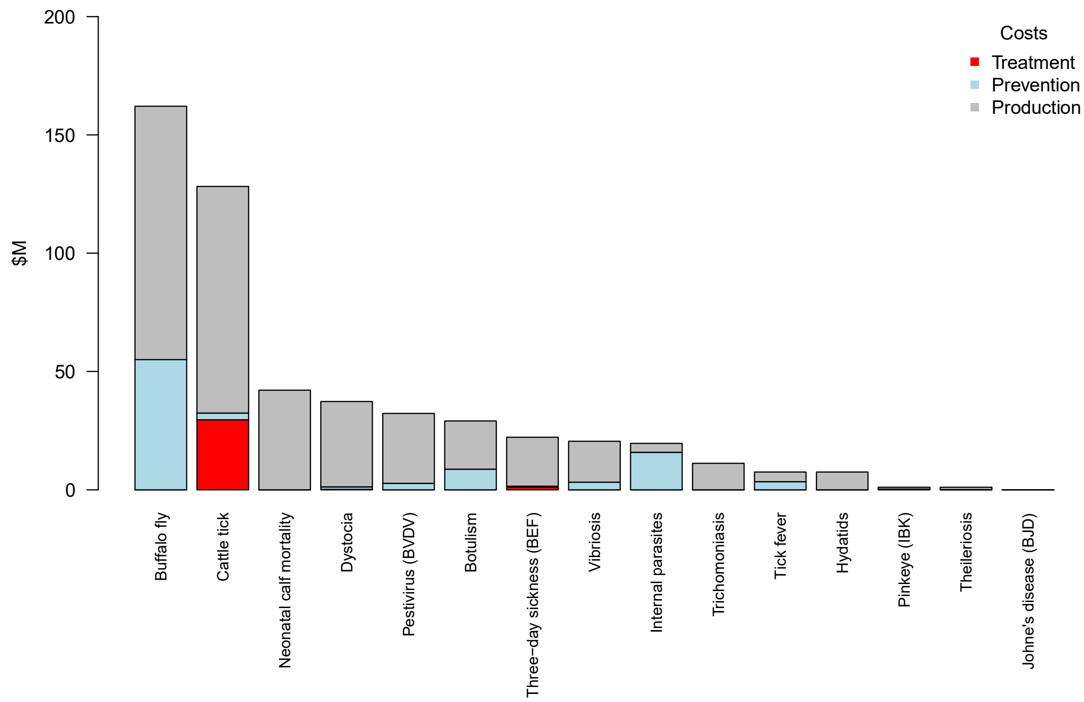


Figure 15: Total cost and achievable gain from better control of key endemic diseases of the northern beef industry

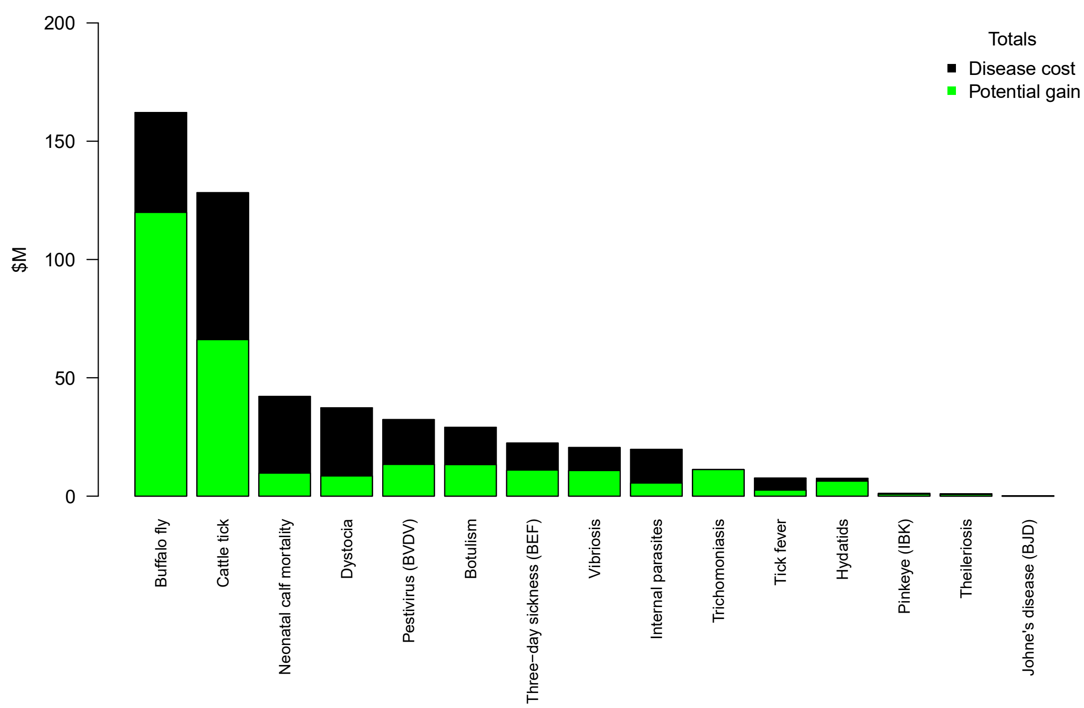


Figure 16: Estimated treatment, prevention and production costs of key endemic diseases of the southern beef industry

