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Beef and sheep industry veterinary residency program

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Abstract

This project delivered a 3-year Beef and Sheep Industry Veterinary Resident training program, with core funding provided by the Scobie and Claire Mackinnon Trust ('industry sponsor') and the MLA Donor Company. Residents were based at the Mackinnon Project, University of Melbourne Faculty of Veterinary and Agricultural Sciences, Werribee. In addition to consultancy and diagnostic work, residents received extensive formal consultancy and research training. This included specialist training in agricultural economics, soil and pasture science, statistics and the use of GrassGro™. They also completed an industry-relevant field research project. These included a project addressing sheep reproduction ('The effect of Ovilis Campyvax® on maiden ewe reproduction on four Victorian sheep farms'), a serological survey to define the distribution of Q fever, an important zoonotic disease in Victorian livestock, and a study of disease surveillance systems ('A farm-based observational approach to disease surveillance'). The latter included a successful pilot program with farmers reporting disease events on their farms to a central database – a 'syndromic surveillance' system.

This training program has produced three highly skilled and competent veterinary consultants, all of whom intend remaining involved in the sheep and beef industries for the foreseeable future.

Co-funding for a second phase of the residency training program has been confirmed from the industry sponsor. If suitable candidates are found, an application will be put to the MLA Donor Company for a second program to run from 2019-2021 ('Beef and sheep industry veterinary residency program – Phase 2').

Executive summary

This project addresses a challenge for Australia's livestock industries – a limited number of veterinary and farm management consultants with a detailed knowledge of the farm as a system. This has been exacerbated by a gradual withdrawal by State Departments of Agriculture from providing extension services. Previously, many consultants were trained and developed their skills in Departments of Agriculture. However, there is now a shortage of skilled advisors at a time when sheep and beef farms need appropriate advice to remain competitive.

The veterinary residency project ran from April 2015 to June 2018, delivering a comprehensive training program using a model developed by the Mackinnon Project. This group, located within the Faculty of Veterinary and Agricultural Sciences (FVAS) at Werribee, has been training veterinary consultants and operating a whole farm consultancy service for the sheep and beef industries since 1982 (see summary in Section 8.3).

Three Sheep and Beef Industry veterinary residents completed their training with the support of the MLA Donor Company and the industry sponsor, The Scobie and Claire Mackinnon Trust. Two residents commenced in April 2015; Tabita Tan (a 2004 Murdoch veterinary graduate) and Elsa Glanville (a 2014 University of Melbourne DVM graduate). Both followed the training model outlined in the Project proposal, being enrolled half-time in parallel Masters courses at the University of Melbourne. The Master of Veterinary Studies (MVS) is a clinical (consultancy and fieldwork) degree, whilst the MVSc is a research degree. Both candidates completed the MVS degree with honours, and have finalised the field work and submitted their theses for the research degrees – 'A pilot study of the seroprevalence of Q fever in cattle, sheep and goats in Victoria' (Tabita Tan) and 'The effect of Ovilis Campyvax® on maiden ewe reproduction on four Victorian sheep farms' (Elsa Glanville).

The third resident was Dr Caitlin Pfeiffer, a 2011 veterinary graduate from the University of Melbourne. She commenced a full-time PhD with the University of Melbourne in March 2014, and was included in the Residency Program in April 2015. She could not enrol in the parallel Masters courses, but completed most of the core clinical and consultancy training activities provided by the training program. Caitlin helped co-ordinate a major disease surveillance project, the Local Area Networks for Disease Information ('LANDI'), led by A/Prof John Larsen, from 2014-2017. This was a key component of her PhD research project – 'A farm-based observational approach to disease surveillance'.

An important component of Caitlin's work was the development and assessment of a syndromic disease surveillance system based upon famers' observations. For this pilot, 39 Victorian farmers were recruited to provide monthly reports about animal health events on their farms within 10 syndromic categories. Using this data, she analysed the prevalence of mortalities among both weaner sheep and ewes, and presented these results to the Australian Sheep Veterinarians conference in September 2016 and International Sheep Veterinary Congress in the United Kingdom in May 2017. She also analysed how reliably farmers reported events on their farms, including whether they sought veterinary assistance during significant disease events. These results were presented at the 3rd International Conference on Animal Health Surveillance at Rotorua in May 2017 ('Identifying timely and reliable respondents for syndromic surveillance of farmers' observations') and the Australian Veterinary Association's annual conference in June 2017 ('When do sheep farmers call the vet?').

The 'Mackinnon model' relies on a mix of strategies to train residents in whole farm consultancy. An important feature is accompanying senior consultants on visits to different sheep and beef enterprises. The program of routine veterinary and consultancy work on farms develops a variety of 'hands-on' skills, including stock and pasture assessment, feed budgeting and allocation of paddocks to different classes of livestock. In addition, it provides a perspective of practical disease management, prevention and decision making within large livestock enterprises. A sound background in routine clinical work is essential, and all residents participated in establishing and interpreting drench resistance trials, routine monitoring of gastro-intestinal parasitism using worm egg counts and bleeding and sampling livestock to investigate conditions, such as sudden deaths, metabolic disease, trace element deficiencies and poor reproductive performance. All are now highly proficient at gross pathology, having completed many field and laboratory necropsies, most as part of the LANDI project and lamb post-mortems to investigate peri-natal mortalities.

Following farm visits, the residents prepared written reports to provide clients with feedback on farm visits and disease investigations, an essential communication skill. This was further developed by preparing more detailed reports, including articles for submission to refereed journals and major technical milestone reports for commercial sponsors.

Regular and active involvement with producer extension groups, such as the Better Beef Network, Lifetime Ewe and Bestwool/ Bestlamb, produced many benefits. These include better understanding of the priorities and concerns of the farmers in these groups, plus developing networks within the industry and recruiting new clients. All residents helped facilitate these groups and also acted as expert presenters.

In the first year of the program (2015) the residents worked closely with senior consultants, accompanying them on field visits and workshops. Subsequently, they became more independent, developing proposals for new clients, both individual and corporate, and investigating disease and management conditions with less supervision. In the second and third years of the program, training and additional coursework focused on expert or specialist skills, such as veterinary epidemiology and data analysis. This has been provided through specialist seminars and workshops delivered by experts such as Dr Ian Dohoo, Prof Mark Stevenson and Dr Simon Firestone.

