Australian egg layer disease benchmarking survey

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A report for Australian Eggs Limited

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Foreword

This project was funded from industry revenue, which is matched by funds provided by the Australian Government.

This report is an addition to Australian Eggs Limited's range of peer reviewed research publications and an output of our R&D program, which aims to support improved efficiency, sustainability, product quality, education and technology transfer in the Australian egg industry.

Most of our publications are available for viewing or downloading through our website:

www.australianeggs.org.au

Printed copies of this report are available for a nominal postage and handling fee and can be requested by phoning (02) 9409 6999 or emailing research@australianeggs.org.au.

Acknowledgments

Australian Eggs Limited provided the funds that supported this project. Industry veterinarians, farm managers and other technical staff contributed to the information detailed here.

About the Authors

Dr Timothy Wilson is a production animal veterinarian with over 35 years' experience in production animal medicine, vaccine and pharmaceutical development studies, veterinary therapeutics policy and regulation.

Dr Peter Scott has more than 40 years' experience in the Australian poultry industry as a veterinary pathologist, veterinarian, researcher and member of egg industry R&D committees. He has successfully completed many projects for the Australian Egg Corporation Limited (AECL) and other industry organisations, and as Managing Director of Scolexia leads the team of veterinarians and researchers involved in this project.

Dr Arif Anwar has extensive international poultry veterinary experience and has been involved in several significant industry projects.

Dr Huang is currently engaged in providing poultry health services to the industry and training veterinary students in poultry health and production.

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Abbreviations

AE	Australian Eggs Ltd
AVEP	Association of Veterinarians in Egg Production (USA)
EDS	Egg drop syndrome
FC	Fowl Cholera
FR	Free range
IB	Infectious Bronchitis
IBV	Infectious Bronchitis virus
ILT	Infectious Laryngotracheitis
MG	*Mycoplasma gallisepticum*
MS	*Mycoplasma synoviae*
MT	Metric Ton
ND	Newcastle Disease
NE	Necrotic Enteritis
ORT	*Ornithobacterium rhinotracheale*
POL	Point of lay
SCFA	Short chain fatty acid
SE	*Salmonella* Enteriditis
SLD	Spotty Liver Disease
ST	*Salmonella* Typhimurium
USA	United States of America
UURTD	Undefined upper respiratory tract disease – a condition where frequently one or more respiratory pathogens can be isolated but do not necessarily cause the typical symptoms associated with those pathogens.

Executive Summary

An email survey was sent to those on the Australian Eggs Ltd email and phone list, with follow-up reminder phone calls made on several occasions. To allow for relative brevity and encourage replies, the initial survey focussed on questions regarding the number of incidents of disease and conditions such as smothering, vent pecking, cannibalism, and predation. Replies were received from all States and sectors of the industry and from over 60 farm managers, owners or veterinarians. The shedding capacity stated by the respondents represented more than half of the national hen flock. A forum of technical advisors discussed the initial results and the follow-up survey to obtain information on the extent of each incident with respect to the number of hens affected, mortality and impact on production in both hens and pullets. The second survey form was also emailed, obtaining a dozen replies, which represented approximately 43% of the industry (by shedding capacity); these were utilised to calculate the impact of diseases and conditions on the Australian industry.

The most frequently reported conditions were smothers and predation/vermin. The most expensive conditions in terms of disease and prevention costs was Spotty Liver Disease (SLD) $17.2M, followed by Fowl Cholera (FC) $15.3M, Infectious Laryngotracheitis (ILT) 14.8M, undefined upper respiratory tract disease (UURTD) $10.7M, colibacillosis $8.6M, coccidiosis $4.2M, Egg Drop Syndrome (EDS) $3.7M, Newcastle Disease (ND) $2.45M, *Mycoplasma gallisepticum* and *M. synoviae* (MG/MS) $2.7M, and smothers $2M. Some of these costs only represent control costs. Diseases and conditions were accepted as reported by survey respondents. The assumptions used for estimating costs are detailed in the methods below.

It is possible that underreporting of the extent of many conditions has occurred. Whilst the number of incidents reported by respondents does not directly relate to incidence as described in various overseas literature, it has been possible to use the data in the Phase 2 survey to estimate total morbidity and mortality and to compare that to overseas studies. No overseas study has sought to cover all conditions and diseases in the same fashion as achieved in this project. The estimated incidents of disease and conditions appears lower than those reported overseas. In agreement with some studies and in contrast to others there was a very obvious difference in the cost and impact of diseases in conditions between production systems, with the free range systems having the highest frequency of incidents and the highest mortality and morbidity.

The results of the survey will enable Australian Eggs Ltd to make rational decisions about funding and will allow egg producers to understand the relative importance of the different diseases and conditions affecting the industry. It is recommended that a follow-up survey be conducted in four to five years with a more intensive face-to-face focus and examination of farm records and flocks.

Overall Conclusions

Smothering and predation are the most commonly reported incidents affecting Australian laying breed birds, both are more prevalent in free range and barn systems, and predation most prevalent in free range systems. In terms of estimated costs of some disease and control factors, SLD is the costliest disease, followed by FC, ILT, UURT, colibacillosis, coccidiosis, EDS, ND, MG/MS, smothers and predation. It is likely that underreporting of the number of incidents has occurred. Further surveys should be undertaken in four to five years utilising a more intensive face-to-face survey approach with additional examination on farm of records and pullets and hens.

1 Introduction

Whilst a full edition of Animal Production Science was devoted to reviews of the welfare of laying hens (Bryden 2021), no attempt was made to survey occurrence or estimate the cost of diseases and conditions. No other recent disease and welfare survey has been undertaken in the Australian layer industry. In order to properly allocate resources with respect to research funding, Australian Eggs Ltd (AE) requires such information to strategically address issues of animal health, food safety and animal welfare. It is therefore necessary to have a relevant snapshot of the current disease/pathogen/welfare situation in the industry overall, and the extent to which different conditions are impacting the health, wellbeing and productivity of the flock. Disease and conditions that are currently considered important in the industry include infectious, parasitological and behavioural problems (e.g. picking and smothers), as well as toxicity and the impact of vermin (predation). The most notable egg-related food safety issues involve *Salmonella* spp., especially *Salmonella* Enteritidis (SE). It is therefore essential for the industry to regularly conduct surveys of the prevalence and impact of disease and management related conditions in the laying flock. The current extent of these problems in laying hens is not well documented. Therefore it is not possible to estimate the national cost of disease and condition related issues (including the direct impact of diseases and conditions as well as the costs of control and treatment) even where the cost of each condition on a particular farm has been investigated.

The cost to the industry in not having such a benchmarking study is that funds may not be allocated to health and welfare issues in the most cost-effective manner. There are also potential opportunity costs such as the lack of funding to support the development and registration of strategically important products such as occurred with the registration of Amoxycillin for layers, the examination of available vaccines for use in SE, or the work to add poultry to the label claim for the Erysipelas vaccine. The information will also assist producers in prioritising management and disease control measures. No overall estimates of whole of industry disease incidence in Australia have been made. Various researchers have made estimates of particular disease incidence; however no attempt has previously been made to rank the importance of different conditions in Australian laying hens (e.g. Muralidharan et al. 2022).

Other industry bodies have increased their ability to prioritise animal health and welfare spending by the use of such disease snapshots – e.g. Meat and Livestock Australia (MLA)'s AHW.087: Cost of endemic diseases (Sackett et al. 2006) and B.AHE0010: Priority list of endemic diseases for the red meat industries (Lane et al. 2015). The Principal Investigator for this project managed the animal health portfolio for MLA following the release of AHW.087 and was able to evaluate funding proposals based on the information in the disease snapshot, to ensure that funding was directed to the major health problems of the red meat industries. It is also probable that without an impartial observation of disease and welfare conditions, and an evaluation of the impact of the condition on productivity and health, that some producers may underestimate the importance of some conditions and overestimate the importance of others. This report will enable individual producers to better assess their priorities and provide a clearer understanding of the costs and impacts of health and welfare conditions.

The project provides a summary of the current disease burden in the Australian layer industry. Particular objectives included:

- identifying the significance of industry diseases ranked by incidence and impact
- identifying disease and welfare issues that are currently difficult to monitor and quantify
- comparing the burden of disease and welfare issues in each main management system, and in each of the main poultry producing States.

- estimating the cost to industry of the prevalence and control of each disease and condition
- undertaking a comparison with any similar study in the United Kingdom and the Netherlands.

In order to rectify this lack of knowledge, Industry veterinarians and technical staff were surveyed with a view to obtaining data on a representative sample of farms (divided among States and main production types). The survey asked for data on all disease and other causes of mortality (e.g. smothers) and morbidity over a one-year time frame. The impact of conditions in terms of morbidity and mortality, and the production losses associated with the condition, including the duration of the condition were surveyed. Data on vaccination and other disease control programs (including water, sanitation and biosecurity practices) was collected and the cost of prevention for some diseases calculated where practical as well as the cost of general disease prevention.

In addition to the survey, State departments of agriculture were approached for information with respect to samples submitted over the same period. Questions asked were structured to avoid confidentiality issues yet still ensure meaningful information that will reflect the industry status.

Following collation of the initial survey data, an online forum was held for poultry veterinarians and key company personnel, to discuss the results and the relative prioritisation of disease, as well as the next phase of the project, which involved a further survey to detail the extent of each incident.

2 Materials and methods

Phase 1

Industry veterinarians or farming managers were surveyed with a view to obtaining data on a representative sample of farms (divided among States and main production types). The survey requested data on causes of mortality and morbidity over a five-year period and the most recent one-year period. The survey details are shown below in Figure 1–5. The surveys were emailed to a list of producers held by Australian Eggs Ltd (AE).

Smothering events were classified as: 'nest-box' (self-explanatory); 'post-transfer' (in the immediate period after transfer to the production house); 'fright/flight' (in response to an obvious fear stimulus); and 'passive' or recurrent (when no obvious reason for the smothering event could be ascertained).

Layer Disease Benchmarking Survey

Veterinary and technical staff survey

Production system(s) on the farm

Please state the number of sheds in each category in the relevant columns and rows.

Shed/production type	Cage	Colony cage	Barn	Free-range	Organic	Caravan
Total number of sheds						
Barn fully slatted?	N/A	N/A				N/A
Barn fully deep litter floor?	N/A	N/A				N/A
Barn partially slatted?						
Aviary system?	N/A	N/A				
Perches present?	N/A	N/A				
Environment control (Cool pad or foggers & fans)						
Naturally ventilated with foggers.						
Foggers, natural ventilation						
Rearing (R) or production (P) shed?Ø						
For pullets - Jump-start rearing?	N/A	N/A				
Average number of birds placed per shed (x1,000s)						

Ø in this row write R for rearing shed or P for production shed in the relevant column and add the number of such sheds after the abbreviation for each type.