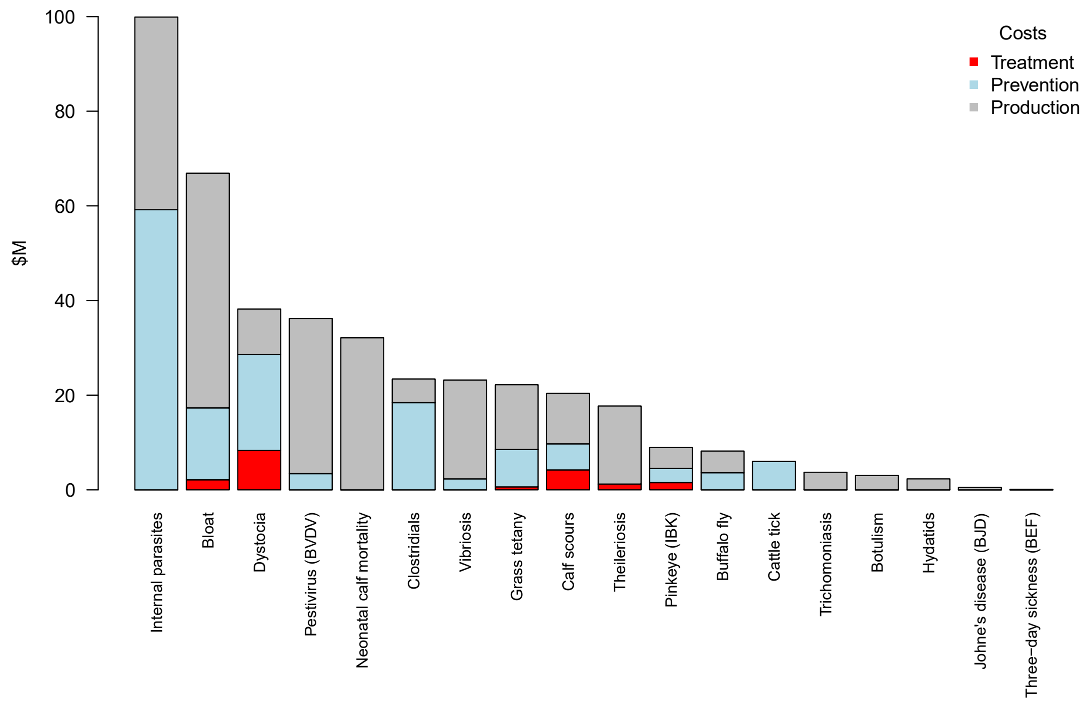
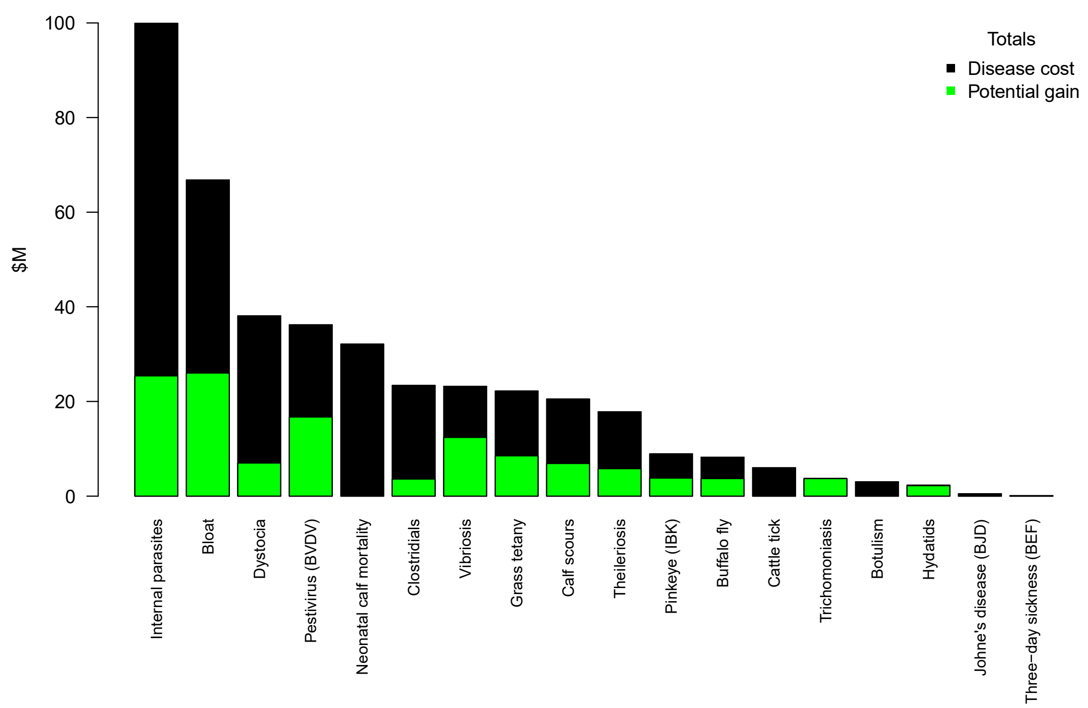


Figure 17: Total cost and achievable gain from better control of key endemic diseases of the southern beef industry



5.2 Sheep summary

The estimated costs of treatment, prevention/control and production losses for the key diseases of the sheep industry for all Australia, Wool, Prime Lamb and Dual Purpose (Merino mated to meat breeds) are presented in Figure 18, Figure 20, Figure 22 and Figure 24 respectively. The potential gains from improved control of endemic disease for all Australia, Wool, Prime Lamb and Dual Purpose is presented in Figure 19, Figure 21, Figure 23 and Figure 25 respectively.

Peri-natal mortality is the most important disease impacting the sheep industry. All flocks in Australia are impacted to some extent by peri-natal lamb mortality. Other diseases in the list including dystocia, mastitis and to a lesser extent campylobacter abortions are a subset of peri-natal mortality. Internal parasites were still a very important issue for the sheep industry due to the insidious ongoing production losses and ongoing cost of control. Peri-natal mortality, internal parasites, dystocia, Flystrike, weaner illthrift, lice and mastitis all cost more than $100M per annum. These diseases also offer greatest potential gain from improved management.

Most diseases did not change in their relative ranking of importance since the 2015 report. There were some exceptions such as PRGT which had a lower total cost compared with the last report even with higher commodity prices. The reduction in cost even is due to assumed lower likelihood of major outbreaks that contribute to a major proportion of the total cost of the disease. There is still considerable uncertainty of the disease prevalence of many diseases on farm. For example, whilst abattoir surveillance report comprehensive information of evidence of pneumonia or arthritis in sheep processed in abattoirs, there is very limited information on of farm prevalence, both in terms of mortality and subclinical disease.

Certain diseases such as virulent footrot may cost significantly more on individual farms with infected sheep although the cost across the whole industry is not as great as some diseases because virulent footrot has limited geographical distribution.

The cost of most diseases increased since the 2015 report due to higher commodity prices for both livestock and wool. The seven percent reduction in sheep numbers since the last report reducing the total cost was overwhelmed by the increase in commodity prices.