A key outcome was the presentation of talks to scientific, industry and farmer conferences, seminars and workshops, including the Australian Veterinary Association (AVA) and farmer extension groups. All residents presented talks to farmer workshops and scientific audiences, reporting the progress and outcomes of their research projects and analyses of other management and animal health aspects of sheep and beef farms (summarised in Tables 1 to 5 and Section 8.2).

In Year 1 (2015), formal training included a farm management economics subject (AGRI30033) delivered by Prof Bill Malcolm, co-author of 'The Farming Game' (Malcolm, Makeham and Wright, 2005), animal disease investigation training delivered by Dr Tristan Jubb, a biostatistics training course run by the University of Melbourne Statistical Group, a Certificate IV course in 'Workplace training and assessment' (required to deliver programs to farmer groups, including Bestwool/ Bestlamb and Lifetime Ewe), and modules of the Masters of Veterinary Public Health (MVPH) program. Dr Tan also completed a Post-graduate Masters in Livestock Health and Production through the Royal Veterinary College, University of London.

In Year 2 (2016), all residents attended a biostatistics training course run by the University of Melbourne Statistical Group and a Statistical Modelling course with Dr Ian Dohoo, a prominent veterinary epidemiologist. Case report seminars were presented on 'Investigation into the premature birth of weak neonates in a Merino flock' (Tan) and 'A detailed neurological assessment of post-partum recumbent ewes' (Glanville).

In Year 3 (2017), a two-day seminar on the use of the GrassGro™ decision support tool was delivered by Lisa Warn, and a half-day seminar on Animal Welfare issues by Prof Andrew Fisher, Director of the Animal Welfare Science Centre. Caitlin Pfeiffer and Tabita Tan also attended an epidemiology workshop on 'Accounting for bias and confounding in data', delivered by Dr Ian Dohoo. Both obtained membership of the Australian and New Zealand College of Veterinary Scientists Epidemiology Chapter by examination. Elsa Glanville increasingly built her expertise in sheep reproduction, including the pre-joining evaluation of ewes and rams and comprehensive investigations into sub-optimal scanning and lamb marking percentages. She presented talks to several farmer groups, including Bestwool at Hamilton and the Southwest Victoria Prime Lamb group.

Finally, in addition to their own research projects and clinical work, residents were actively involved in the design and conduct of other research activities conducted by the Mackinnon group, including:

- The LANDI disease surveillance project supported by the Victorian Sheep & Goat and Cattle Compensation Funds from 2014-Jan 2017 (all residents)
- Investigation of balanitis in beef bulls (MLA project BAHE 0227; TT & EG);
- A serological survey of the prevalence of toxoplasmosis in Victorian ewe flocks (sponsored by Coopers Animal Health; EG);
- Improving small ruminant health in the central dry zone of Myanmar (ACIAR-funded project with Dr Angus Campbell; EG);
- Assessing the efficacy of an autogenous vaccine against pneumonia of goats caused by *Mannheimia haemolytica* (sponsored by Nuchev P/L with A/Prof John Larsen; TT);
- Assessment of the benefits to reproductive efficiency of a commercial mineral supplement (Multimin™) in meat flocks (funded by Virbac Animal Health with John Larsen; TT & EG), and
- The effect of stocking density and mob size on lamb marking percentages (TT with Dr John Webb Ware)

The residency training program has produced three highly skilled and competent veterinary consultants, all of whom intend remaining involved in the sheep and beef industries for the foreseeable future. Consequently, the benefits from this program will accrue for the next 25-30 years. Two of the residents have already found placements within the Mackinnon Group, from which they will continue their contributions to these industries during the next phase of their careers.

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1 Background

1.1 The challenge – Decreasing consultancy capacity

This project addresses a challenge for Australia's red meat livestock industries – a limited number of consultants with a broad industry knowledge and expertise. There is currently a major withdrawal by State Departments of Agriculture from extension activities. Governments see the issue as one that should be managed by industry itself, and in some cases reduced government funds are being directed towards private providers of extension services. However, the sources of expertise and training and development are being lost. Who will develop the extension consultants of tomorrow? Where are the 'super experts' and 'expert generalists' who will serve as the source of expert advisors, at both an industry and farm level?

At a time when farmers need more advice to grow and develop their farming businesses, and enable family-run farms to remain competitive, there is going to be less expertise available, and less capacity and ability to train the farm advisors of tomorrow.

There is of course ongoing investment in research and development, including by MLA and other Research and Development Corporations, and many of these projects include postgraduate research students. Although this is vital in providing scientific capability into the future, the focussed nature of modern biological research means that these PhD graduates may have excellent scientific skills in the field of their project, but usually very little industry knowledge. Furthermore, these graduates are often lost from the livestock sector, because their biological research skills are applicable to and highly sought after by the biomedical research industry.

1.2 The response – The Mackinnon Project as a training model

To address this challenge, it is useful to consider another model of capacity development and training. The Mackinnon Project has trained industry experts in advanced animal health and management for over 30 years. During this time, it has evolved from service providing advice to sheep and beef cattle producers, based on knowledge of the farm as a complex biological and economic system. This 'systems approach' owes a lot to the vision of the founding director, Dr Fred Morley, and recognizes that the financial viability of grazing enterprises is essential to the social, economic and environmental health of rural Australia.

Based within the University of Melbourne's Faculty of Veterinary Science at Werribee, the Mackinnon Project is a leading provider of information for farmers in the grazing industries in south-eastern Australia, and has utilised this structure to train future industry consultants and leaders. Consultants trained by the Mackinnon Project now occupy a diverse range of senior positions and make a substantial contribution to the Australian grazing industries (see Appendix in Section 8.3).

There are two factors that have been critical for the capability-building success of the Mackinnon Project model. Firstly, trainees have been embedded within a high-performing industry consultancy and field research organisation, with sufficient project load, expertise and critical mass to provide a suitable environment for training. Secondly, the model has not focussed on training to techniques, but rather training to the industry. The decline in Government investment in extension capacity building, and in university funding, means that there is scope to increase the training output from the Mackinnon model.