Figure 1 Veterinary and technical staff survey form – production system details

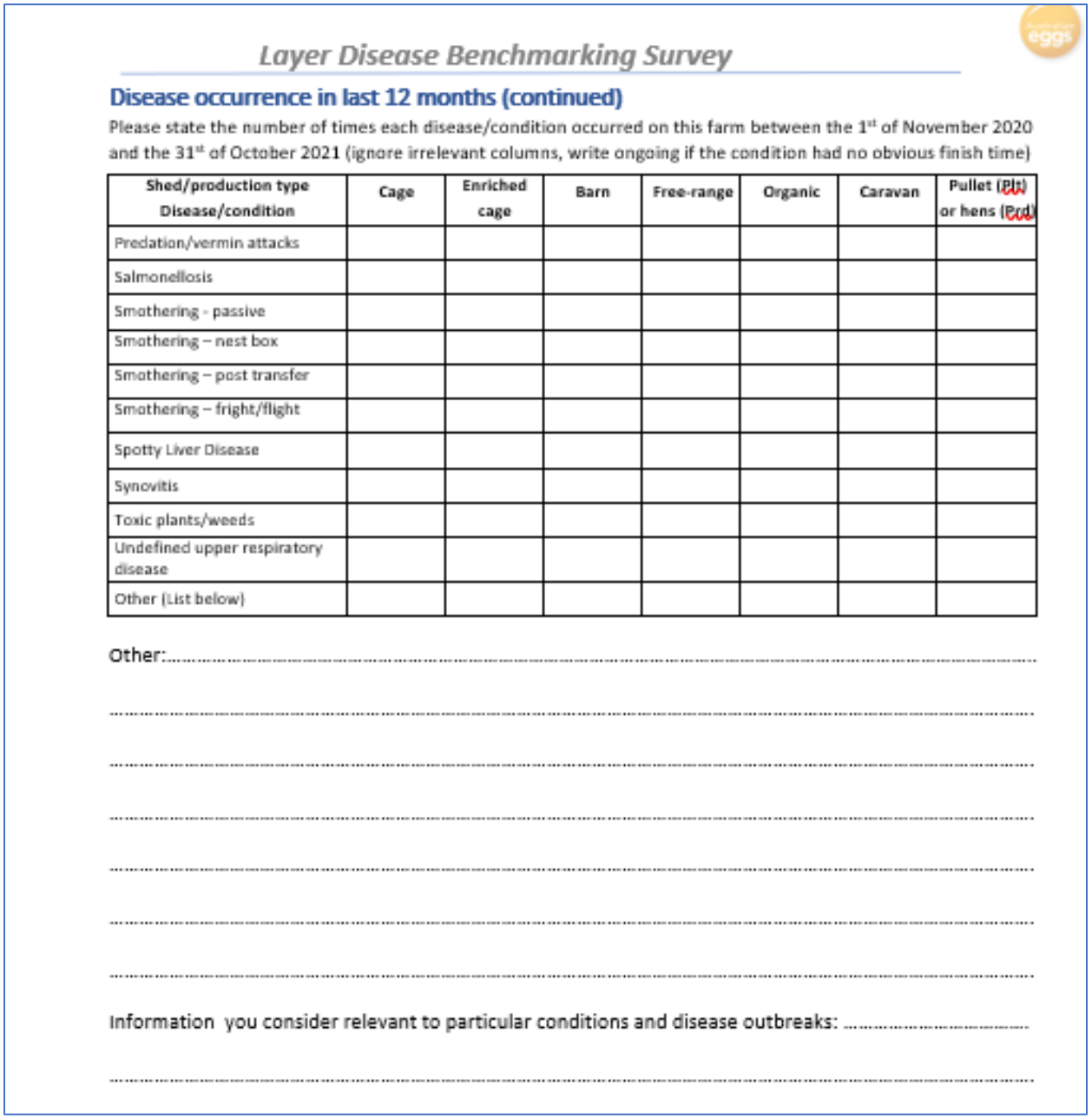
Layer Disease Benchmarking Survey

Disease occurrence in last 12 months

Please state the number of times each disease/condition occurred on this farm between the 1st of February 2021 and the 31st of January 2022 (ignore irrelevant columns, write ongoing if the condition had no obvious finish time)

Shed/production type Disease/condition	Cage	Colony cage	Barn	Free-range	Organic	Caravan	Pullet (Pl) or hens (Prd)
AEV (Avian encephalomyelitis)							
Antibiotic responsive condition of unknown cause							
Aspergillosis							
Big Liver and Spleen							
Black Head (Histomoniasis)							
Brachyspira (Spirochaetosis)							
Candidiasis							
Cannibalism							
Cestode (Tapeworm)							
Chlamydiosis							
Coccidiosis							
Colibacillosis							
EDS (Egg drop syndrome)							
Erysipelas							
Fatty Liver							
Favus (Fungal infection, ringworm)							
Feed disruption (mechanical, formulation, ingredient issues)							
Fowl Cholera (*P. multocida*)							
Galibacterium							
Gizzard Erosion							
Hysteria							
IBV (Infectious Bronchitis)							
ILT (Infectious Laryngotracheitis)							
Infectious Coryza							
Keel deformity							
Keratoconjunctivitis							
Lice							
Marek's Disease							
Mites							
Mycoplasmosis							
Mycotoxicosis							
Necrotic Enteritis							
Nematode (Roundworms, including caecal worm)							
ORT (Ornithobacteriosis)							
Osteomyelitis							

Figure 2 Veterinary and technical staff survey form – condition occurrence last 12 months



Layer Disease Benchmarking Survey

Disease occurrence in last 12 months (continued)

Please state the number of times each disease/condition occurred on this farm between the 1st of November 2020 and the 31st of October 2021 (ignore irrelevant columns, write ongoing if the condition had no obvious finish time)

Shed/production type Disease/condition	Cage	Enriched cage	Barn	Free-range	Organic	Caravan	Pullet (Plt) or hens (Prd)
Predation/vermin attacks							
Salmonellosis							
Smothering - passive							
Smothering – nest box							
Smothering – post transfer							
Smothering – fright/flight							
Spotty Liver Disease							
Synovitis							
Toxic plants/weeds							
Undefined upper respiratory disease							
Other (List below)							

Other:.....

.....

.....

.....

.....

.....

.....

Information you consider relevant to particular conditions and disease outbreaks: .....

.....

Figure 3 Veterinary and technical staff survey form – condition occurrence last 12 months

The one-year period survey pages were repeated asking for the details of conditions that had occurred over the last 5 years.

In addition details of details of treatments and prevention as well as biosecurity were requested as follows, in Figure 4 and Figure 5.

Layer Disease Benchmarking Survey

Treatments/Prevention

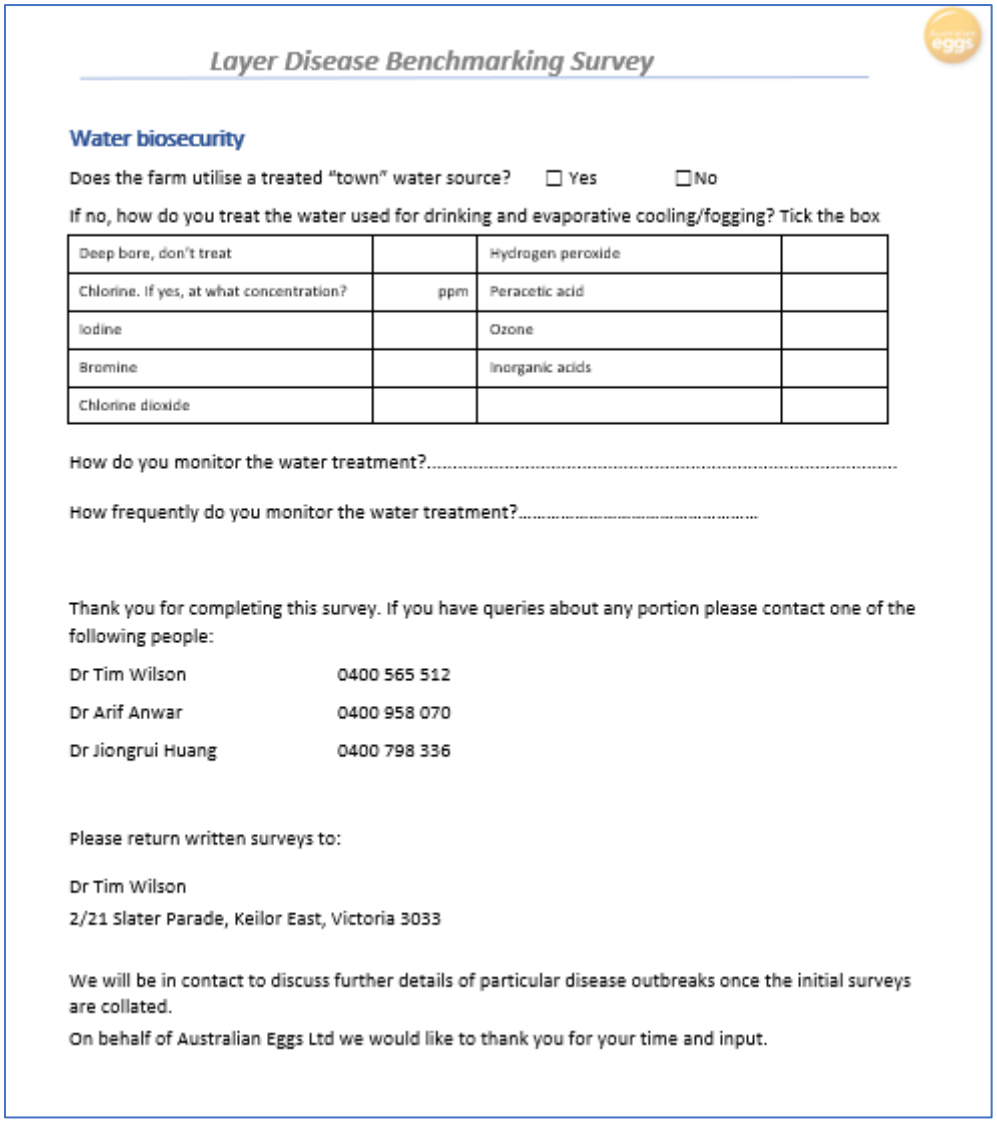
Please state the routine veterinary products/treatments used on this farm between the 1st of November 2020 and the 31st of October 2021 (ignore irrelevant columns). **List the age(s) in weeks** for each treatment (day-old = d.o.)

Shed/production type Treatment	Cage	Enriched cage	Barn	Free-range	Organic	Caravan
Beak trim						
Infectious Bronchitis vaccine						
Marek's Disease vaccine						
Newcastle Disease vaccine (live)						
Newcastle Disease vaccine (killed)						
Fowl Cholerae vaccine						
ILT vaccine						
Mycoplasma (MG – ts-11) vaccine						
Mycoplasma (MS -MS-H)						
Egg Drop Syndrome (EDS) vaccine						
Fowl Pox vaccine						
Avian Encephalomyelitis vaccine						
Salmonella vaccine (ST – live)						
Blood taken for serology						
Piperazine						
Levamisole						
Flubendazole						
Off-label benzimidazole						
Salmonella testing (drag swabs etc)						
Veterinary visits to farm						
Antibiotics used in water						
Antibiotics used in feed						
Electrolytes added to water						
Other (List below)						

Other: ……

……

Figure 4 Veterinary and technical staff survey form – treatments and prevention details



Layer Disease Benchmarking Survey

Water biosecurity

Does the farm utilise a treated "town" water source? ☐ Yes ☐ No

If no, how do you treat the water used for drinking and evaporative cooling/fogging? Tick the box

Deep bore, don't treat		Hydrogen peroxide	
Chlorine. If yes, at what concentration?	ppm	Peracetic acid	
Iodine		Ozone	
Bromine		Inorganic acids	
Chlorine dioxide			

How do you monitor the water treatment?.....