Figure 18: Estimated treatment, prevention and production costs of key endemic diseases of the sheep industry

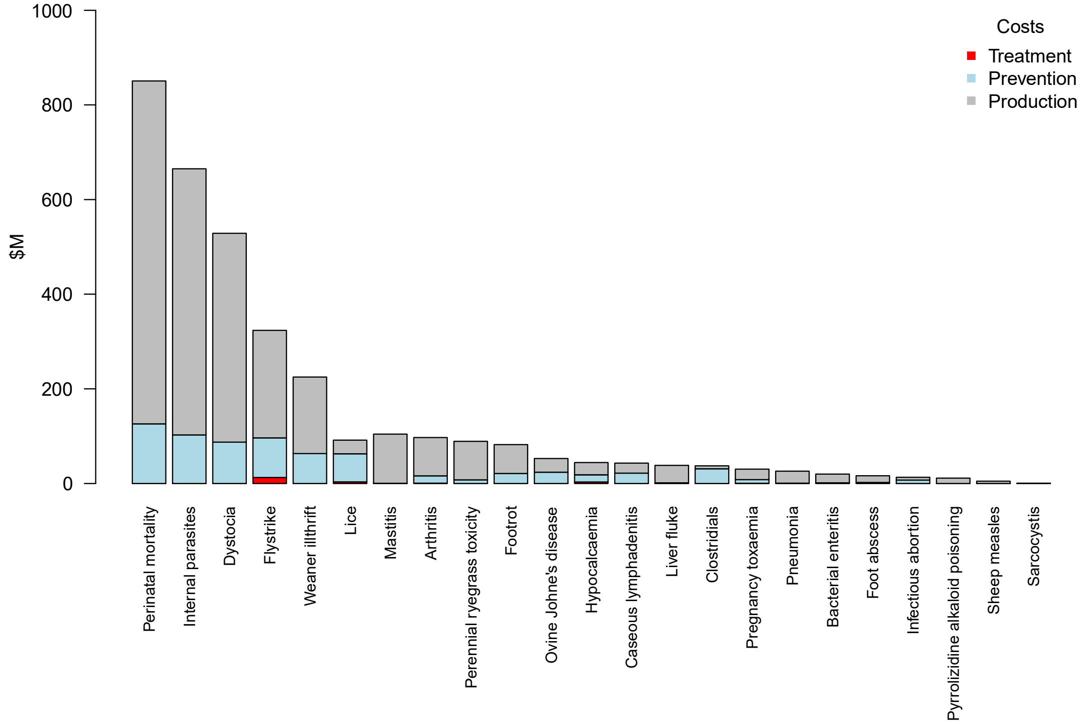


Figure 19: Total cost and achievable gain from better control of key endemic diseases of the sheep industry

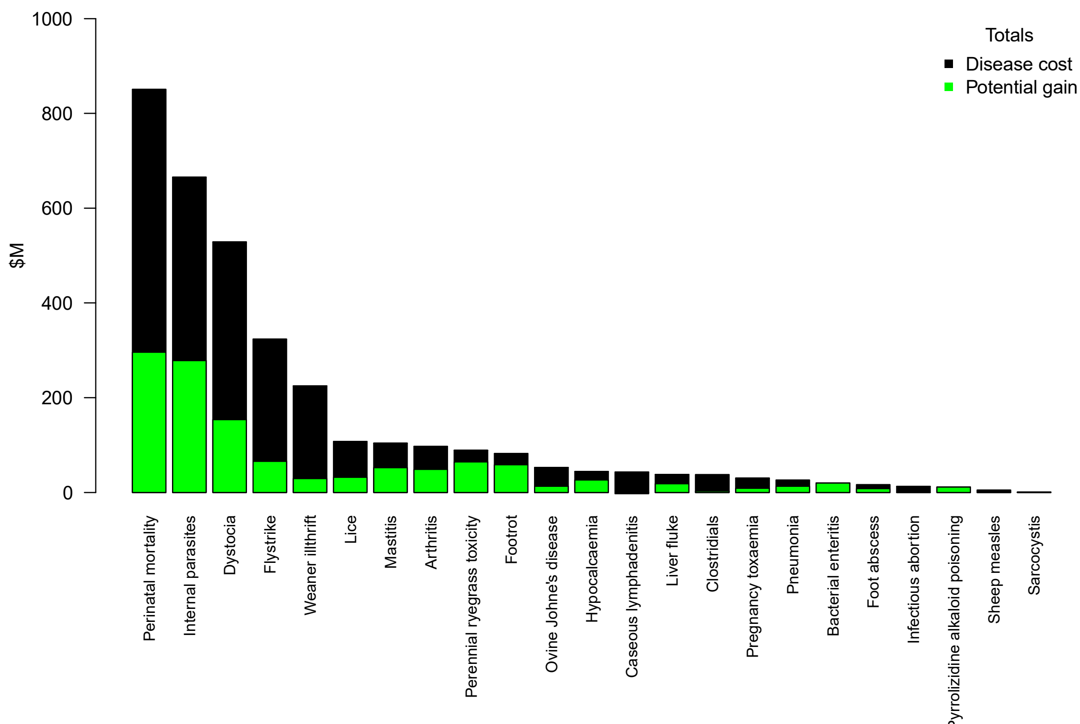


Figure 20: Estimated treatment, prevention and production costs of key endemic diseases of the wool industry

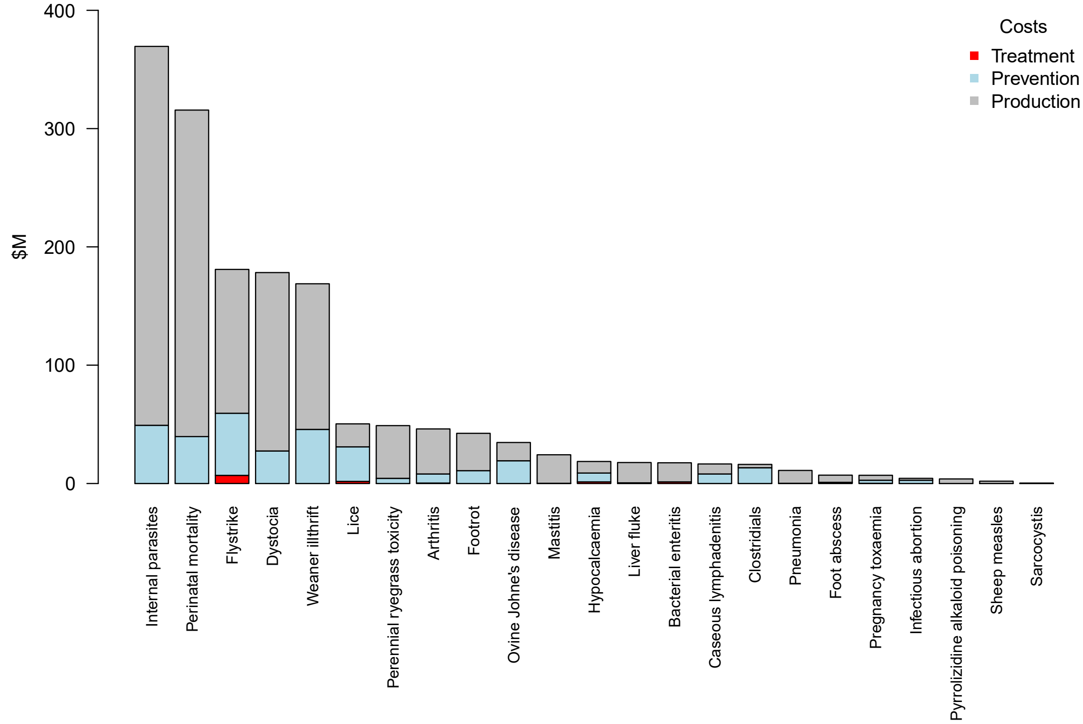


Figure 21: Total cost and achievable gain from better control of key endemic diseases of the wool industry