The University has also initiated changes to assist the cost-effectiveness of increased capacity building through the Mackinnon model. These developments are exemplified by the Dairy Veterinary Residents training program, funded by Dairy Australia, the Geoffrey Gardiner Foundation, and the University of Melbourne, with in-kind support from hosting veterinary practices. Graduate trainees are paid a tax-free stipend, making their incomes competitive with other early- to mid-career professionals in the sector, but at a reduced cost to the program. The trainees are enrolled in parallel Masters degrees, which allow the trainee to make a positive contribution to industry knowledge while developing their critical analysis and independent skills, plus gain a recognised qualification from the Residency.

This proposal is for a 3-year Australian Beef and Sheep Industry Veterinary Residency Program, employing the Mackinnon experience and approach of training to the industry, and the structure and funding efficiencies derived from the existing Dairy training program. A suitable Industry sponsor is available – The Mackinnon Trust – which allocated funding of $150,000 per year for training of young veterinarians within the Mackinnon Project, to be complemented by the MLA Donor Company.

2 Project objectives

The Outcome of this project will be a future cohort of livestock industry technical experts and leaders.

The specific outputs of the project are to:

- Establish a Beef and Sheep Industry Resident Program and engage three additional early-career industry professionals in a 3-year program utilising the structure and capacity-building ethos of the Mackinnon Project.

- Enrol Residents in a Masters-level postgraduate course and provide them with advanced training enabling the development of competent, highly trained professionals with skills to improve farm productivity and economic performance, industry awareness of public issues and biosecurity.

- Provide Residents a series of training modules including whole-farm analysis, advanced clinical techniques and disease investigation, ruminant nutrition and reproduction, statistics, current and emerging animal welfare issues and management of a secure food supply. Modules will be available to industry advisers and consultants and other interested groups wishing to develop specialised skills, leveraging the investment in the Resident Training Project.

- Engage the Residents in research projects relevant to Australian livestock industries, disseminating results and other project findings to RDCs, farm managers, consultants, veterinarians and other industry personnel, and leading to a Masters research higher degree

- Promote significant project achievements through the media to stimulate and encourage students to consider livestock industry career opportunities.

3 Methodology

The program comprises a 3-year Beef and Sheep Industry Veterinary Resident training program, with core funding provided by the Mackinnon Trust and MLA Donor Company. The Residents are based at the Mackinnon Project, University of Melbourne Faculty of Veterinary and Agricultural Sciences, Werribee. In addition to consultancy and diagnostic work they work on an industry-relevant field research project, reflecting the diversity of Australia's beef and sheep industries. These industry projects and related partners are negotiated in conjunction with MLA.

The Mackinnon Project provides week-to-week management of the project, with Residents having the Director of the Mackinnon Project, Associate Professor John Larsen, as their primary supervisor. As part of the program, Residents receive training in veterinary whole-farm consultancy for the sheep and beef industries, led by Mackinnon staff, with modules presented by external experts as appropriate.

3.1 Structure of Residency program

Depending upon their academic and professional backgrounds, Residents will enrol in a research higher degree at the University of Melbourne; either a Master of Veterinary Science (MVSc), Master of Agricultural Science (MAgSc) or Doctor of Philosophy (PhD). If enrolled in a research masters, this will usually be on a part-time basis and they will also enrol part-time in the Master of Veterinary Studies (MVS) course. Thus, the combined 'parallel Masters' program runs for the term of the Residency, three years.

The MVS is a clinical degree with two core subjects each year, Advanced Clinical Skills (ACS) and Principles of Medicine and Surgery (PMS). A summary of the work components and assessment of each subject in each year are as follows:

1) Advanced Clinical Skills (VETS70014):
    a) Clinical work (20% of total) – this includes disease investigations and post-mortems (many as part of LANDI disease surveillance project), visits to consultancy clients and maintaining a case log, teaching of veterinary students and other on-farm work (eg. drench resistance tests, assessment and investigation of poor reproductive performance or trace element status)
    b) Major work (80% of total) – this includes a written assignment on major disease or management investigations (approximately 1500-4000 words, suitable for submission to Cattle or Sheep vet newsletter), clinical seminars and communications with clients (eg. written reports and presentations at farmer workshops).
2) Principles of Medicine and Surgery (VETS70017):
    a) 'Class work' (20%) – includes internal tutorials and other non-assessed subjects, such as biostatistics and farm economics/ financial analysis
    b) Assessment of MVPH subjects (if enrolled that Semester) and major reports (80%). The latter includes reports to farmer or corporate clients and articles written for the Mackinnon Project newsletter and other farmer or professional publications (eg. Australian Sheep Veterinarians newsletter).

3.2 Outline of the Farm Management Economics subject (AGRI 30033)

This subject is used to set the scene for all other subjects and cases. The aim is to get Residents thinking critically about how a farm works financially as well as the technical aspects of farm management and animal health.

Week 1 - Introduction: Farm management case study to introduce key concepts and principles of whole farm economic analysis

Week 2 - Animal Farm: Farm management economic analysis of animal activities and animal farming businesses

Week 3 - Crop Farm: Farm management economic analysis of crop activities and crop farming businesses

Week 4 - Farm Visit Case Study 1: Case study assessing the performance of a real farm business

Week 5 - Analysing Farm Change (1): Case study of economic worth and financial feasibility of a change to a farm business using partial budget methods

Week 6 - Analysing Farm Change (2): Case study of economic and financial analysis of a major farm business investment using capital budgeting methods

Week 7 - Analysing and managing farm risk: Farm business and financial risk. Futures markets and price risk management.

Week 8 - Farm Visit Case Study 2: Case study evaluating a change to a farm business to increase profit

Week 9 - Farm Economic modelling: Systems simulation, programming methods, risk analysis

Week 10 - Farm Management Economic Analysis in Professional Practice: Leading farm management consultants and researchers

Week 11 - Farm Management and Business Growth:

Week 12 - Applications of Farm Management Economic Theory to Practice: Production economics and common fallacies and flawed methods used in farm management analysis; climate change and the carbon farming initiative

3.3 Outline of Master of Veterinary Public Health modules

3.3.1 Principles of Animal Health Management (VETS50005)

Now Management in Disease Emergencies (VETS90085).