How frequently do you monitor the water treatment?.....

Thank you for completing this survey. If you have queries about any portion please contact one of the following people:

Dr Tim Wilson 0400 565 512

Dr Arif Anwar 0400 958 070

Dr Jiongrui Huang 0400 798 336

Please return written surveys to:

Dr Tim Wilson

2/21 Slater Parade, Keilor East, Victoria 3033

We will be in contact to discuss further details of particular disease outbreaks once the initial surveys are collated.

On behalf of Australian Eggs Ltd we would like to thank you for your time and input.

Figure 5 Veterinary and technical staff survey form – water biosecurity details

It is a requirement of Australian Eggs Ltd (AE) that farm and producer names remain confidential and so data was aggregated. Due to limited responses from Caravan and organic producers it was not feasible to report results for that sector without compromising the identity of the producers. Similarly the reporting of separate State data would compromise the requirement to ensure no producer could be identified and so the data is reported nationally.

Correspondence with State and Territory governments was undertaken to solicit and then utilise relevant government disease data.

Following collation of the veterinary & management survey data, a zoom meeting with veterinarians and relevant technical staff was held to discuss the initial results and Phase 2 of the project.

Phase 2

A second survey was undertaken which asked for details on production losses associated with each condition, including the duration of the condition was used to quantify the impact of each incident reported in Phase 1. The details of the follow-up survey are displayed below in Figure 6 and Figure 7.

Comments on results observed and any potential related initiating factors, mitigating factors and any other observation you would like to make.

.....

.....

.....

.....

.....

Layer condition benchmarking survey follow up information (average of impact of incidents of that condition over at least 2 months during 2022)

Condition	Shed type[1]	Average No. birds placed/shed	Age(s) at time of incident (wks)	No of birds affected per incident	No of birds dead per incident	Impact of incident on Hen day %[2]	Impact on egg recovery %[3]	Length of impact (d)
Smothers all (or:)[4]								
Passive								
Nest-box								
Post transfer								
Fright								
Predation/vermin								
Spotty Liver Disease								
Undefined upper respiratory tract disease								
Worms (nematodes & cestodes)								
Fowl Cholera								
Big Liver Spleen								
Pecking/cannibalism								
Antibiotic responsive conditions								
Erysipelas								

1. C = cage, Bs = barn with all slats Bl = barn with at least some litter, FR = free-range 2. Just state the change in total % not the proportion of the drop, i.e. if the hen day% dropped from 95% to 93% just put "2% drop"
3. for changes in egg recovery %, state the difference as the change in % (not the proportion of the change) with an up or down arrow. 4. Either answer generically for all smother types or for each type individually.

Figure 6 Follow-up technical survey form – layer details

Pullet condition benchmarking survey follow up information

Condition	Shed type[1]	Average No. birds placed/shed	Age(s) at time of incident (weeks)	No of birds affected per incident	No of birds dead per incident	Impact of incident on expected weight gain[2]	Impact on uniformity[3]	Length of impact (d)
Smothers all (or:)[4]								
Passive								
Nest-box								
Post transfer								
Fright								
Coccidiosis								
Infectious Laryngotracheitis (ILT)								
Colibacillosis (*E. coli*)								
Necrotic enteritis								
Worms (nematodes & cestodes)								

1. C = cage, Bs = barn with all slats Bl = barn with at least some litter, FR = free-range 2. Use the performance objective to calculate expected growth for that age over the time period affected.
3. Simply report the change in uniformity % over the period as an increase or decrease % (not a proportion of the %) e.g. for a drop from 90-88% report ↓ 2.
4. Either answer generically for all smother types or for each type individually.

Figure 7 Follow-up technical survey form – pullet details

Phase 3

The final phase of the project aimed to validate estimated disease prevalence where practical by targeted on-farm sampling.

The planned activities and scoring systems are shown below in Figure 8.

Survey follow-up farm visits

The purpose of the farm visit is to help verify survey results where that can be achieved practically.

Instructions

Depending on farm size and nature, select two sheds of the same housing type in which the flocks are performing in a manner consistent with the overall farm history and current production figures. For larger farms with multiple production types select two of each of the main production types (cage, barn or free range) to the extent practical to fit in with one visit to the farm. Each production type should be reported separately.

For each shed examine daily records and record details requested below where they are available. Examine 100 birds and feather score 25 of those (see scoring system below) and keel score 100 (see scoring system below). Note signs of picking or cannibalism where apparent and record severity and number of birds affected.

In each shed perform an autopsy examination on 10 birds and look for and record signs of septicaemia, perihepatitis, airsaculitis, pericarditis, hepatomegaly, splenomegaly and any other pathology. Record the presence of roundworms or tapeworms on a scale of -, +, ++ or +++. Use the attached recording sheet.

Feather scoring

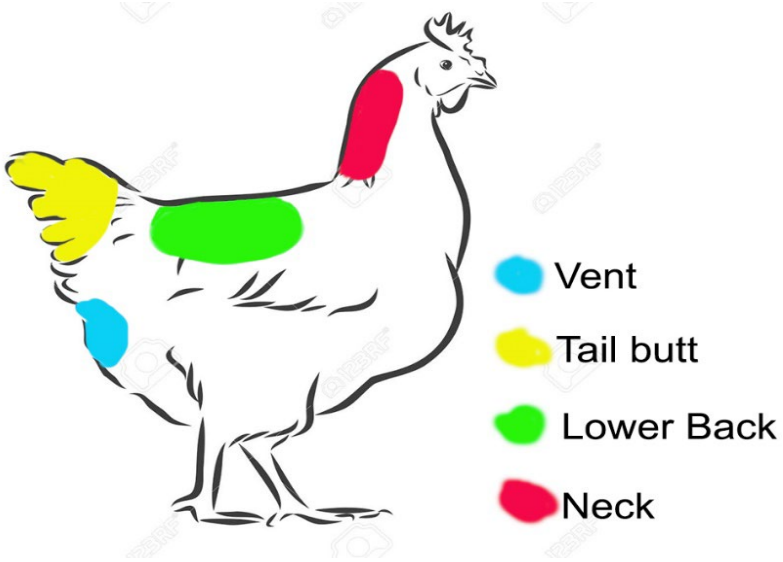
Use the scoring system of Bilcik and Keeling (1999) with slight modifications. The areas of the body of the hens to be evaluated will be lower back, tail butt, vent, and neck, according to the criteria outlined in the following table:

Figure 8 Follow-up farm visit instructions

Score	Neck/Lower back	Tail butt	Vent
0	Intact feathers	Intact feathers	No injuries or scratches
1	Some feathers scruffy, up to 3 missing feathers	Few feathers separated but none broken or missing	< 5 pecks or scratches
2	More damaged feathers, > 3 feathers missing	A lot of feathers separated and/or a few broken or missing	5 or more pecks/scratches or 1 wound < 1 cm diameter
3	Bald patch < 5 cm diameter or < 50% of area	All feathers separated, a lot of broken or missing feathers	Wound > 1 cm and < 2 cm diameter
4	Bald patch > 5 cm diameter or > 50% of area	Most of the feathers missing or broken	Wound >2 cm diameter
5	Completely denuded area	Almost all feathers missing	-

The feather scores will be recorded on Form 2.

The areas to be evaluated are depicted in the following diagram:



Keel scoring

Palpate the keel bone by running 2 fingers down the edge of the keel bone feeling for alterations such as s-derivations, bumps, or depressions. The following scoring system will be used:

4 = normal keel bone,

3 = slight deformation,

2 = moderate deformation,

1 = severe deformation. Scholz et al. (2008)

References

Scholz, B., S. Ronchen, H. Hamann, M. Hewicker-Trautwein, and O. Distl. 2008. Keel bone condition in laying hens: A histological evaluation of macroscopically assessed keel bones. Berl. Munch. *Tierarztl. Wochenschr*. 121:89–94.(Cited and used by S. Kappeli, S. G. Gebhardt-Henrich, E. Frohlich, A. Pfulg, H. Schaublin, and M. H. Stoffel (2011) Effects of housing, perches, genetics, and 25-hydroxycholecalciferolon keel bone deformities in laying hens. *Poultry Science* 90:1637-1644.)

Recording sheets below:

Figure 9 Follow-up technical survey form – feather and keel scoring details

Property code (farm identity need be known only by the veterinarian)……..

State: ……

Veterinarian:……(Name)

Production type: (circle) Cage Barn Free-range

Breed:……

Flock age: ……wks

No of birds placed: ……. Date of placement:……

Parameter	25 wks	35 wks	45 wks	55 wks	65 wks	75 wks	Last recorded	@ ? wks
Hen day% #								
Average egg # mass								
% blood stained eggs #								
% of floor eggs #								
% of 2nd and discarded eggs #								
Cumulative mortality								
Cumulative morts smothers								
Cumulative morts predation								
Disease incidents *								
Antibiotic use**								

As recorded for that week

* incidents in the period, so for the first column from placement to 25 wks etc. Record details below.

** as above for timing, record number of uses (eg one for a 5 day water treatment) & details below.

Disease incidents.

Diagnosis:……diagnosed by: Veterinarian Farm staff (circle)

Age when birds affected:……..wks. Length of disease outbreak:……wks

Figure 10 Follow-up technical survey form – production and condition impact details

Related mortality per week……% Reduction in hen day%:……% (i.e. 2% if production fell from 92 to 90 but returned to 91 or above after the event or maintained 90 for two weeks after the disease finished)

Impact on egg quality (describe)……

Other comments on the outbreak/antibiotic use:……

……

……

Bird examination form (1) Keel & feather score Property code:……Shed No:……

Bird Number	Lower back score	Tail butt score	Vent score	Neck score	Keel score
1					
2					
3					
4					
5					
6					
7					
8					
9					
25 rows for the various feather scoring positions and 100 rows for keel scoring.					

Figure 11 Follow-up technical survey form – condition details and scoring form

Autopsy findings Property code:…….

Shed No:……

Finding: Bird No:	Hepato-megaly*	Spleno-megaly*	Round-Worms 0 to +++	Tape-worms 0 to +++	Significant findings
1					
2					
3					
4					
5 – 10					

Figure 12 Follow-up technical survey form – post-mortem details recording form

* Hepatomegaly and splenomegaly were specifically included as a result of input following the technical meeting.

Assumptions

The following details and assumptions were used in quantifying those data provided by respondents which were qualitative rather than quantitative.

Phase 1 – incidents

Where number of incidents were reported as:

- ongoing – assumed 3 per month so 36/year
- numbers with a plus sign – were included at 1.5 times the number stated
- number recorded as weekly – have been included at 52 per year
- some incidents of predation were reported at 3–5% – were included at 7 per month which is 84 per year
- where a '?' was entered – one incident is recorded.

The following details were utilised to determine the total number of hens and pullets and the number of hens in each segment of the industry reported by Australian Eggs Ltd as at the 30th of June 2022 (www.australianeggslorg.au/egg-industry).