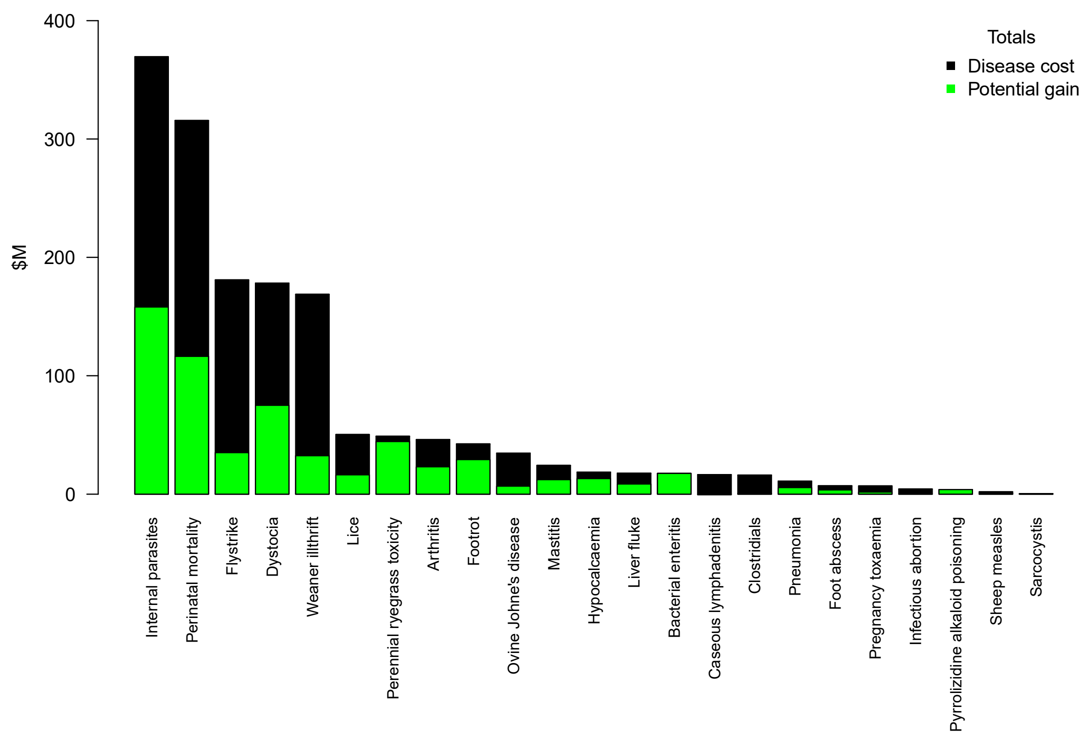


Figure 22: Estimated treatment, prevention and production costs of key endemic diseases of the prime lamb industry

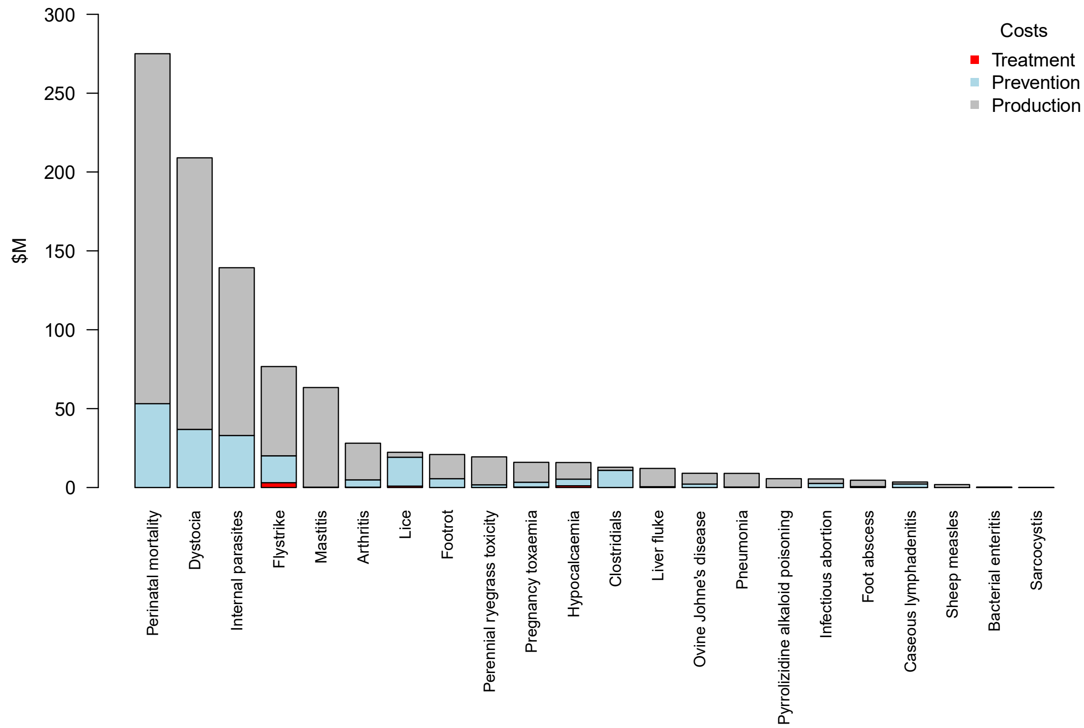


Figure 23: Total cost and achievable gain from better control of key endemic diseases of the prime lamb industry