Managing an emergency disease response and the various components of such a response requires the ability to plan and manage effectively. This subject covers the knowledge required to plan and execute response components using a project management template. A series of lectures and tutorials covers leadership skills, delegation and teamwork, and gives details of how to plan,

execute, monitor and evaluate a project. This subject was delivered in Sem 1 2015 by Ron Glanville (ex-Qld CVO) and Malcolm Ramsay.

3.3.2 Selection and Interpretation of Laboratory Tests (VETS90083)

A two-week full-time training course which ran from Monday 13 July to Friday 24 July 2015 at the Parkville Veterinary Campus of the University of Melbourne. Specific training activities were scheduled at the Victorian State Government veterinary laboratory in Bundoora and CSIRO's Australian Animal Health Laboratory in Geelong.

3.3.3 Communication in Disease Emergencies (VETS90084)

During emergency situations, effective public communications is of crucial importance. Gaining public trust and co-operation during any emergency needs the right messages to be targeted at the appropriate times to the right audiences using the most appropriate media. In animal disease emergencies, public co-operation is required to maximise good biosecurity and gain maximum compliance with disease management efforts.

A 10-week module run in August covering: Communications Strategies and Plans; Creating a Communications Strategy; Getting the Message Across; Putting the Communications strategy together; The media release; Good vibes–getting it right together; Interviews–being media ready; Evaluating and improving your communications; Revision & Examination.

3.3.4 Epidemiology of Epidemics (VETS90086)

This subject uses online lecture notes and study materials to provide an overview of the epidemiology of animal disease epidemics, which is reinforced with detailed studies of epidemics in later subjects. Learning outcomes include:

- a basic understanding of the generalised course of animal disease epidemics in fully susceptible populations;
- an overview of the main epidemiological questions faced by animal disease control managers during an epidemic
- A basic understanding of the main epidemiological tools and techniques to be used during an epidemic (e.g. modelling, GIS, etc)

On completion, students should understand the main epidemiological problems faced by animal disease control managers and read and understand the literature describing historical animal disease epidemics.

3.3.5 Transboundary Animal Health disease (VETS90087)

Focuses on highly contagious livestock epidemics. Several diseases are of importance due to high rates of transmission and/or morbidity and mortality. These include the 'vesicular diseases' – foot-and-mouth disease (FMD), Vesicular Stomatitis (VS), and Swine Vesicular Disease (SVD), and two serious diseases of swine, classical swine fever (CSF) and African swine fever (ASF). These diseases have been responsible for two of the most serious animal disease outbreaks in recent time, the CSF epidemic in the Netherlands in 1997-98 and the FMD epidemic in the UK in 2001.

3.3.6 Disease Investigation at the Farm Level (VETS90092)

Correctly identifying an emergency animal disease on the farm, interpreting the circumstances precipitating its appearance, and devising immediate control measures in anticipation of a larger campaign, lie at the heart of a response. Lectures, tutorials, and a practical exercise train students in ascertaining and recording epidemiological history, clinical details and the performance of a post mortem examination. These will form the background to designing an immediate on-farm response.

This module is only offered every 2 years and needs 'Epidemiology of Epidemics' as a prerequisite. None of the Mackinnon Residents undertook this module as they had insufficient time when offered in second Semester of 2017 because they were completing their research projects.

3.3.7 Vector borne and wildlife reservoirs (VETS90088)

This subject focuses on vector-borne and wildlife reservoir emergency diseases. Recently, many emergency animal diseases have a complex epidemiology, either involving insect vectors and/or or wildlife reservoirs. Many of these outbreaks were initially new or emerging, and in some cases were zoonotic. Accordingly, they posed challenges to control and eradication not encountered with simple disease epidemics. Examples include West Nile Fever (WNF), Bluetongue virus (BTV), African Horse Sickness (AHS), and infection with Hendra and Nipah viruses.

4 Results

4.1 The Residents

Tabita Tan is a veterinary graduate from Murdoch University (BVMS Hons, 2004; BSc 2002). She is also a Member of the Australian and New Zealand College of Veterinary Scientists (MANZCVSc) by examination in Ruminant Nutrition. During her residency Tabita completed a Postgraduate Masters in Livestock Health and Production through the Royal Veterinary College (University of London) in 2015 and gained Membership into the Epidemiology Chapter of the Australian and New Zealand College of Veterinary Scientists in 2017. Tabita submitted her Masters research thesis for examination on 9 June 2018.

Elsa Glanville is a DVM (Hons) graduate of the University of Melbourne (2014). She comes from a family farm that runs a self-replacing Merino flock in the Bathurst area of NSW. She also holds a PhD in wildlife ecology ('Thermoregulatory and compensatory responses to cold in a mammal *Rattus fuscipes*', 2010), and a Bachelor of Advanced Science (Hons, 2005) from the University of Sydney for which she was awarded the University Medal in Zoology. Elsa submitted her Masters research thesis for examination in December 2017 and this was passed with no amendments in March 2018.

Caitlin Pfeiffer is a BVSc (Hons) graduate from the University of Melbourne (2011). She enrolled in a full-time PhD with the University of Melbourne in March 2014, with Angus Campbell, John Larsen, Mark Stevenson and Simon Firestone as her co-supervisors. She was included in the Residency Program as an adjunct to her PhD studies in 2015, and so did not enrol in the parallel Masters courses (MVS and MVSc). Nevertheless, she completed many of the core clinical and consultancy training activities provided in the MVS program. For example, she completed one unit of the Masters of Veterinary Public Health course in 2014 ('Epidemiology of Epidemics' – an eight-week online

course with a final examination). However, she was unable to formally enrol in subjects from the MVPH course because she was undertaking a PhD.