Calculation of the number of condition incidents in the Australian flock

The hen or pullet number reported by Australian Eggs Ltd. on the 30th of June 2022 and the reported shedding capacity of the survey respondents were compared. The proportion of the total population for each class of farming system was used to calculate a multiplier to enable calculation of the total number of incidents for the whole industry as follows:

Incidence multiplier = 1/(Shedding capacity of class reported in the survey/Number in class reported by AE)

The results of these calculations for each segment of the industry are displayed in Table 1 below.

Table 1 Multipliers used to estimate total number of incidents in each farming system

Farming system	AE data*	Percentage	Survey No	Survey %**	Multiplier
All hens	21,187,845	100	13,920,000	0.657	Not used#
Free range	11,865,198	56	6,338,000	0.534	1.872073
Cage	6,568,235	31	5,232,000	0.797	1.255301
Barn	2,118,785	10	1,994,000	0.941	1.062580
Other	635,636	3	355,000	0.559	Not done
Hens plus pullets	28,850,829				
Rearing	7,662,975		3,436,000	0.448	2.230202

* Data from Australian Eggs Ltd as at the 30th of June 2022 (www.australianeggs.org.au/egg-industry).

\# All hen incidents were calculated by the addition of free range, cage and barn incidents. Other systems were not included.

** % of shed capacity of surveyed farms for that enterprise type compared to the bird number from AE data.

Phase 2 – impact of each incident

The number of eggs produced in the 2022 financial year was divided by the number of hens reported by AE to give an average egg production per hen of 311 eggs per year, which equates to an average hen day production of 0.85% assuming a 52-week laying period, which will vary on production type and individual flocks.

The number of eggs lost per incident not including the impact of further losses from mortality was calculated by the following equation:

Ave egg loss = No. of affected per incident x 0.85342 x % loss x the number of days affected.

To this was added the impact of lost production because of the ongoing loss from mortalities, with the following assumptions used:

- For diseases that affect hens more commonly in early lay, assume 75% potential production is lost, i.e. 311 x 0.75 = 233.25
- For diseases that affect hens equally at any time throughout production, assume a 50% loss, i.e. 311 x 0.5 = 155.5
- For diseases that primarily affect hens in the latter stages of production assume a 25% loss, i.e. 311 x 0.25 = 77.75

As very few details were supplied in the Phase 2 survey for barn systems in particular, and for certain other situations, the following assumptions were made to allow a calculation to be made with respect to the impact of a condition:

- Undefined upper respiratory disease in cages reported in Phase 2 but not 1 – use barn incidence.
- SLD in cages – whilst some incidents were reported in cages, no details were given in Phase 2. It was determined that it was not valid to use FR or barn incident number.
- Predation and vermin in barn systems – use an average of cage and free range.
- SLD in barn systems, assume the number affected and the number dead per incident is the same as for FR.
- Undefined Upper Respiratory Tract Disease for barns – proportion dead compared to affected – use the average of the cage and FR, similarly for time affected.
- Worms (nematodes and cestodes) for barn systems – assume number dead, hen day% and length the same as FR.
- Fowl Cholera barn systems – proportion dead compared to affected – use the average of the cage and FR, similarly for time affected and hen day% impact.
- Pecking/cannibalism for barn systems – assume the same hen day% reduction and length as for FR.
- When length of impact was described as “10 days plus a chronic tail”, 4 days were added to the average impact.
- Where the length of impact of worms was described as “ongoing if not treated”, 56 days impact was assumed.

The value of hens was estimated using the following cost assumptions:

- Pullets placed $14.00
- Cost @ POL $16.00
- Cost at peak lay $14.00
- Cost at end of lay $ -1.00

For calculating the cost of mortality the birds were valued as follows:

- Hen value for conditions primarily affecting birds around peak of lay – $14.00
- Hen value for conditions occurring throughout lay (average of 14.00 and -1.00) – $ 6.50
- Hen value for conditions occurring later in lay (average of 6.50 and-1.00) – $ 2.75

The value of pullets was estimated as follows, utilising the age ranges cited for different conditions in the Phase 2 survey as shown in Table 2.

Table 2 Estimation of pullet values

Week	$ Value	Week	$ Value	Week	$ Value	Week	$ Value
Delivered	2.00	5	5.75	10	9.50	15	13.25
1	2.75	6	6.50	11	10.25	16	14.00
2	3.50	7	7.25	12	11.00		
3	4.25	8	8.00	13	11.75		
4	5.00	9	8.75	14	12.50		

The cost of vaccines and levies was not included in the initial pullet price. The number of replacement pullets vaccinated was based on assuming a 52-week laying period from 21 weeks of age, so 73 weeks of age at the end of lay. This will result in a slight overestimate of pullet numbers, assuming that more flocks continue in lay past 73 weeks than cease production prior to that age. From Table 2 the dollar-value per bird of reported incidents at certain age ranges was calculated as follows:

All age average	$ 8.00
8–16 weeks	$11.00
5–12 weeks	$ 8.38
4–16 weeks	$11.23
5–16 weeks	$11.85

Egg prices were calculated on the basis of the following assumptions, and calculations shown in Table 3.

Table 3 Assumptions used to calculate average egg prices

Egg prices	Average $/dozen	% of farm sales	% of cage	% of barn	% of FR
Ungraded cage	2.25	20	66.67	0.00	0.00
Ungraded barn	2.50	4	0.00	40.00	0.00
Ungraded free range	3.00	15	0.00	0.00	25.00
Graded cage	2.75	10	33.33	0.00	0.00
Graded barn	3.05	4	0.00	40.00	0.00
Graded free range	3.60	30	0.00	0.00	50.00
Cage-free high end retail	4.00	2	0.00	20.00	0.00
Free range high end restaurant & retail	5.60	15	0.00	0.00	25.00
Average Cage	2.42	30			
Average Barn	3.02	10			
Average Free range	3.95	60			
Average overall industry	3.40				

Assumptions regarding the impact of the reduction in growth rate in pullets to lifetime production were as follows:

- The negative impact would have a permanent impact on lifetime production on the number of birds stated to be affected per incident of a similar magnitude to the growth reduction. So for example, a stated 10% reduction in growth would lead to a 10% reduction in lifetime egg production for each individual bird affected.
- The average lifetime egg production as noted above was 311 eggs/hen.
- As we have no indication of which sector the affected pullets would be placed in, the average egg price of $2.95 per dozen was utilised.

Assumptions re vaccine use and pricing were as follows:

- Proportion of the industry vaccinating for a particular condition was based on the number of responses noted in Table 11 from the Phase 2 survey, except as noted under results for coccidiosis vaccines, for which a question was not included.
- It was assumed that all pullets are either vaccinated against coccidiosis or treated with coccidiostats.
- Vaccine prices were based on the use of the largest volume vials, which will underestimate the overall cost. Also cost to the customer passed on by vaccination crews or hatcheries will be higher than the average retail cost used for calculations here.
- Vaccine prices were averaged between companies where more than one company supplies, and by taking into consideration the standard use pattern.
- For ND, it was assumed that all birds in NSW and Victoria are vaccinated with killed vaccine and 20% of layer breed birds in other States are vaccinated with the killed vaccine. It was assumed that on average 1.5 doses of live vaccine were administered.
- There was no allowance made for the use of a combined killed ND/EDS vaccine, which would reduce overall cost.

- For IB, 7 vaccinations per bird lifetime was assumed based on the replies to Phase 2 of the survey.
- For ILT, it was assumed that 3.5 doses of vaccine were administered per bird.
- No inclusion for staff time, diluents or water treatments have been included.
- Since vaccination crew costs for those vaccines that require bird handling will be spread over more than one disease, they will be listed separately. No cost for hatchery handling has been included.

Statistics

For the majority of reporting, simple descriptive statistics were utilised. Where scores for feather cover or keel deviations were compared, non-parametric examination of the data was utilised including the Kruskal Wallis test and, for comparison of two groups, the Mann-Whitney test (GraphPad Prism 9 for Windows 64-bit Version 9.5.1 (733) January 2023).

3 Results

Initial responses to the emailed survey were limited, and several follow-up emails and phone calls were made to encourage replies. Sixty eight survey responses for particular production systems were received. Some respondents only reported the one production system, and others several. Twelve responses were received from New South Wales, 11 from Queensland, 9 from South Australia. 3 from Tasmania, 29 from Victoria, and 3 from Western Australia. The total shedding capacity of the different production systems covered by the survey responses is displayed in Table 4 below.

Table 4 Housing capacity of survey respondents

System	Housing capacity ('000)
Cage production	5,232
Barn production	1,994
Free range	6,338
Other	355
Total production	**13,919**
Cage rear	1,180
Barn rear	2,366
Other	260
Total rearing	**3,806**

Incidents of the most common 15 conditions reported in Australian hens over a five-year period are detailed in Table 5. Incidents of conditions reported in Australian hens over a one-year period are shown in Table 6. Details of incidents of diseases reported in Australian hens are shown in Table 7 (five years) and Table 8 (one year).

Table 5 Top 15 incidents reported in Australian hens for five years

Condition/disease	Cage	Barn	Free Range	Total
Predation/vermin	50	52	3,222	3,326
Smothering – passive	20	223	1,683	1,926
Smother nest box	8	90	1,084	1,182
Spotty Liver Disease	85	67	901	1,053
Fowl Cholera	16	196	538	750
Undefined URT disease	0	75	517	592
Nematodes	90	45	424	559
Keel deformity	40	190	262	492
Antibiotic responsive?	0	200	230	430
Smother fright/flight	10	88	323	423
Colibacillosis	32	197	187	416
Feed disrupt	35	88	241	364
Cestode (Tapeworm)	47	56	252	355
Mites	131	33	184	348
ILT	29	0	261	290

Table 6 Incidents reported in Australian hens for one year

Production system	Cage	Barn	Free range	Total
All smothers	19	112	735	866
Predation/vermin	15	2	658	675
Smothering – passive	10	65	301	376
Smothering – nest box	8	22	283	313
Spotty Liver Disease	16	12	202	230
Undefined upper respiratory disease	0	49	155	204
Nematode (Roundworms)	19	7	131	157
Fowl Cholera	4	36	101	141
Smothering – fright/flight	1	24	110	135
Feed disrupt	19	5	109	133
Keel deformity	0	46	59	105
Cestode (Tapeworm)	15	16	67	98
Antibiotic responsive conditions	1	40	52	93
Mites	31	5	53	89
Coccidiosis	0	36	36	72
Antibiotic use	0	0	62	62
Colibacillosis	45	12	3	60
Smothering – post transfer	0	1	41	42
Lice	0	0	41	41
EDS (Egg drop syndrome)	0	0	36	36
Hysteria	0	0	36	36
Cannibalism	5	8	14	27
Mycoplasmosis	2	7	17	26
Toxic plants/weeds	0	0	16	16
Fatty Liver	11	1	3	15
Gizzard Erosion	8	2	4	14
ILT (Infectious Laryngotracheitis)	4	0	10	14
Synovitis	0	5	5	10
Erysipelas	0	0	8	8
Infectious Coryza	0	0	8	8
IBV (Infectious Bronchitis)	0	2	5	7
Mycotoxicosis	2	2	1	5
Keratoconjunctivitis	0	0	4	4
Brachyspira	0	0	2	2
Gallibacterium	0	0	2	2
ORT (Ornithobacteriosis)	0	0	2	2
Big Liver and Spleen	0	0	1	1
Marek's Disease	0	1	0	1

Smothers and predation were reported as the most common incidents, with Spotty Liver Disease (SLD) being the most common disease over one and five years. Undefined upper respiratory disease was

more common in the recent one-year period whereas fowl cholera was the second most common disease over the five-year period. In addition to these three diseases, nematodes, keel deformity, antibiotic responsive conditions, cestodes, mites and colibacillosis made up the top 8 disease conditions, with the most incidents reported. Incidents of colibacillosis were the 7th most commonly reported over the five-year period but were not included in the top 8 most commonly reported in the one-year period. Incidents of mites were reported in the top 8 common conditions in the one-year period.