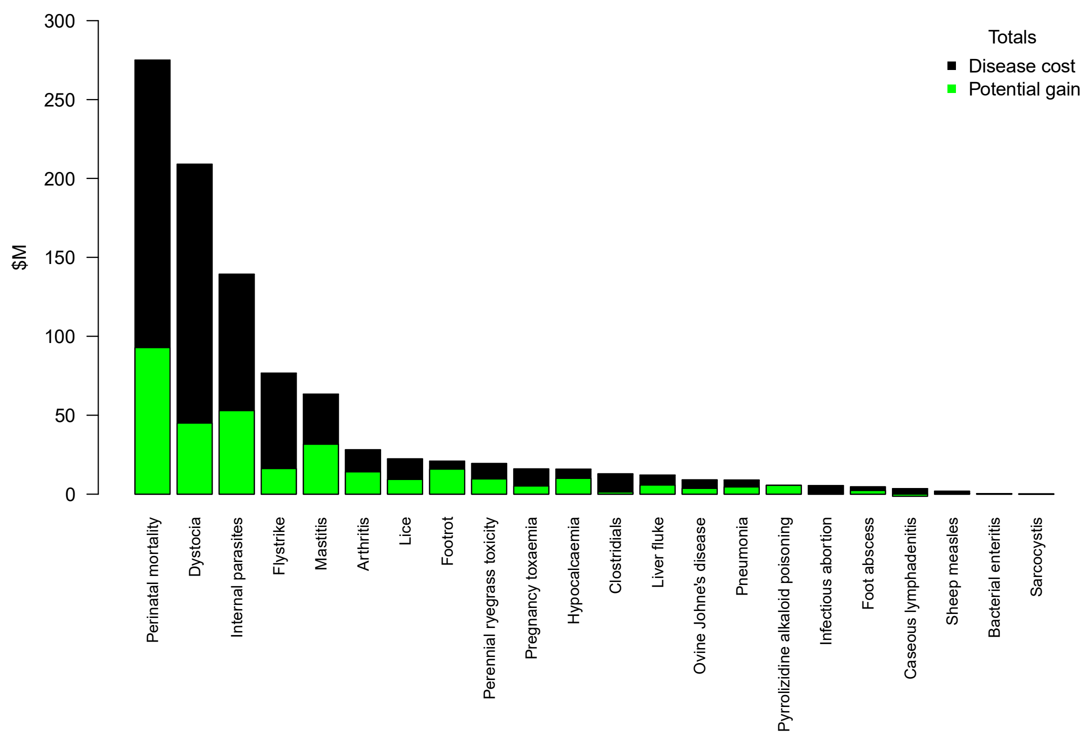


Figure 24: Estimated treatment, prevention and production costs of key endemic diseases of the dual-purpose sheep industry

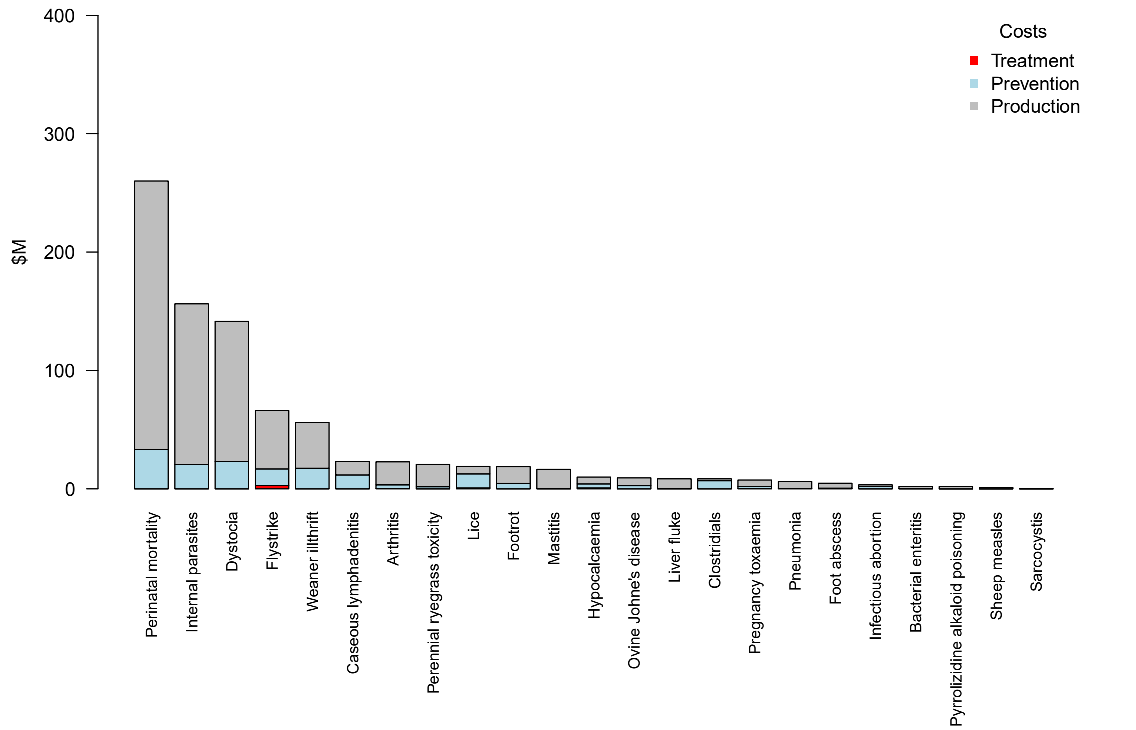
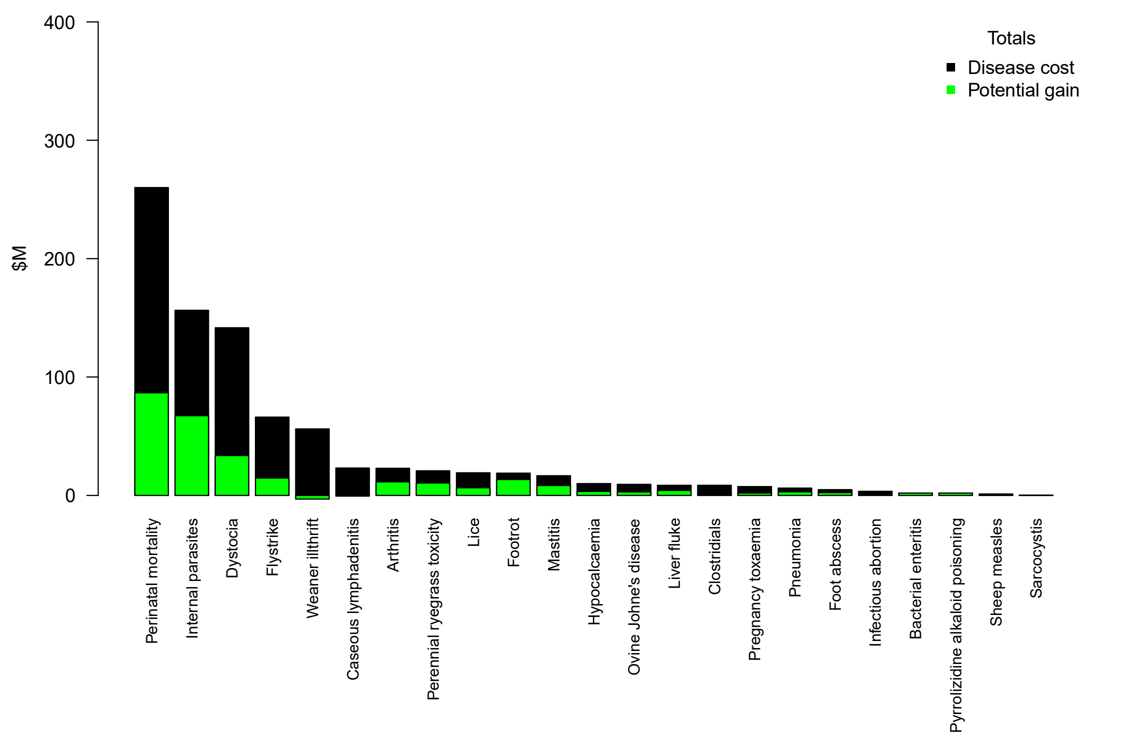