Caitlin undertook study for and gained Membership into the Epidemiology Chapter of the Australian and New Zealand College of Veterinary Scientists in 2015 and participated in most of the training undertaken by Mackinnon Residents (see Table 1).

4.2 Consultancy training – Tutorials and formal course subjects

In the first year of the program (April 2015 to 31 Dec 2015), Drs Tan, Glanville and Pfeiffer completed an intensive training program as follows:

- The Farm Management Economics unit offered by Professor Bill Malcolm (School of Agriculture) and Ms Lisa Warn (Mackinnon) in May-June 2015. This included 12 lectures and two field trips to discuss farm financial performance and analysis with progressive farmers
- Small group tutorials from Mackinnon consultants (Table 1)
- Animal Disease Investigation training course sponsored by Agriculture Victoria at Bendigo (14-15 May presented by Drs Tristan Jubb & Rob Suter)
- Biostatistics training course run by the University of Melbourne Statistical Group – 'Introduction to biostatistics and design of research trials'
- Certificate IV course in 'Workplace training and assessment', which is a prerequisite for delivering to farmer groups, including Bestwool/ Bestlamb and Lifetime Ewe programs

The time available for tutorials and external training over the final two years of the residency program progressively reduced as the clinical and research activities became busier, including presentations at farmer workshops and professional conferences. A summary of tutorials and training given over the three years summarised in Table 1 and the presentations at professional conferences are listed as an Appendix (Section 8.2).

The MVPH modules undertaken from the Masters of Veterinary Public Health course offered by Dr Simon Firestone and Prof Mark Stevenson, epidemiologists with the Faculty of Veterinary and Agricultural Sciences are summarised in Table 2. All units were formally assessed by assignments and exams, with high evaluations in the subjects undertaken by each resident.

Table 1. Tutorials and other training courses undertaken by Mackinnon Project Residents from 2015-2017

Date	Topic	Tutor[A]	Delivered to[B]
21 Apr 2015	Introduction to Sheep management systems	AC	TT, EG, CP
14-15 May 2015	Animal Disease Investigation training course	TJ, RS AgVic	TT, EG, CP
May-Jun 2015	Farm Management Economics unit	BM, LW	TT, EG
Jun-Jul 2015	Introduction to biostatistics and design of research trials	MSG	TT, EG, CP
Sep 2015	Lifetime Ewe – 'train the trainer' workshop	AgVic	EG
8 Sep 2015	Herd Structure, management and weaning of the Australian Beef Industry	JWW	TT, EG, CP
26 Oct 2015	Calf management and diseases of cattle	JWW	TT, EG, CP
27 Nov 2015	Interpreting soil tests and planning a fertiliser program	LW	TT, EG, CP, LT, KS
27 Nov 2015	Pasture species for high rainfall areas	Lisa Warn	TT, EG, CP, LT, KS
25 Feb 2016	Drought feeding 1	JWW	TT, EG, CP
Mar 2016	Certificate IV course in 'Workplace training and assessment'	Southern Cross TAFE	TT, EG, CP, LT, KS, BK
Mar 2016	Growing more winter feed	PCG Wrightson seeds	TT
Mar-Apr 2016	Surveillance design and evaluation – online course	Santero Project	TT
5 May 2016	Drought feeding 2 & using GrazFeed™	JWW	TT, EG, CP
May 2016	Multilevel Modelling for analysis – 4-day short course presented by Dr Ian Dohoo	Ian Dohoo	TT, EG
1 Jun 2016	Trace element nutrition	JWW	TT, EG, CP
19 Jul 2016	Internal parasites of sheep & cattle	JL/ NA	TT, EG, CP, LT, KS
5 Dec 2016	Footrot training course for veterinary advisers	JWW	TT, EG, CP
Jan-Jul 2017	Epidemiology study group and ANZCVS membership exam	ANZCVS – Epi membership	TT
24 Mar 2017	Practical assessment of pastures	JWW	TT, EG
27 Mar 2017	Using the GrassGro™ decision support tool (1)	LW	TT, EG, CP, LT, KS, BK
12 Apr 2017	Using the GrassGro™ decision support tool (2)	LW	TT, EG, CP, LT, KS, BK
3-7 Apr 2017	Epidemiology workshop	Ian Dohoo	TT
29 Aug 2017	Understanding farm economics & benchmarking	JWW	TT, EG, LT, KS, BK
Sep 2017	OneHealth – 6-week on-line course	Univ. Basel	TT
30 Oct 2017	OneHealth conference, Melbourne	Conference	TT, EG

[A]AC = Dr Angus Campbell, TJ = Dr Tristan Jubb, RS = Dr Robert Suter, BM = Prof Bill Malcolm, MSG = UoM statistical group, JWW = Dr John Webb Ware, LW = Lisa Warn, JL = A/ Prof John Larsen; [B] TT= Tabita Tan, EG = Elsa Glanville, CP = Caitlin Pfeiffer, LT = Leah Tyrell, KS = Kelly Stanger, BK = Beata Kirk (the last three are junior Mackinnon consultants)

Table 2. Units taken from the Masters of Veterinary Public Health (MVPH) program

Semester	MVPH unit	Brief description	Completed by[A]
2015-Sem 1	Principles of Animal Health Management (Management in disease emergencies)	Response to animal disease emergencies	TT, EG
2015-Sem 2	Selection and Interpretation of Laboratory Tests	Intensive 2-week course	TT
2015-Sem 2	Communications in Veterinary Emergencies	On-line course on managing the media in disease emergencies	EG
2016-Sem 1	Epidemiology of Epidemics	10-week online course with group assignment and final exam	TT, EG, CP
2016-Sem 2	Transboundary animal diseases (emergency animal disease 1)	10-week online course with final exam	TT, EG
2017-Sem 1	Disease investigation at farm level	10-week online course with final exam	TT
2017-Sem 2	Vector borne & wildlife reservoirs (emergency animal disease 2)	10-week online course with final exam	TT

[A] TT = Tabita Tan, EG = Elsa Glanville, CP = Caitlin Pfeiffer

4.3 Consultancy training – Farm visits (MVS)

In each year of the program, each resident participated in from 20-40 farm visits and farmer workshops with senior Mackinnon consultants. This included:

- Pasture and stock assessment, feed budgeting and paddock allocation
- Farm benchmarking
- Decision making regarding enterprise options: financial evaluation, appropriateness for land class
- Stocking decisions e.g. cost-benefit of selling versus keeping different classes of stock
- Control of gastro-intestinal parasites, including routine monitoring, formulation of control programs and testing for anthelmintic resistance
- Participation and presentations to producer extension groups (Better Beef Network, Lifetime Ewe, Bestwool/ Bestlamb, Southwest Prime lamb group, Bred Well/ Fed Well and Grasslands Society Pastures Updates
- Disease investigations:
    - Sudden deaths and high mortality rates in adults and lambs, including testing and exclusion of Anthrax
    - Neonatal lamb losses
    - Weaner illthrift and mortality
    - Ewe morbidity and mortality:
        - Metabolic disease: pregnancy toxaemia and hypocalcaemia

        - Musculoskeletal damage & secondary neurological deficit associated with recumbency ('Downer ewes')
    - Chronic wasting, ovine Johne's disease investigations
    - Clinical acidosis associated with drought feeding
    - Poor reproductive performance in sheep and cattle, including eradication of ovine brucellosis and investigation of abortions in sheep
    - Diarrhoea, including bacterial enteritis and gastro-intestinal parasitism
    - Metabolic and nervous disease, including transmissible spongiform encephalopathy (TSE) exclusion
    - Eye disease
    - Urinary tract disease in rams and bucks

For the clinical cases, the residents initially drafted reports to farmers following visits to farms with senior consultants. They were also involved in many disease investigation cases, including contacting clients and the primary examination and transport of animals.

Assessment for the MVS is based upon delivery of at least one case report each semester and the preparation of written material, such as newsletter articles and reports to farmers. A summary of case reports and related presentations, and Mackinnon newsletter items written, are shown in Tables 3 and 4, respectively.

Table 3. Case reports and presentations as part of the residency program

Date	Case report or newsletter article	Type	Presented by
2015-Sem 1	Investigation of phalaris toxicity	Case report	Glanville
2015-Sem 1	Footrot consultancy report	Contracted report	Pfeiffer
2015-Sem 2	Investigation of infertility on a wool flock	Case presentation	Glanville
2015-Sem 2	Arthritis in lambs	Case presentation	Tan
Sep 2015	Presentation – 'Aspects of neonatal lamb survival'	Mackinnon farmer seminar[A]	Glanville
2015-Sem 2	Organise discussion forums, undertake biostatistics and develop materials for teaching biostatistics to veterinarians	MVPH	Pfeiffer
18 May 2016	Q-fever MVSc research presentation	Confirmation seminar	Tan
26 May 2016	Investigation of downer ewes	Case presentation	Glanville
26 May 2016	Eradication of ovine brucellosis from a ram flock	Case presentation	Tan
May 2017	International sheep Vet Congress – 4 presentations	ISVC, Harrogate, UK	Glanville, Pfeiffer
Nov 2016	A detailed cases series investigation into 'downer' post-partum ewes	Case presentation	Glanville
Nov 2016	Investigation into the premature birth of weak neonates in a Merino flock	Case presentation	Tan
Feb 2017	Improving perinatal lamb survival and ewe nutrition	Meredith Lifetime Ewe group	Glanville
June 2017	Investigation of sub-optimal reproductive performance in ewe flocks	SW prime lamb group	Glanville
Sep 2017	Trace element talk to Hamilton Bestwool	Bestwool seminar	Glanville
28 Sep 2017	Presentation – 'Economic returns from increasing reproduction'	Mackinnon farmer seminar[B]	Glanville

6-8 Nov 2017	Campyyvax research presentations	MLA post-grad conference & UoM completion seminar	Glanville
6-8 Nov 2017	Q-fever MVSc research presentation	MLA post-grad conference	Tan
28 Nov 2017	Disease surveillance – PhD research presentation	UoM completion seminar	Pfeiffer
20 Mar 2018	Q-fever MVSc research presentation	UoM completion seminar	Tan

[A] 70 farmers attending; [B] 80 farmers attending

Table 4. Mackinnon newsletter articles written as part of the residency training program

Date	Topic	Author[A]
Sep-15	Laboratory analysis of supplementary feeds	TT
Mar-16	The value of compost as an alternative fertiliser	TT
Jul-16	Selection for increased feed efficiency in beef cattle	TT
Nov-16	Culling ewes for reproductive performance	TT
Feb-17	High prices for cattle – an opportunity to change enterprise mix?	TT & JWW
Jul-17	Biosecurity – keeping endemic disease out	TT
Oct-17	Don't underestimate Q fever	TT
Dec-17	Bluetongue virus in northern Victoria	TT
May-18	Lice control in long-wool sheep	TT
Apr-18	Q fever (VFF autumn magazine)	TT
Aug-15	How much does it cost to shear a sheep?	EG
Feb-16	The right tool for the job – Part 1: livestock decision making tools	EG
May-16	The right tool for the job – Part 2: matching feed availability with demand	EG
Oct-16	Wet weather and fleece & feet problems	EG
Mar-17	Rams – keep an eye on the prize	EG
Jun-17	What can I do with a down ewe?	EG
Jan-15	Field insights into FMD	CP
Jun-15	Keeping stock safe on phalaris pastures	CP
Nov-15	Prevention of arthritis in lambs and calves	CP
Mar-16	Planning ahead for ewe health at lambing	CP
Oct-16	Reducing weaner sheep losses – lessons from surveillance data	CP
Mar-17	Farmers decisions about livestock health	CP
Jun-17	Ewe mortality – what's it really costing you?	CP
Feb-18	Sheep movements in Victoria – insights from the NLIS database	CP

[A] TT = Tabita Tan, EG = Elsa Glanville, CP = Caitlin Pfeiffer

4.4 Consultancy training – Additional work and undergraduate teaching (MVS program)

Additional clinical, research and teaching activities are summarised in Tables 5 and 6. These have included:

- Assisting with collection of samples from bulls and cows for MLA Atypical Balanitis research project (B.AHE.0227) (TT & EG with John Larsen)