Table 7 Top 15 disease incidents reported in Australian layer hens over five years

Disease	Cage	Barn	Free Range	Total
Spotty Liver Disease	85	67	901	1,053
Fowl Cholera	16	196	538	750
Undefined URT disease	0	75	517	592
Nematode	90	45	424	559
Keel deformity	40	190	262	492
Antibiotic responsive	0	200	230	430
Colibacillosis	32	197	187	416
Cestode	47	56	252	355
Mites	131	33	184	348
ILT	29	0	261	290
Erysipelas	0	0	240	240
Lice	0	10	217	227
Necrotic Enteritis	10	0	150	160
Toxic plants/weeds	0	36	74	110
Fatty Liver	83	1	7	91

Table 8 Top 15 disease incidents reported in Australian layer hens over one year

Disease	Cage	Barn	Free Range	Total
Spotty Liver Disease	16	12	202	230
Undefined URT disease	0	49	155	204
Nematodes	19	7	131	157
Fowl Cholera	4	36	101	141
Keel deformity	0	46	59	105
Cestode (Tapeworm)	15	16	67	98
Antibiotic responsive	1	40	52	93
Mites	31	5	53	89
Coccidiosis	0	36	36	72
Colibacillosis	45	12	3	60
Lice	0	0	41	41
EDS	0	0	36	36
Mycoplasmosis	2	7	17	26
Toxic plants/weeds	0	0	16	16
Fatty Liver	11	1	3	15

Pullets

The number of incidents reported in pullets over one-year and five-year periods are shown in Table 9 and Table 10, respectively. Incidents of smothers were the most commonly reported in the one-year period, with coccidiosis the second most common, followed by ILT, colibacillosis and Necrotic Enteritis (NE). This was slightly different to the five-year report with coccidiosis, feed disruption, ILT, NE, and smothering being the conditions with the highest incidents over the 5 years surveyed. The total number of incidents reported for any condition was not high, with 52 incidents reported for passive smothering over one year, and 153 incidents of coccidiosis being reported over the five-year period.

Table 9 Top 15 incidents reported in Australian pullets over a one-year period

Condition/disease	Cage	Barn	Total
Smothering – passive	0	52	52
Coccidiosis	0	27	27
ILT	5	12	17
Colibacillosis	4	11	15
Necrotic Enteritis	0	12	12
Nematode (Roundworms)	0	12	12
Smothering – fright/flight	0	10	10
Hysteria	0	6	6
Feed disrupt	0	5	5
Aspergillosis	0	4	4
Cestode (Tapeworm)	0	3	3
IBV (Infectious Bronchitis)	0	2	2
Cannibalism	0	0	0
Predation/vermin	0	0	0
Gizzard Erosion	0	0	0

NB Incidents of diseases in the organic sector have been removed from the table.

Table 10 Top 15 incidents reported in Australian pullets over five years

Condition/disease	Cage	Barn	Total
Coccidiosis	12	141	153
Feed disrupt	3	78	81
ILT	20	35	55
Necrotic Enteritis	5	40	45
Smothering – fright/flight	0	20	20
Colibacillosis	15	4	19
Keel deformity	0	18	18
Hysteria	0	17	17
Nematode	0	10	10
Mites	6	4	10
Synovitis	0	10	10
Predation/vermin	5	0	5
Aspergillosis	0	4	4
Cannibalism	0	0	0

NB Incidents of diseases in the organic sector have been removed from the table.

Vaccination, diagnostics, veterinary input and prophylaxis

Table 11 and Table 12 list the number of respondents who completed the treatment page of the survey and the number who regularly use vaccines or other veterinary, treatment and nutritional inputs. The majority of respondents vaccinate for IB, Marek's Disease, ND, ILT, *Mycoplasma gallisepticum*, EDS, Fowl Pox, Avian Encephalomyelitis, and utilise a live *Salmonella* Typhimurium vaccine. Half of the respondents utilise a Fowl Cholera vaccine and half vaccinate their birds for *Mycoplasma synoviae*.

The majority of respondents undertake *Salmonella* testing at least once a year, beak trim their birds, use anthelmintics and undertake serology to assess the effectiveness of vaccination. Half of the free range respondents had used in-water antibiotics.

Table 11 Vaccine utilisation in the Australian egg industry

Treatment	Cage	Barn	Free range	Total
Infectious Bronchitis vaccine	8	7	15	30
Marek's Disease vaccine	7	6	12	25
Newcastle Disease vaccine (live)	7	6	12	25
Newcastle Disease vaccine (killed)	7	6	10	23
Fowl Cholera vaccine	3	4	11	18
Infectious Laryngotracheitis vaccine	7	6	11	24
Mycoplasma (MG – ts-11) vaccine	6	5	8	19
Mycoplasma (MS – MS-H)	5	5	8	18
Egg Drop Syndrome (EDS) vaccine	7	6	12	25
Fowl Pox vaccine	7	7	10	24
Avian Encephalomyelitis vaccine	7	6	11	24
Salmonella vaccine (ST – live)	5	5	9	19
E.coli	3	2	4	9
ORT	1	2	2	5
Coryza	1	1	2	4
Number of survey replies for this section	10	8	18	36

Table 12 Veterinary input, diagnostics, prophylaxis and treatments in the Australian layer industry

Shed/production type treatment	Cage	Barn	Free range	Total
Beak trim	8	6	12	26
Anthelmintic	8	7	16	31
Electrolytes or multivitamins (water)	3	2	5	10
Probiotics	1	1	1	3
Organic acids and phytobiotics	1	1	1	3
Antibiotics used in water	1	3	9	13
Antibiotics used in feed	0	2	4	6
Veterinary visits to farm	4	3	8	15
Salmonella testing (drag swabs, etc.)	10	5	10	25
Blood taken for serology	8	6	7	21
Number of survey replies for this section	10	8	18	36

Online discussion

The online industry veterinary and technical staff meeting (EggNet) to discuss phase one results and give input into the second phase survey was undertaken on the 4th of November 2022. Participants noted concerns about several conditions that did not appear important in the survey results, which covered the 2021 year. These included presentation of birds with hepatomegaly and splenomegaly from which *E.coli*, *E. rhusiopathiae* or *P. multocida* were often isolated. An increase in the amount of feather pecking and subsequent cannibalism was reported in flocks from the late 30s to early 40 weeks of age, as was an increase in the incidence of fowl cholera, including in vaccinated birds. Erysipelas was also noted as an ongoing issue, and it is possible that there was underreporting due to the efficacy of vaccination programs on affected farms limiting new outbreaks. These concerns were taken into consideration in the design of the Phase 2 survey.

Responses for the second phase of the survey were received from veterinary and technical staff of 12 different enterprises, consisting of nine predominantly free range, two cage and one barn with a total housing capacity of 9.1 million hens and rearing capacity of 2.6 million pullets. As with phase one of the survey, responses were slow to arrive with the last response received in May 2023. The data supplied by the respondents was used along with the assumptions noted in the materials and methods section to calculate some of the economic losses associated with the conditions. Only sparse data was received for barn flocks in the Phase 2 survey, so further assumptions were required to utilise the incidents data from Phase 1. The costs of treatment or prevention are not included. and no estimation is made of the impact in the reduction of conditions due to prophylactic measures in the following costings.

The economic losses are reported below in Table 13 and Table 14.

Table 13 Some economic losses from conditions in the Australian layer flock ($'000)

Condition	Mortality	Egg loss	Combined loss
Smothers (all)	144	1,731	1,955
Predation/vermin	63	825	928
Spotty Liver Disease	1,033	11,510	14,272
Undefined URT disease	836	9,521	10,660
Internal parasites	0	746	746
Fowl Cholera	1,133	10,605	11,460
Pecking/cannibalism	6	77	86
Antibiotic responsive conditions	47	1,594	1,657
Erysipelas	65	843	950

The most costly condition reported in the Australian layer flock (Table 13) was SLD, followed by Fowl Cholera and Undefined upper respiratory tract disease (UURTD). Smothers from all causes was the next most costly condition followed by antibiotic responsive conditions of unknown causes. This was similar in free range systems (Table 14) with a change in order between FC and UURTD.

Table 14 Some economic losses associated with conditions in free range laying hens ('000)

Condition	Number affected	Number dead	Ave eggs lost	Mortality $	Egg loss $	Combined $ loss
Smothers	31.4	31.4	4,901	124	1,613	1,817
Predation/vermin	15.9	15.9	2,497	63	822	925
Spotty Liver Disease	2,733.5	172.1	32,587	680	10,726	13,136
Undefined URT disease	627.4	119.0	21,386	470	7,040	7,813
Internal parasites	3,339.9	0.0	2,241	0	738	738
Fowl Cholera	461.5	231.0	21,526	912	7,086	7,721
Pecking/cannibalism	48.0	1.3	211	5	70	78
Antibiotic responsive	360.7	6.5	3,603	26	1,186	1,229
Erysipelas	23.0	16.5	2,562	65	843	950

Table 15 and Table 16 only include the calculations for losses associated with mortality and decreased egg production. Impact on ongoing liveability for remaining hens and egg quality have not been estimated. There were limited survey responses to the questions on egg quality, and it is difficult in practice to assess the ongoing impact of incidents over time with respect to liveability.

Table 15 Some economic losses associated with conditions in caged laying hens ('000)

Condition	Number affected	Number dead	Eggs lost	Mortality $	Egg loss $	Combined $ loss
Smothers	0.05	0.05	7.41	0.3	1.5	1.8
Predation/vermin	0.04	0.04	5.85	0.2	1.2	1.4
Spotty Liver Disease	0.00	0.00	0.00	0.0	0.0	0.0
Undefined URTD	275.04	13.02	2,977.07	84.6	600.4	685.0
Internal parasites	22.62	0.00	1.08	0.0	0.2	0.2
Fowl Cholera	2.02	0.02	2.11	0.1	0.4	0.5
Pecking/cannibalism	1.01	0.02	3.21	0.1	0.6	0.8
Antibiotic responsive	0.48	0.38	58.91	2.4	11.9	14.3
Erysipelas	0.00	0.00	0.00	0.0	0.0	0.0

In cage systems, the condition leading to the greatest financial loss through egg loss and mortality was UURTD (Table 15). In barn systems (Table 16) the leading cost from conditions was due to Fowl Cholera, followed by UURTD and then SLD.