Figure 25: Total cost and achievable gain from better control of key endemic diseases of the dual-purpose sheep industry



5.3 Priority list summary

The updated priority list of diseases costings has resulted in modest changes to the ranking and the estimate of real costs of disease for both cattle and sheep. A significant influence on the industry-level cost estimate for each disease has been the change in the underlying population of cattle and sheep and their distribution in Australia.

There has been a reduction in the cattle population of 3.2M since the 2105 report. The national herd size has decreased 12.3% and decreased 8.2% for the northern and 8.6% for the southern industries respectively. There has been a relatively greater reduction in the number of beef farming businesses; the estimated reduction in beef farming businesses between the two reports is 3,200 enterprises (there are 41.6% fewer beef farming businesses in Australia and 37.4% fewer in the northern and 43.0% fewer in the southern industries respectively). There are 5.0M fewer sheep nationally since the 2015 report. The national flock size has decreased 7.0% and decreased 34.5% for the pastoral, 6.7% for the sheep/wheat but increased 3.5% for the high-rainfall regions respectively. There has been a similar larger reduction in the number of sheep farming enterprises over this period. There has been a reduction in sheep farming businesses of 27,300 farms over this time (27.3% fewer sheep farming business nationally with 40.5% fewer in the pastoral region, 28.1% fewer in the sheep/wheat region and 23.4% fewer in the high-rainfall region respectively. This means the average herd/flock size has increased between reports whilst the national herd/flock size has decreased.

The other key change since the 2015 report has been the significant increase in animal values. The CPI-adjusted average weekly prices for saleyard cattle (c kg liveweight) of various categories used in the current estimates (with absolute and relative change to 2015 report prices in parentheses) were medium cows 292.53c (+134.27c, +84.8%); medium steers 383.33c (+173.86c, +82.4%); trade steers 439.48c, (+205.83c, +88.1%); feeder steers 442.21c (+214.35c, +94.1%); northern cows 282.93c (+116.82c, +70.3%); and northern bullocks 361.63c (+139.19c, +62.6%). Similar changes were observed for sheep being mutton 600.81c (+251.61c, +72.1%); trade lambs 816.53c (+289.05c, +54.8%); light lambs 830.33c (+267.66c, +47.6%); heavy lambs 826.16c (+265.51c, +47.36%); restocker lambs 872.98c (+323.68c, +58.93%); and Merino lambs 765.07c (+276.41c, + 56.6%). Most lines of wool have enjoyed modest real increase in value across this period of around 25–30%, with notable exception of a decline in real returns for coarser wool.

The estimated costs at herd/flock and national level need to be viewed in the light of the demographic and animal/commodity real price changes.

There has been a slight re-ranking of the priority list of cattle diseases. The near-universal challenge of parasites (buffalo fly, ticks and internal parasites) to cattle makes these diseases predominate total cost of endemic disease to industry. Similarly, ubiquitous diseases that affect herd reproduction (vibriosis, pestivirus and trichomoniasis) continue to have large impacts across industry. Many diseases, such as dystocia and clostridia are controlled as well as current technology and systems allow; there are few avenues for more profitable improvement. Some diseases, such as internal parasites suggest that there may be systemic misuse of preventives; not all drenches are required or administered at the correct time and into the correct class of animal. Improved profits may follow use of more evidence-based approaches to internal parasite control. This is discussed under this disease. The emergence and spread of parasite drug resistance combined with a slowing of development of new chemicals for treatment combine to make effective parasite control increasingly difficult. Industry is encouraged to develop integrated pest management techniques and to adopt monitoring and testing approaches to control.

Pestivirus remains a difficult disease to quantify. Whilst pestivirus has been re-ranked downwards in impact from the 2015 report, this is a disease whose impact is not evenly distributed throughout industry. Most farms experience no or modest losses due to pestivirus each year, but the potential for catastrophic losses in naïve herds experiencing an outbreak during mating combine to provide an 'average' herd loss that is rarely experienced by any individual farm. The risk of large-scale losses due to a herd outbreak is not fully captured within average herd loss estimates. Producers need to consider risk as well as average cost-benefit of control when deciding on the course of action for their herd.

The effects of climate change on vector-borne disease are also difficult to quantify. The home range of ticks and vector-borne diseases such as bovine ephemeral fever, tick fever and theileriosis are likely to change with a changing climate. In general, warming will extend the home range of these diseases further south and inland. However, increasing drought frequency and intensity that accompanies climate change will reduce survival of the host vectors, thereby reducing challenge to livestock in these years. One consequence is a likely reduction in average herd/flock impact but with increased severity of outbreaks when conditions are more favourable.

5.4 Key findings

- Endemic diseases remain a significant cost to industry
- Parasitic diseases dominate endemic disease costs of cattle
- Sheep disease costs are dominated by peri-parturient losses (lambs and ewes) and internal parasites
- Improved control and prevention opportunities exist for some but not all listed diseases
- Changes to industry demographics and to the value of animals combined with the range, effectiveness and cost of controls modify the cost-benefit for optimal control on a near annual basis. Control programs, extension messages and research priorities should flexibly respond to a changing cost-benefit equation.
- Trends in disease costs are difficult to determine from raw estimates. Consideration of changes described above are required
- Regular revision of the priority list of endemic diseases is recommended

5.5 Benefits to industry

This section has summarised the estimated priority list of endemic disease costs and has discussed aspects of key diseases and given consideration for the future management of these diseases for cattle and sheep. Industry can use this information to identify opportunities, prioritise research, focus extension and monitor trends in endemic diseases and their impacts to the red meat industry.