- Management of Q fever and pneumonia caused by *Mannheimia haemolytica* on a large dairy goat farm, including field work to develop autogenous vaccines for the flock against both disease agents (TT with John Larsen)
- Monitoring of alternative fertiliser and carbon capture trials (EG & TT with Lisa Warn).
- Establishment of trials investigating the effect of mob and paddock size on lamb survival and weaning rates (TT with John Webb Ware).
- Post mortem examination of animals submitted to the FVAS Pathology Department as part of the Mackinnon LANDI Project, a disease surveillance project funded by Victorian sheep and cattle producers through the Victorian Sheep and Goat and Cattle Compensation Funds (202 cases investigated; 58 in 2014, 65 in 2016 and 79 in 2016)
- Reporting of LANDI cases to AgVic Yes! database
- Assisting DVM pathology practical classes, including lamb necropsies and LANDI cases
- Supervising DVM4 student practical classes (vasectomy and castration of rams) and taking DVMs and DVM4 students on farm visits

Table 5. Additional research and special activities undertaken as part of the residency training program

Year	Research or field activity	Funding/ mentor	Resident[A]
2015-Sem 2	Investigation atypical balanitis in beef bulls	MLA BAHE.0227/ JL	EG & TT
2015-17	Improving small ruminant production in the central dry zone of Myanmar	ACIAR/ AC	EG
2016-Sem 1 & 2	The impact of paddock size on ewe lambing performance	AgVic/ JWW	TT
2016-17	Evaluating the efficacy of an autogenous *Manheimia haemolytica* vaccine in a dairy goat flock with severe pneumonia	Private sponsor/ JL	TT
2017-Sem 2	Participation in AgVic Bluetongue response	AgVic disease response	TT

[A] TT = Tabita Tan, EG = Elsa Glanville

In Years 2 and 3, Drs Glanville & Tan worked with senior consultants to develop proposals for new clients, with three new clients engaged in a full Mackinnon farm consultancy program in 2016-17. Dr Glanville further developed a special interest in sheep reproduction. This led to retrospective investigations of poor lamb marking percentages on several farms, including one delivered as a case study as part of the residency training assessment and a Mackinnon Project farmer seminar. Several more producers expressed concerns over poor marking percentages after this presentation, and these were investigated more thoroughly in 2016 and 2017.

Table 6. Undergraduate teaching activities undertaken as part of the residency training program

Year	Case report or newsletter article	Type	Presented by
Oct 2015	Diagnosis and control of internal parasites of sheep	DVM3 'case conversation'	Pfeiffer & Tan
Nov 2015	Chronic disease in small ruminants	DVM3 'case conversation'	Glanville
Oct 2015	Host DVM1 students on 'Introduction to animal Health in Production Systems' – trip to Dookie College	DVM1 teaching	Glanville
2015-Sem 2	Development and delivery of 1-day disease surveillance workshop for third year BAg program and Biosecurity lecture to BAg2	Bachelor of Agriculture (BAg) teaching	Pfeiffer
2015-Sem 2	'Communicating with beef and sheep client' workshops	DVM3 teaching	Pfeiffer
2015-Sem 2	Supervision of DVM4 student research project 'Investigation into Causes of Mortality in Mature Peri-Parturient Ewes in Victoria' (student awarded 2015 ANZCVS Epidemiology Award)	DVM4 teaching	Pfeiffer
2016-Sem 1	Footrot workshop	DVM3 'case conversation'	Tan
2016-Sem 1	Diagnosis and control of internal parasites of sheep	DVM3 'case conversation'	Tan & Glanville
2017-Sem 1	Diagnosis and control of internal parasites of sheep	DVM3 'case conversation'	Tan
2017-Sem 1	Co-supervise DVM4 research project: 'Longitudinal monitoring of *Campylobacter* serology on two Victorian sheep farms'	Mentoring & supervision	Glanville

4.5 Research training (MVSc)

4.5.1 A pilot study of the seroprevalence of Q fever in cattle, sheep and goats in Victoria (Tabita Tan)

Q fever is an important public health concern throughout the world and infection can result in debilitating and lifelong illness in some people. It is caused by the bacterium *Coxiella burnetii* and the most frequent source of infection for humans are domestic ruminants. Over a quarter of human Q fever cases in Victoria are locally acquired indicating that it is endemic in the state. In addition, outbreaks of human Q fever in Victoria associated with local livestock are causing concern that the incidence of disease is increasing. However, information regarding the amount of infection present in the animal reservoir are lacking in Victoria. The aim of this pilot study was to survey cattle, sheep and goats in Victoria to estimate the individual animal-level, herd-prevalence and within-herd-prevalence of *Coxiella burnetii* infection.

This study was carried out from February 2015 to May 2017. Over 1500 blood samples were collected, using a two-stage sampling process, from livestock on farms and at abattoirs. Sera were screened using a commercial Q fever ELISA kit validated for ruminants. True prevalence and intra-class correlation coefficient for each species was estimated using a Bayesian approach to account for

known test imperfections. Post-hoc sample size estimates were calculated based on survey results to inform future study planning.

Results: Q fever is endemic in Victoria at low levels and may even be non-endemic in some parts of the state. Of the herds and flocks that were sampled, 8% (95% confidence interval, 5 to 13%) had at least one animal seropositive for Q fever. The overall true animal-level prevalence was 1.3% (95% confidence interval, 0.9 to 2%). Although the overall herd- and animal-level prevalence estimates were very low, the individual animal-level prevalence within infected herds (within-herd prevalence) was much higher, ranging from 12 to 19%, by species. Finding a small number of groups of animals with elevated levels of within-herd seroprevalence, whilst not detecting positive results in the rest of the sampled population, indicates that the prevalence of exposure to *Coxiella burnetii* was geographically uneven, being highly clustered within a small number of farms in Victoria.

Post-hoc sample size estimates based on survey results indicate large numbers of farms and animals are required for further studies to confirm this very low rate or the absence of infection in some areas of Victoria. However, a greater priority and more cost-effective approach would be to establish why some farms are at higher risk, and this could be efficiently investigated using a case-control study. The findings of this pilot study present a step forward in understanding the epidemiology of *Coxiella burnetii* in this region of Australia and point to further areas of investigation and how to conduct such studies.