Table 16 Some economic losses associated with conditions in barn laying hens ('000)

Condition	No affected	No dead	Eggs lost	Mortality $	Egg loss $	Combined $
Smothers	2.98	2.98	462.65	19.34	116.4	135.8
Predation/vermin	0.02	0.02	5.85	0.10	1.5	1.6
Spotty Liver Disease	51.41	25.18	1,727.58	352.56	432.8	787.3
Undefined URTD	208.27	43.27	7,474.55	281.24	1,881.1	2,162.3
Internal parasites	24.44	0.00	30.37	0.00	7.6	7.6
Fowl Cholera	149.40	80.10	13,981.03	220.28	3,518.6	3,738.8
Pecking/cannibalism	0.17	0.17	26.44	1.11	6.7	7.8
Antibiotic responsive	157.50	2.86	1,573.22	18.57	395.9	414.5
Erysipelas	0.00	0.00	0.00	0.00	0.0	0.0

Impact on egg quality

Some respondents noted the following impacts of diseases on the proportion of A grade eggs: Undefined URT disease – up to 15% reduction; Fowl Cholera, antibiotic responsive conditions and Erysipelas – up to a 25% reduction; and for pecking and cannibalism one respondent estimated that all eggs could be downgraded in severe cases. Given the limited responses it was decided not to attempt to model the economics of the impact of downgraded egg quality. However, the losses reported in egg quality would add considerably to the impact of the conditions noted by those respondents. The pulping egg price at the time of writing (June 2023) averaged $1.50 per kilogram (P. Scott pers. comm.). For 60 g eggs, this is equivalent to $1.08 per dozen compared to the average industry price of $3.40 (see Table 3).

Pullets

Data on the number of incidents of conditions in pullets is displayed in Table 17 and using the assumptions listed in the materials and methods section the estimated economic impacts of the conditions are shown in Table 18.

Table 17 Details regarding incidents of various pullet conditions

Condition	Average placed/ shed	Age at time of incident (weeks)	No. of birds affected per incident	No. of birds dead per incident	Negative impact on growth
Smothers (all)	30,000	All	22.5	22.5	0
Coccidiosis	30,000	5 to 12	3,750	1,500	0.2
Infectious Laryngotracheitis (ILT)	30,000	4 to 16	15,000	3,000	0.2
Colibacillosis (*E. coli*)	30,000	All	15,000	3750	0.2
Necrotic enteritis	30,000	5 to 16	3,750	2,250	0.2
Worms (nematodes & cestodes)	30,000	4 to 16	7,500	Nil	0.1

Table 18 Some economic impacts of pullet disease and behaviour

Condition	$ value at time	Total affected	Total dead	Value of mortality ($'000)	Potential eggs lost ($'000)	Total loss ($'000)
Smothers (all)	8.00	4,366	4,366	35	0	35
Coccidiosis	8.38	225,808	90,323	757	3,453	4,209
Infectious Laryngotracheitis (ILT)	11.23	568,702	113,740	1,277	8,695	9,972
Colibacillosis (*E. coli*)	8.00	501,795	125,449	1,004	7,673	8,676
Necrotic enteritis	11.85	100,359	60,215	714	1,535	2,248
Worms (nematodes & cestodes)	11.23	267,624	0	0	2,047	2,047

The two most costly conditions affecting pullets in the Australian flock (Table 18) were ILT and colibacillosis followed by coccidiosis. NE and nematodes and cestodes also give rise to significant costs. Once again, these calculations do not take into account the impact of preventative measures or the cost of those measures.

General comments from the Phase 2 survey

This section simply records the comments of veterinarians in this general section of the survey.

Impact on uniformity was noted by some respondents. These included for coccidiosis, ILT and NE, a loss of up to 50% uniformity, for colibacillosis and nematodes and cestodes a loss of up to 15%. Due to the limited nature of the data, no economic modelling was undertaken to estimate the economic impact of the changes in uniformity.

General comments on the results of Phase 1 and any potential related initiating factors, or mitigating factors and any other observations were received from respondents and are listed below.

Mycoplasma: While MG is very uncommon in commercial layer poultry, the incidence of MS field strains that are not vaccine related is increasing.

Erysipelas: The introduction of the off label sheep and pig inactivated vaccine has essentially a 100% outcome in mitigating the clinical disease, and in general the removal of the vaccine can occur after 3 years.

Coccidiosis: The introduction by many in the industry of coccidial vaccination has reduced the incidence of clinical coccidiosis (P. Scott pers. comm.).

Fowl Cholera: The incidence continues to increase and control methods can have mixed outcomes, with many questions about the most effective control methods to be resolved both about those sites where control has remained difficult and also the duration of immunity. The loss of some key government and technical support personnel is a concern.

Undefined URT disease requires further investigation.

Husbandry: The recognition of the importance of husbandry and facilitation is declining as a new generation of corporate managers with no poultry production background or training oversee poultry companies. This, coupled with the retirement of experienced farm managers and technical advisors,

and the shortage of skilled and semi-skilled workers, have led to a decrease in the number of staff familiar with the importance of husbandry. The fundamentals around air quality and other stressors are still inadequately handled and appreciated within the industry.

Salmonella: ST Phage 9 and SE can cause clinical signs with peritonitis, etc. (P. Scott pers. comm.).

Spotty Liver Disease: Can be asymptomatic.

IBV: Actually validated clinical impacts of IBV are minimal.

EDS: Still occurs sporadically in unvaccinated or inefficiently vaccinated flocks.

Fowl Pox: Still occurs sporadically at low levels and in vaccinated birds so that there are questions regarding the efficacy of vaccination or if the field strain is not protected by commercial vaccines.

Enteric Protozoa and Brachyspira: Significance uncertain but expect at least some impact on the heath of the microbiome.

Ectoparasites: Emerging issue and poor industry understanding regarding control, and also some limitations in the available treatments and control agents.

BLS: Some reports in South Australia, but does not appear to be an industry problem.

Farm visits

Two free range farm visits to examine older HY-Line hens were undertaken to evaluate the reliability of data supplied during the survey period. The time between the receipt of the last stage two survey and the contracted end of the project limited the number of farm visits that were possible. Three separate sheds were examined. The results of the visits are summarised in Table 19 and Table 20 below. The feather scoring and keel scoring standards are listed in the materials and methods. In short, feather scoring on the hens at various sites was undertaken using a scale from 0 (feathers all intact or vent with no scratches) to 5 (completely or almost completely denuded of feathers). The vent score 4 was for hens with a wound of more than 2 cm length. For keel scoring, a score of 4 indicated a normal keel, and 1 a severely deformed keel bone.

Feather scores are displayed in Table 19 and keel scores in Table 20. Significant differences between the two farms were seen for feathers scores for the lower back, tail, and neck, but not for vent scores. Feather scores from the two houses on the one farm were not different.

Table 19 Feather scores of free range birds 53 (ID1 & ID2) and 55 (ID4) weeks of age

	Lower back score			Tail butt score			Vent score			Neck score		
	(ID1)	(ID2)	(ID4)	(ID1)	(ID2)	(ID4)	(ID1)	(ID2)	(ID4)	(ID1)	(ID2)	(ID4)
	0	1	3	0	1	2	0	0	0	0	1	1
	0	0	3	0	0	3	1	1	0	3	2	3
	0	0	1	0	1	1	1	0	0	0	0	3
	3	0	2	2	0	2	0	0	1	3	0	2
	1	0	3	0	0	4	0	0	0	0	0	2
	1	1	3	1	1	3	0	0	0	0	1	2
	1	2	1	1	0	4	0	0	0	3	0	2
	1	1	3	0	0	3	0	0	0	1	1	1
	1	2	1	1	0	2	0	0	0	0	0	2
	0	0	3	1	0	2	0	0	0	0	0	3
	1	0	1	0	0	2	0	0	0	1	0	1
	1	1	1	1	0	1	1	1	0	1	1	0
	1	1	1	0	0	2	0	1	0	0	0	1
	2	0	3	2	1	3	0	0	1	0	0	1
	1	0	1	0	0	2	0	0	2	0	0	2
	1	1	1	0	0	1	0	1	0	0	2	0
	0	0	1	0	1	0	0	3	2	0	0	2
	1	2	1	0	0	1	0	0	0	0	1	0
	0	0	3	0	1	2	0	1	0	0	0	2
	0	1	1	0	0	2	1	0	1	0	0	1
	1	1	2	1	1	3	0	0	0	0	2	1
	0	1	2	1	0	1	0	0	1	0	1	2
	1	0	1	0	0	3	0	0	0	0	0	2
	1	3	3	0	0	2	0	0	0	1	0	3
	1	0	1	0	1	1	0	0	0	0	0	2
Median*	1^a	1^a	1^b	0^a	0^a	2^b	0	0	0	0^a	0^a	2^b
Average	0.8	0.72	1.84	0.44	0.32	2.08	0.16	0.32	0.32	0.52	0.5	1.64

* Median used for non-parametric data.
Different superscripts within the one shaded or non-shaded indicate significant differences between groups $P < 0.001$.

There were no significant differences found between sheds for keel scores (Table 20). There were 7 scores of 1 and 17 scores of 2 from the 225 birds examined (10.6%) (Table 20). Scores of 1 and 2 indicate more severe keel deviations/damage.

Table 20 Keel scores of free range birds 53 (ID1 & ID2) and 55 (ID4) weeks of age

	Keel score								
	(ID1)	(ID1)	(ID1)	(ID1)	(ID2)	(ID2)	(ID2)	(ID2)	(ID4)#
	3	4	4	3	4	4	4	4	2
	4	3	3	4	3	3	4	4	4
	3	4	3	3	4	2	4	4	4
	3	4	4	3	4	4	3	4	4
	4	4	4	4	4	4	4	4	4
	4	4	3	2	4	3	3	4	4
	3	3	2	4	4	4	4	3	4
	4	4	3	1	4	3	3	4	4
	4	4	2	3	1	3	3	4	2
	4	4	3	4	3	4	4	3	3
	4	4	4	2	3	4	4	3	1
	4	4	3	2	4	4	3	4	2
	4	3	4	3	3	3	4	4	4
	3	4	4	1	3	3	4	4	4
	1	3	3	3	4	4	4	4	4
	4	2	3	2	4	4	3	4	4
	3	2	4	3	4	2	4	3	4
	4	4	3	4	4	4	3	3	4
	3	4	3	4	4	4	4	4	2
	2	4	4	4	4	3	3	4	1
	1	4	4	4	3	4	4	3	4
	4	3	4	4	4	4	4	4	4
	3	4	4	4	3	4	3	2	4
	4	4	4	4	3	3	4	4	4
	2	4	3	4	4	4	4	3	4
Median*		4				4			4
Average		3.28				3.56			3.40

* Median used for non-parametric data.

\# Only 25 hens were examined in house ID4.
There were no significant differences between groups.

Farm visit production figures

The three free range houses examined all experienced outbreaks of SLD. The hen day % for two of these sheds was considerably below standard for at least 10 weeks post-infection, with a reduction of 23% and 25% for houses ID1 and ID2 respectively and the hen day % for house ID4 was reduced by 5% compared to the management guide. (midrange stated; 25 weeks – 95.2 %, 35 weeks – 95.1%, 45 weeks – 92.7%, 55 weeks – 90.2%) (1623667568-hlb_alternative_guide_2021_uk_updated_6-3-21.pdf (hyline.co.uk))

The cumulative mortality was above standard, with levels increasing from 6.2% at 25 weeks to 14.9% at 53 weeks in house ID1, and in house ID2 3.87–13.65%. Cumulative mortality in house ID4 increased from 0.3% at 25 weeks to 6.87% at 55 weeks. The management guide lists expected mortality rates of 0.46% by 25 weeks,– 0.97% by 35 weeks, 1.52% by 45 weeks, and 2.16% by 55 weeks. Smothers related

mortality varied between houses with 1.9% recorded for house ID1 at 53 weeks and 0.3% recorded for house ID2 at 53 weeks. No smothering related mortalities were reported for house ID3.