6. Future research and recommendations

This report, and its predecessor (B.AHE.0010), provides the essential business case for research into endemic disease for the cattle and sheep industry. Industry may use this to direct future research activities into fields offering the greatest benefit — either now or in the future.

Research organisations may use this report to justify investment in their research proposal by industry. Producers may use this report to evaluate the effectiveness of their own disease control programs.

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6. Appendix: Removed diseases

6.1 Cattle

6.1.1 Bovine Johne's disease

The disease

Bovine Johne's disease (BJD) is due to infection with *Mycobacterium avium subsp. Paratuberculosis* (MAP). BJD is endemic within the dairy industry of Victoria, Tasmania, South Australia and New South Wales with the highest prevalence of infected dairy herds in the southeast. Disease has occasionally been identified in a few beef cattle herds at a low within-herd prevalence in Victoria – generally a result of spill-over contact with dairy animals (cattle strains of MAP) with 67% of infected beef herds introducing disease with dairy or dairy cross cattle (Larsen, Ware and Kluver, 2012). There is however an increasing rate of isolation of sheep strain (S strain) from beef cattle (again at very low within-herd prevalence) in the sheep-beef regions (northeast and western districts) of Victoria. Disease was historically absent from Western Australia, Queensland and the Northern Territory however the confirmation of a novel bison strain in cattle from and originating from a large Queensland Brahman stud has resulted in trace forward contacts into each of these jurisdictions. A study of ovine Johne's disease found that disease was less likely in sheep carried on sandy soils compared to heavier clay soils; the authors attributing the low MAP-binding power of sandy soils as potential explanation MAP (Dhand *et al.*, 2009). This, combined with the low stocking density of the beef industry suggests BJD would have difficulty establishing on most beef properties; especially in the north. The distinction between host-adapted strains of MAP has been removed and this has impacted some state-level regulations and requirements for movement of livestock between jurisdictions. Johne's disease is a chronic incurable disease however most infected beef cattle do not live long enough to express clinical disease. The average age of the index case in a beef study was 5.7 years (Larsen, Ware and Kluver, 2012). Diagnostic tests have inadequate sensitivity to detect infected individuals and therefore test-and-cull programs to eradicate disease from infected herds are ineffective. Vaccines provide incomplete protection and cross-react with tuberculosis tests (that may be used in other countries). Vaccination may assist to control disease but may not guarantee eradication of disease from infected herds. Many countries ban the importation of cattle from herds confirmed to have diseased and/or BJD vaccinated cattle. The direct economic impact of clinical BJD in dairy herds was found to be modest (Shephard, Williams and Beckett, 2016). The effect in beef cattle herds is likely much smaller than for dairy. A recent study estimated that eradication (by destocking) was not feasible until the annual clinical incidence exceeded 5% (Webb Ware, Larsen and Kluver, 2012). The (potential) loss of trade due to regulatory restriction presents a greater source of loss of many producers than the direct effect of disease on cow survival within the herd. Beef stud herds may be limited in ability to sell bulls and live exporters may have cattle excluded from markets due to the presence of disease. Not all infected farms will experience approximately 'average' economic impacts; some infected farms will experience business-threatening loss of incomes if confirmed (or suspected) to have disease. The removal of most regulatory requirements further reduces the impact of BJD in the beef industry

	Unknown aetiology									*Known aetiology*
2015							X			
2022							X			

Prevention

There are no effective preventive methods besides strict quarantine and selective introductions. The poor sensitivity of diagnostic tests makes introduction of test-negative animals a risk. The persistence of MAP in the environment (and especially water) can negate animal movement controls. A vaccine can assist control but not eradicate disease from most infected herds. A single-dose vaccine is available for use, and this has markedly reduced the expression of clinical disease in dairy herds that use vaccination.

Low efficacy/ unproven preventives available — *Effective preventives available*

2015		X								
2022		X								

Treatment

There are no registered effective treatments.

Low efficacy/ unproven treatments available — *Effective treatments available*

2015	X									
2022	X									

Distribution

There appears to be an increasing spread from sheep and dairy cattle to the beef herd in the south. The level of establishment of BJD in the northern industry following introduction and dissemination of the bison strain is unknown.

Distribution contracting — *Distribution stable* — *Distribution increasing*

2015							X			
2022						X				

Prevalence

The within-herd prevalence of clinical disease and infection with MAP is low. New Zealand modelling studies suggest the within-herd prevalence of S-strain in beef herds may stabilise at less than 1% infected.

Prevalence decreasing — *Prevalence increasing*

2015					X					
2022					X					

<u>**Economics**</u>

Assumptions: Johne's disease – southern

Table 129: Assumptions: Johne's disease – southern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	The organism can potentially inhabit a range of environments but is less persistent in dry regions	-	**
% herds infected	5% of southern cattle properties may be infected at low prevalence: 2% of adult cattle develop clinical disease per year.	1% of southern cattle properties may be infected at low prevalence: 2% of adult cattle develop clinical disease per year. (see Prevention)	**
Mortalities	100% mortalities in clinical cases	-	***
Weight loss	No weight loss, fertility or other production effects are costed as all production losses are captured in mortality (100%).	-	***
Fertility	50% of clinical cases fail to provide a calf in the year of their death/culling	-	***
Market avoidance	Nil – the issue of live export market restrictions is not discussed in this report	-	N/A
Movement restrictions	Quarantine of studs and infected/suspect herds	-	***
Treatment	No treatment	-	**
Prevention	Strict quarantine and selective introductions	Silirium vaccine is available. Widespread use in the dairy industry is limiting spillover into the southern beef industry	***

Based on the adopted prevalence and impacts of the disease on the classes of animals affected, GHD has calculated the annual cost of Johne's disease in cattle in southern Australia at $0.5M as shown in Table 130.

Table 130: Economic cost of bovine Johne's disease – southern

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Cattle	$0	$0	$0	$0	$0	$0	$0	$0	$7.91	**$0**	**$0**	**$7.92**
Per Herd	$0	$0	$0	$0	$0	$0	$0	$0	$921	**$0**	**$0**	**$1,456**
Total	**$0M**			**$0M**			**$0.5M**			**$0.5M**		

No gain from improving disease control in the southern herd is assumed (affected herds are all within the low category already).

Assumptions: Johne's disease – northern

Table 131: Assumptions: Johne's disease – northern (cattle)

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	The organism can potentially inhabit a range of environments but is less persistent in dry regions	-	**
% herds infected	1% of northern cattle herds may be infected (exposed): 1% of adult cattle develop clinical disease per year.	0.2% of northern cattle herds may be infected (exposed): 1% of adult cattle develop clinical disease per year. This is due to reduced spillover from the southern industry	**
Mortalities	100% mortalities in clinical cases	-	***
Weight loss	No weight loss, fertility or other production effects are assumed; all production losses are due to deaths.	-	***
Fertility	50% of clinical cases fail to provide a calf in the year of their death/culling	-	***
Market avoidance	Nil – the issue of live export market restrictions is not discussed in this report	-	N/A
Movement restrictions	Quarantine of studs and infected/suspect herds	-	***
Treatment	No treatment	-	**
Prevention	Strict quarantine and selective introductions	-	***

Based on these assumptions the annual cost of Johne's disease in cattle in northern Australia at $0.1M (Table 132).

Table 132: Economic cost of bovine Johne's disease – northern

	Treatment			Prevention			Production			Total		
	H	M	L	H	M	L	H	M	L	H	M	L
Per Cattle	$0	$0	$0	$0	$0	$0	$0	$0	$3.91	$0	$0	$3.91
Per Herd	$0	$0	$0	$0	$0	$0	$0	$0	$2,460	$0	$0	$2,460
Total	**$0M**			**$0M**			**$0.1M**			**$0.1M**		

Again, no gain from improved disease control in northern herds has been assumed as all infected herds are within the low category already.

Total cost of disease

The total cost of Johne's disease in cattle across Australia at the current prevalence of disease is estimated at $0.6M per annum. The 2015 report estimate was $2.8M per annum (equivalent to $3.2M in 2022).

Changes since last report

The use of silirium vaccine in the dairy industry is decreasing risk of spillover infection into the southern beef industry. Disease is unlikely to establish in northern Australia

Bovine Johne's disease was originally ranked 16th in 2015. The estimated cost of disease is insufficient to maintain bovine Johne's disease on the priority list.

6.3 Sheep

6.3.1 Sarcocystis

The disease

Sarcocystis (sarcosporidiosis or sheep measles) is caused by a group of protozoon parasites (*Sarcocystis spp*). Cats are infected by eating infected uncooked meat and act as the definitive host producing sporocysts that are passed in the carnivore's faeces. These are subsequently ingested by sheep where sarcocysts develop in muscle and offal. Meat identified with sarcocystis infection is not acceptable for human consumption (Munday, 1990). The financial impact of sheep measles arises from carcase trim, condemnation and offal rejection as there are no apparent health or production impacts in sheep, although experimental infection can cause serious wool and bodyweight production losses in previously naive animals and occasional reports of abortions are documented (Munday, 1990). Based on abattoir monitoring (Animal Health Australia, 2021), the prevalence of sarcocystis has declined markedly. The southern regions are at highest risk, particularly Tasmania, but sarcocystis here was only detected in 1.6% of inspected carcases with all other states recording a prevalence of <0.3% of carcases.

	Unknown aetiology									*Known aetiology*
2015										X
2022										X

Prevention

There is no preventive strategy for sarcocystis apart from control of feral cats and avoid feeding raw meat to cats and dogs and removing carcases from access by these scavengers.

	Low efficacy/ unproven preventives available									*Effective preventives available*
2015		X								
2022		X								

Treatment

No treatment is available.

	Low efficacy/ unproven treatments available									*Effective treatments available*
2015	X									
2022	X									

Distribution

Distribution seems to be widespread across sheep growing regions, although more common in southern regions. In Tasmania it is noted to be more common around townships presumably due to the association with higher cat populations.

	Distribution contracting				*Distribution stable*					*Distribution increasing*
2015					X					
2022					X					

<u>Prevalence</u>

Prevalence appears to be decreasing.

	Prevalence decreasing									*Prevalence increasing*
2015					X					
2022				X						

<u>Economics</u>

Assumptions: Sarcocystis

Table 133: Assumptions: sarcocystis in sheep

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
Regional Extent	Distribution Australia wide	-	***
% Flocks affected	Based on abattoir surveillance, about 0.88% of sheep were infected with sarcocystis. Prevalence appears to be higher in southern regions though is averaged across all sheep growing regions.	Based on abattoir surveillance, about 0.1% of sheep were infected with sarcocystis. Prevalence appears to be higher in southern regions though is averaged across all sheep growing regions NSHMP 2020-21	**
Mortalities	Nil	-	**
Weight loss	Nil	-	***
Fertility	Nil	-	***
Fleece weight	Nil	-	***
Wool price	Nil	-	***
Market avoidance	Carcase condemnation: a. Condemnation: 0.01% of adults (Department of Agriculture Forestry and Fisheries, 2014) *b.* Carcase trim 0.13% of adults. Average 5.6 kg trim/carcase	Assume condemnation rate of 0.01% and carcase trim rate of 0.1% with average trim per carcase of 5.6 kg trim/carcase used previously. (NSHMP 2020-21)	**

Variable	2015 Assumptions	2022 Assumption Changes	Confidence
	(GHD, 2011; Hernandez-Jover et al., 2013)		
Movement restrictions	Nil	-	***
Treatment	Nil	-	***
Prevention	Avoid offal feeding to cat Control of feral cats (no cost considered as definitive hosts controlled for other reasons).	-	***

Based on these assumptions the annual cost of sarcocystis in sheep in Australia is estimated at $0.6M (Table 134). The 2015 estimate was $0.9M (equivalent to $1.0M in 2022)

Table 134: Economic cost of sarcocystis in sheep

	Treatment			Prevention			Production Losses			Total		
	H	M	L	H	M	L	H	M	L	**H**	**M**	**L**
Per Sheep	$0	$0	$0	$0	$0	$0	$0.01	$0	$0	**$0.01**	**$**	**$0**
Per Flock	$0	$0	$0	$0	$0	$0	$18	$0	$0	**$18**	**$0**	**$0**
Total	**$0M**			**$0M**			**$0.6M**			**$0.6M**		

If the prevalence of sarcocystis is reduced by 50% then the cost to industry would reduce by $0.3M. Note that no value on potential production losses has been considered as they have not been proven in field conditions.

<u>Changes since last report</u>

The cost of Sarcocystis to the sheep industry has reduced because of the lower prevalence identified during abattoir monitoring even though the value of sheep has increased substantially.