Autopsy findings

Autopsies of birds on the visited farms were conducted by experienced poultry veterinarians and the findings are shown in Table 22. Birds that would normally be selected for culling were examined, including birds which were no longer in lay. Birds which appeared healthy were not selected so that the findings do not reflect the health status of the whole flock. The most common findings include caecal worms, egg peritonitis, ovarian regression or non-functioning. Splenomegaly was noted in 7 birds ex 30 and round worms were noted in 10 hens.

Table 21 Summary production figures obtained from three commercial hen houses

		ID1				ID2				ID4			
Parameter	**Week:**	**25**	**35**	**45**	**53**	**25**	**35**	**45**	**53**	**25**	**35**	**45**	**55**
Hen day %		80	69	69	77	78	67	68	75	89	86	82.8	81
% floor eggs		20	23	18	17	12	15	19	17				
Cumulative mortality		6.2	9.2	11.05	14.96	3.87	6.54	10.2	13.65	0.3	3.54	4.82	6.87
Smothers related mortality		1.35	1.83	1.9	2.11	0.27	0.35	0.36	0.49				
Antibiotic use		Yes	Yes	Yes						Yes			
Disease		SLD				SLD				SLD			
Related decrease in hen day %		23				25				5			
Related mortality/week		1% per week for 7 weeks				0.5% per week for 7 weeks				>0.1% for 5 weeks			

Table 22 Autopsy findings – hens from three commercial hen houses

Hepato-megaly	Spleno-megaly	Round-worms (0 to +++)	Tape-worms (0 to +++)	Significant findings
				ID1
-	+	0	0	Caecal worms, dilated mid-jejunum
-	+	0	0	Slight deviation of keel bone, egg peritonitis, caecal worms
-	-	+	0	No abdominal fat, caecal worms
-	-	+	0	Pecked out vent, white spots on liver, egg peritonitis
-	-	0	0	Black discoloured ovarian follicles, caecal worms
-	-	+++	0	Moderate keel bone deviation, caecal worms
-	+	0	0	Egg peritonitis
-	-	0	0	Severe egg peritonitis
-	-	+	0	Caecal worms, ovary regression
-	-	0	0	NSF, ovary regression
General findings of caecal worms (6/10) & ovarian regression, slight keel bone deviation in some & egg peritonitis				
				ID2
-	-	0	0	Non-functioning ovary, caecal worms
-	-	+++	0	Caecal worms, dilated mid jejunum
-	-	0	0	No abdominal fat
-	-	+	0	Dilation of mid jejunum, slight keel bone deviation, no abdominal fat, caecal worms
-	-	0	0	Moderate deviation of keel bone, egg peritonitis
-	+	++	0	Egg peritonitis, pericarditis, caecal worms
-	-	0	0	Slight deviation of keel bone
-	-	0	0	Perihepatitis, egg peritonitis
-	-	0	0	No abdominal fat
-	-	0	0	Caecal worms, no abdominal fat
General findings, egg peritonitis, serous atrophy, lack of abdominal fat, caecal worms & some roundworms				
				ID4
-	+	+++	0	Internal layer
-	-	0	0	
-	-	0	0	
-	-	0	0	
-	+	0	0	Egg peritonitis
-	-	0	0	
-	+	0	0	Intestinal dilation syndrome, non-layer
-	-	++	0	
-	-	0	0	Intestinal dilation syndrome, non-layer
-	-	+++	0	Egg peritonitis

Treatment and prevention costs

Note this report does not cover the cost of disease control in breeders.

Costs of the use of common vaccines are listed in Table 23. The proportion of the national flock vaccinated is based on the assumptions listed in the materials and methods and on the proportion of respondents to the Phase 2 survey who indicated that they use vaccine. In the case of the proportion of coccidiosis vaccine used and anticoccidials used in feed, the estimation comes from industry discussions, approximating the use of coccidial vaccines in hatcheries at approximately 4 million pullets, with up to a further 1 million vaccinated on farm.

Table 23 Estimations of the cost to industry of vaccines for some diseases

Vaccine	% of Industry	Per bird cost	Industry $
Infectious Bronchitis vaccine	0.83	0.05	849,771
Marek's Disease vaccine	0.69	0.05	686,251
Newcastle Disease vaccine (live)	0.69	0.17	2,449,625
Infectious Laryngotracheitis vaccine	0.67	0.35	4,945,245
Mycoplasma (MG – ts-11) vaccine	0.53	0.12	1,386,627
Mycoplasma (MS – MS-H)	0.50	0.12	1,313,647
Egg Drop Syndrome (EDS) vaccine	0.69	0.25	3,693,896
Fowl Pox vaccine	0.67	0.05	730,663
Avian Encephalomyelitis vaccine	0.67	0.12	1,692,666
Salmonella vaccine (ST – live)	0.53	0.02	268,379
E.coli	0.25	0.04	236,456
Pasteurella multocida (Fowl cholera)	0.50	0.32	3,390,057
Ornithobacterium rhinotracheale	0.14	0.32	941,682
Coryza	0.11	0.32	753,346

The cost of vaccination with respect to vaccination crews is in addition to the above costs, and is calculated on the bases of the average number of times pullets are vaccinated using a vaccination crew. This does not include the use of farm staff undertaking water-based vaccinations.

Enquiries made of vaccination crew providers disclosed a pick-up cost per bird of just under 30 cents and an additional cost for each vaccine used of 7–8 cents per bird. Utilising the Phase 2 survey results to give a total number of birds vaccinated, and allowing for those that are given once or require two doses, the estimated cost of bird handling for on-farm vaccinations to the industry is approximately $16,350,000. As more than one vaccine is usually delivered at each pick-up there is no attempt to allocate the pick-up costs to the individual disease. However, it should be noted that those vaccines requiring two pick-ups such as cholera, *E. coli*, ORT, coryza and erysipelas may increase the number of pick-ups required from one to two, and thus would add at least $0.36 per bird to the disease control cost. Off-label use of Erysipelas vaccine has not been included in Table 23 and has a current cost for the vaccine itself of approximately $0.355. If no other bird handling vaccines were being used on a production site that needed to introduce Erysipelas vaccination, the cost per bird would be 2 x 0.355 + 2 x 0.285 + 2 x 0.075 = $1.43 per bird.

Coccidiosis

As coccidiosis prophylaxis can be achieved by either vaccination or in-feed anticoccidials this is addressed separately.

It is assumed from discussions with breeding companies that approximately 4M pullets a year are vaccinated in hatcheries and up to another 0.5M are vaccinated on-farm and, as noted in the materials and methods, that all other pullets are treated with an anticoccidial up to around 11 weeks of age. Coccidiostat prices range from $4–8 per tonne, the cumulative intake to 11 weeks is approximately 3.02 kg/pullet (Hy-Line Brown Alternative Systems Management Guide mid-range) (1623667568-hlb_alternative_guide_2021_uk_updated_6-3-21.pdf (hyline.co.uk)). Using $6/Metric ton this equates to a cost per pullet of $0.006 x 3.02 = 1.8 cents per pullet. Ignoring issues of availability and comparative market share of coccidial vaccines, the 'average' price for coccidial vaccines is approximately $0.155/dose. So total expenditure on coccidial vaccines is approximately $700,000 and for coccidiostats approximately $381,000, a total of $1,081,000 for coccidiosis prevention. This does not take into account the cost of treatment of outbreaks.

Feed additives

As the majority of feed additives have the potential to mitigate several conditions, there is no attempt made to allocate the use of feed additives for particular diseases except for SLD and *Salmonella*. In general the cost of phytobiotics, probiotics, short chain fatty acids (SCFA) cost between $3.50 and $6.00/MT. Many pullet flocks will be treated with a combination of at least two such products up until around 17 weeks and so will have consumed approximately 6.1kg of feed, which would lead to a cost of approximately 2.9 cents per additive per bird (P. Scott pers. comm.). Making an assumption that all pullets are treated, this would equate to an industry rearing cost of $1,228,000.

With respect to general health use of additives in layers, the same costing would apply with two additives being used for approximately 55 weeks of lay, assuming an average 120 g/bird daily intake. Each bird will consume 46.2 kg at an average cost per additive of $0.00475/kg or close to 22 cents/bird. This would equate to a total industry cost of $9,300,000.

SLD control additives will incur a cost of approximately $0.0012 per bird per day (P. Scott pers. comm.). Only cage-free production systems need to use preventative measures for SLD and the overall industry price of additive inclusion to reduce the impacts of SLD, assuming all free range and barn birds are treated for 25 weeks, would be $2,937,000.

Salmonella reduction by the use of feed additives will cost approximately $ 0.0005 per bird per day (P. Scott pers. comm.). If all birds were treated for 55 weeks the cost to industry would be $4,078,500.

Literature review

In order to fulfil the last request of AE for this project (to compare the Australian data with similar data from the UK and the Netherlands), a literature search was made on Web of Science & Scopus including and excluding the terms:

- review
- survey
- benchmark
- disease
- layer
- egg
- poultry
- epidemiology

- mortality
- prevalence
- United Kingdom
- Netherlands

No similar benchmarking survey was found in the UK or the Netherlands, with only a few papers being relevant, which will be compared and contrasted in the discussion section. The majority of papers with relevance to this study only examined a limited number of conditions or a single disease.

4 Discussion

A study comparing the response rate for farm surveys undertaken by email or post (Zahl-Thanem et al. 2021) showed a much greater response rate when the same survey was posted to 3,000 farmers than for the same survey emailed to 3,000 farmers (41.1% and 21.4% respectively). However, there was little difference in the overall non-response bias or in results of the survey from either method. To increase the response rate in this survey we undertook follow-up phone calls and, given that the number of hens potentially housed by the respondents represented more than half the industry, it can be concluded that a sufficient sample size was reached. Both small and large producers responded, as well as producers from all main egg producing States. As can be seen in Table 1, a larger proportion of the Australian cage and barn sectors were represented in replies, however, a sufficient proportion of each of the major sectors of the industry was represented and the relative proportions were allowed for in estimating total incidents.

Responses varied in detail, particularly with the barn results for Phase 2 of the survey. Responses from Victoria were over-represented when compared to the proportion of the industry based in that State, however, there were enough responses from the other States to ensure that State bias in results could be recognised if present. There was a very limited response from caravan and organic producers, so the results may be quite skewed by the individual reporting rigour and the small number of respondents. It was decided not to publish data on this sector to ensure confidentiality.

The results of Phase 1 of the survey reflect the number of incidents reported by respondents. It appeared that a large portion of respondents simply multiplied the one-year data by five to give the five-year total. As a result, the main focus of discussion will be centred on the one-year results. Some slight changes in the rank of diseases and conditions between the five-year and one-year period were noted.

For overall production systems in this study, smothers was the most reported incident followed by reports of predation/vermin. Smothers accounted for 22% of all incidents in the free range system and 25% of incidents in barn systems, with 8.8% incidence reported for caged birds.

A German study evaluating 'welfare parameters' of laying hens in Bavaria (Louton et al. 2017), noted mortalities due to smothering of 9.7% and due to predation of 11%, however, salpingitis was listed as more commonly reported at 14.9% of farms. They also reported that bacterial and parasitological illness were responsible for 9.7% of mortalities. In this Australian survey, predation was primarily observed in free range systems, and smothering in free range and barn systems, which is simply a function of the type of housing where predators are generally kept out of sheds. Stadig et al. (2015; 2016), reporting a workshop discussion by farmers, also noted a higher incidence of smothering in non-cage systems although Louton et al. (2017) did not. Also, in contrast to the findings of this Australian survey, Louton et al. (2017) reported a lower number of incidents of smothering, with 29.4% of farmers reporting mortality due to smothering "several times", 22.7% reporting smothering only once, and 46% stated that it did not occur in their flock.

Predation/vermin was the next most reported incident. Given the wish to decrease the effort required to fill in the survey, to try and increase the participation rate these two factors were included in the one question so it is not possible to distinguish which was being referenced. This grouping accounted for 19.7% of all incidents in free range systems and 7% in cage systems, and only accounted for 0.5% of reported incidents in barns. It might be assumed that the majority of the incidents reported in barns were with respect to vermin. Hegelund et al. (2006) reported the loss to predation in free range organic farms was 6.4% (range 0–14.2%), which was less than 11% reported by Louton et al. (2017).

More incidents of Spotty Liver Disease (SLD) were reported than any other disease. The majority of SLD incidents were reported in free range systems. SLD represented 27% of incidents in free range systems and 11.6% of the barn system incidents. SLD was not noted in the top 10 cage-free layer diseases in the AVEP survey of layers in the USA in 2018 (Gingerich 2019) but a section of the report included a discussion of the disease mostly seen in "pastured layers" in Missouri and Arkansas during hot humid weather.

Undefined Upper Respiratory Tract Disease (UURTD), nematode infestation and Fowl Cholera (FC), the next most commonly occurring incidents. Gingerich (2019) noted that nematode infection as the 7th most common disease in cage-free layers, and IB as the most significant disease in caged layers and the 5th most significant in cage-free layers. They did not list FC in the top 10. However, Hegelund et al. (2006) reported FC as a significant cause of mortality in their survey of free range organic farms in Denmark. Farooq et al. (2002) did not include FC or nematodes in their list of the most common causes of mortality in laying hens in the Chakwal district of Pakistan. They did, however, list chronic respiratory disease, IB, and coryza in the top three causes of mortality in their survey. Fossum et al. (2009), saw a significantly higher occurrence of bacterial and parasitic diseases in hens kept in litter-based housing systems and free range systems than in hens kept in cages. Gingerich (2019) reported that Fowl Cholera continued to be a problem with high mortality rates of 2–5% per day in the USA flock. Of interest he noted that vaccination in the face of an outbreak had a positive impact on disease progression.

Keel deformity comprised 10% of incidents in barn flocks and 2% of free range flocks. The LayWel project notes that for most free range systems no data was recorded for damage to keel bones, although they state later that recent evidence suggests that keel bone fractures are sustained by a high proportion of birds in all systems (although they only included enriched cages). Cannibalism was not recorded as very common in this survey at just under 0.7% of all incidents reported. However Fossum et al. (2009) observed mortality due to cannibalism in 18.6% of litter based systems and in 26.1% of free range systems, and in only 5% of cage systems in Sweden. British producers stated that vent pecking was the cause of 1.3% of their total mortality (Pötzsch et al. 2001), and Louton et al. (2017) reported 7.8% of mortality as a result of vent pecking in their survey.

Smothering was the most common incident reported in pullets followed by coccidiosis, ILT, colibacillosis and nematode infection. There were no reports of incidents of smothering or coccidiosis in cage reared pullets. The AVEP survey reported IB as the most common cause of mortality in cage reared pullets, followed by coccidiosis and ILT and in cage-free pullets; coccidiosis was the most common cause of mortality followed by smothering, IB and post SE bacterin hepatitis (Gingerich 2019).

Mites were not reported as commonly in this survey as in other reports. Mite infestation only represented 2.2% of all incidents reported in a one-year period whereas a survey of caged poultry in China found that 91.3% of respondents found ectoparasites in their hens. Louton et al. (2017) reported that 66% of farms surveyed reported issues with red mites (*Dermanyssus gallinae)*; Heerkens et al. (2015) also reported a contamination rate of 93%. Sherwin et al. (2010) found higher rates of mite infestation in conventional cages than free range. In this survey the number of incidents of mite infestation in cages represented 14.4% of all incidents reported in cage farms, whereas for barns the proportion was 1.1%, and in free range farms the number of incidents of mite infestation reported was 1.6%. Whether these figures represent a gross underestimate of reality cannot be determined, although the farm visits with examination of feather scores and keel scoring did not note any mite activity.

The economic losses here do not represent the whole cost of diseases and conditions surveyed. However, utilising the same underlying assumptions and the input from the survey participants allows

for a logical ranking of the economic importance of each condition, which should be relatively robust. SLD was the most expensive disease in terms of egg production lost and mortality, with the cost of feed additives aimed at prevention at approximately $17.2M. This is followed by FC, with disease and vaccination related costs of $15.3M, and ILT with a combined cost of $14.8M. UURTD has a cost of at least $10.7M, and general respiratory vaccination costs could potentially be added to that.

It could be argued that the low reported incidence, and thus cost, of many of the viral diseases for which vaccines are used indicates successful disease control with little other underlying costs to the industry. However, the costs of biosecurity, water treatment, and serological and bacteriological monitoring have not been taken into consideration here. Also any negative impact of vaccines or preventive products on production have not been noted. The cost for coccidiosis and its control (but not treatment) is listed at $5.3M but it is possible that preventive products also have some negative impact on performance, and this has not been included in the costing.

The issue of hepatomegaly and splenomegaly of unknown cause, which was raised in the on-line forum, was not confirmed by the Phase 2 survey or by the farm visits undertaken. Nor was there any evidence of increased feather pecking and subsequent cannibalism noted by respondents. On the farm visits, feather scores were generally acceptable. Keel scores were also not indicative of serious problems but the farm visit sample was very small. The impact of SLD on one of the farms was in the extreme range for this disease with 23–25% reduction in egg production and excessive mortality for 7 weeks.

As the second phase survey did not seek to obtain information on all conditions but just the ones of major concern agreed by the on-line forum, it is not possible to calculate an overall mortality rate for the industry. However, for the significant conditions covered, the number of reported mortalities in hens was 2.8%. Similarly for pullets the mortality rate relating to reports on just the major conditions will result in an underestimate. The average mortality rate found in the survey was 2%. In the survey reported by Louton et al. (2017), mortality during lay varied from 0.8% to 30% with a mean of 7.6%. In most of the flocks in that survey (82.2%), mortality did not exceed 10%. Weeks et al. (2012) observed mortality rates of 5.4% in caged hens and 9.5% in hens with access to free range. Likewise, Mathews & Summers (2014) surveyed egg production systems in the USA and reported that hen mortality (and other health issues) were higher in aviary barn systems than in cage systems. This finding was confirmed by Karcher et al. (2015) who reported an increasing difference in mortality rates as the age of birds increased with aviary systems having higher mortality than either conventional cages or enriched cages.

It is suggested that a follow-up survey be undertaken after four or five years to ascertain any variation in the economic importance of the various conditions affecting Australian laying hens and pullets. Given the lack of detail in some responses, it is suggested that a larger number of target visits for face to face interviews be undertaken in addition to further detailed physical examination of flocks and farm records on site. This should allow for an even more accurate estimation of the costs and impacts of disease, conditions and the effectiveness of control methods, as well as help Australian Eggs Ltd make rational decisions about the allocation of research funds.

5 Conclusion

Smothering and predation are the most commonly reported incidents affecting Australian laying breed birds, with both more prevalent in free range and barn systems, and predation most prevalent in free range systems. In terms of estimated costs of some disease and control factors, SLD is the costliest disease, followed by FC, ILT, UURT, colibacillosis, coccidiosis, EDS, ND MG/MS and smothers. It is likely that underreporting of the number of incidents has occurred. Further surveys should be undertaken in four to five years utilising a more intensive face to face survey approach with additional examination on farm of records and pullets and hens.

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7 Plain English Summary

Project Title:	Australian egg layer disease benchmarking survey
Australian Eggs Limited Project No	1I002
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Objectives	The project aims to provide a summary of the current disease burden in the Australian layer industry. The estimated disease burden will be validated by limited and targeted on-farm sampling. Particular objectives – the project will identify: • Significance of layer industry diseases ranked by incidence and impact. • Disease and welfare issues that are currently difficult to monitor and quantify. • The comparative burden of disease and welfare issues in each production system. • The comparative burden of disease and welfare issues in each State. • The current costs to industry of prevention and control of each disease. • The significance of the Australian layer disease burden relative to the UK and the Netherlands. This information will be collated in such a way that it can be compared with current international data.
Background	The cost of disease, behavioural conditions and preventive measures in the Australian egg industry have not been previously quantified or ranked. It is important that Australian Eggs Ltd understand the relative importance of each condition, and that the industry utilises appropriate control and prevention measures to ensure profitability. This project was undertaken to help rank the various conditions using survey data.
Research	Two separate phases of research were undertaken. The first phase was to identify by survey the number of incidents of different conditions affecting the different segments of the industry including free range, barn and cage systems. In the first phase, organic and caravan producers participated but in order to ensure confidentiality, this data is not discussed in the report. The most commonly encountered disease was Spotty Liver Disease. Following a technical forum to discuss the results of the Phase 1 survey, a Phase 2 follow-up survey was undertaken to

	identify the extent of each incident reported in Phase 1. Following collation of the data, an economic assessment was made of the cost of disease and preventive measures.
Outcomes	The conditions that were most frequently encountered by producers were smothers and predation/vermin. These were more frequent in the non-cage sectors. The most expensive conditions in terms of both prevention and impact on mortality and production are listed in order of magnitude with the most expensive being Spotty Liver Disease (costing the industry at least $17.2M). This was followed by Fowl Cholera ($15.3M), Infectious Laryngotracheitis ($14.8M), undefined upper respiratory tract disease ($107M), colibacillosis ($8.6M), coccidiosis ($4.2M), Egg Drop Syndrome ($3.7M), Newcastle Disease ($2.45M), Mycoplasma gallisepticum and synoviae ($2.7M), and smothers ($2M). These figures do not include treatment costs. Except for Spotty Liver Disease, the number of incidents multiplied by the number of mortalities and birds affected gave a lower incidence for most conditions than those reported overseas. Because the Phase 2 survey did not ask for details of all conditions, the overall mortality rate reported here (2.8% in hens and 2% in pullets), will be an underestimate and is lower than those reported overseas
Implications	Efforts should be made to address the major conditions and diseases at both an industry and an individual farm level. This survey should be repeated in 4–5 years with a more intensive face to face survey and farm visits to assess both records and birds.
Key Words	Survey; hens; pullets; Australia; mortality; disease; smothers; predation; cannibalism; spotty liver; cholera; infectious laryngotracheitis; undefined upper respiratory tract disease; colibacillosis; coccidiosis; Egg Drop Syndrome; Newcastle Disease; Mycoplasma; economic cost
Publications	