4.5.2 The effect of Ovilis Campyvax® on maiden ewe reproduction on four Victorian sheep farms

Reducing reproductive wastage is an important objective for the Australian sheep industry. *Campylobacter fetus fetus* and *C. jejuni* infections in ewes contribute to reproductive wastage through abortions, stillbirths and the birth of small, weak neonates at greater risk of starvation-mismothering-exposure (SME).

A combined vaccine against *C. fetus fetus* and *C. jejuni* (Ovilis Campyvax®, MSD Animal Health) is registered in Australia to reduce reproductive wastage due to *Campylobacter*, but few independent field trials of the vaccine have been conducted in commercial flocks. This study investigated the effects of Ovilis Campyvax® on maiden ewe reproduction in a randomised controlled field trial on four winter-/spring-lambing Victorian sheep farms.

Conception and lamb marking rates were compared amongst nineteen-month-old Merino and Merino-cross ewes randomly allocated to vaccination or control groups at mating on each farm (*n* = from 211 to 249/group). Ewes were grazed together from mating until immediately prior to lambing, when they were set-stocked in treatment groups in matched paddocks. Antibody titres to *Campylobacter spp.* were measured at mating, mid-gestation pregnancy diagnosis and lamb marking in a subset of ewes, and a cross-sectional study of cause of neonatal lamb death was also conducted on each farm during lambing.

Vaccination had no effect on ewe conception rate (67% to 117%, depending on farm). Two of four farms had serological evidence of prior exposure to *C. fetus fetus*, and variable exposure to this organism occurred during gestation on all farms. *Campylobacter jejuni* titres were high on all farms at mating, but decreased thereafter. Despite serological evidence of a good response to *C. fetus fetus* vaccination on all farms, vaccination did not significantly increase lamb marking rates (63% to

100%, depending on farm). The main causes of lamb mortality were dystocia, starvation-mismothering-exposure and predation. There was an indication of different patterns in the causes of neonatal lamb mortality between vaccinated and control ewes. This was not statistically significant, but corresponded with anecdotal observations made by the flock owners. Additional large-scale studies into vaccination and the causes of neonatal lamb mortality are needed to investigate this observation.

Vaccination appeared to prevent *Campylobacter*-associated neonatal lamb mortality and morbidity on the farm with the greatest exposure to *C. fetus fetus*. On that farm, 55% of unvaccinated ewes that failed to rear a lamb had 'high' *C. fetus fetus* titres (≥ 1:80), compared to 0% of ewes that reared a lamb. In addition, *C. fetus fetus* was only recovered from necropsied lambs born to unvaccinated ewes.

The results demonstrate that ewes can be vaccinated with Ovilis Campyvax® during mating without reducing conception rates. However, the effect of *Campylobacter* vaccination on reproductive output is complex and multifactorial, and vaccination effects may be obscured by other causes of reproductive loss. Vaccination may reduce the contribution of *Campylobacter* infections to lamb loss due to SME. However, the dystocia risk in vaccinated ewes may increase depending on ewe nutrition. If this is the case, the nutrition of vaccinated ewes could be managed more economically to obtain the full benefits of vaccination – this is an avenue for future research.

4.6 Research training – Other projects

4.6.1 International agricultural development

The 'Dahat Pan Project' is an Australian Centre for International Agriculture Research (ACIAR) project investigating the productivity of subsistence farmers in two villages in the Central Dry Zone of Myanmar, led by Prof Dennis Poppi, University of Queensland School of Agriculture Food Sciences, and Dr Angus Campbell, Mackinnon Project. Following involvement in her final DVM year, Elsa Glanville collaborated with the cattle team and helped manage a large and complex data set, leading to a series of recommendations for extension strategies. This provided substantial learning opportunities, including capacity building, development of extension material, and data recording and verification, all within the context of a developing nation.

4.6.2 The seroprevalence of *Toxoplasma gondii* in Victorian sheep flocks

Lamb survival is an important component of farm productivity and profitability, especially in dual purpose Merino and prime lamb flocks. Infectious agents of abortion and neonatal loss, including *Toxoplasma gondii,* can have an important role in reproductive wastage, although this is often sporadic and not investigated or identified. Toxoplasmosis is also a significant zoonotic disease.

The prevalence and risk factors for *T. gondii* infection in Victorian sheep flocks are not known. Consequently, this project investigated the seroprevalence of *Toxoplasma gondii* in mature ewes reared on farms in each of the major sheep-rearing regions of Victoria. On each farm a questionnaire was completed to collect information about potential risk factors, including proximity to bush, stocking density, supplementary feed practices and watering points and the presence of feral and domestic cats.

Following approval from both human and animal ethics committees at the University of Melbourne, sampling started in July 2016 and is nearly complete. Serological testing using a commercial ELISA kit is being performed by a commercial veterinary laboratory, with partial funding to support this testing coming from Coopers Animal Health following an application by Elsa Glanville.

4.7 Research training (PhD): A farm-based observational approach to disease surveillance (Caitlin Pfeiffer)

Animal health surveillance provides current, accurate information about livestock diseases, critical for international markets as well as for government regulations, protecting animal welfare and detecting emerging disease risks for humans and animals. Disease surveillance on sheep and beef farms in southern Australia is limited by irregular veterinary contact and a high tolerance for common disease events. Farm workers frequently observe disease events, but these observations are not captured by existing surveillance systems. Can farmers' observations be a valid surveillance data source? By investigating the usefulness of observational data, behavioural factors that influence reporting and a method for targeting surveillance, this research hypothesises that farm-based observational data can effectively complement existing surveillance strategies.

Thirty-nine Victorian farmers from 7 beef, 16 sheep and 16 mixed beef-sheep enterprises were enrolled in a pilot investigation of syndromic reporting of animal health events (Fig. 1). These farmers reported disease events each month from August 2014 to November 2016, in ten syndrome categories such as deaths, lameness and nervous signs (Table 7).

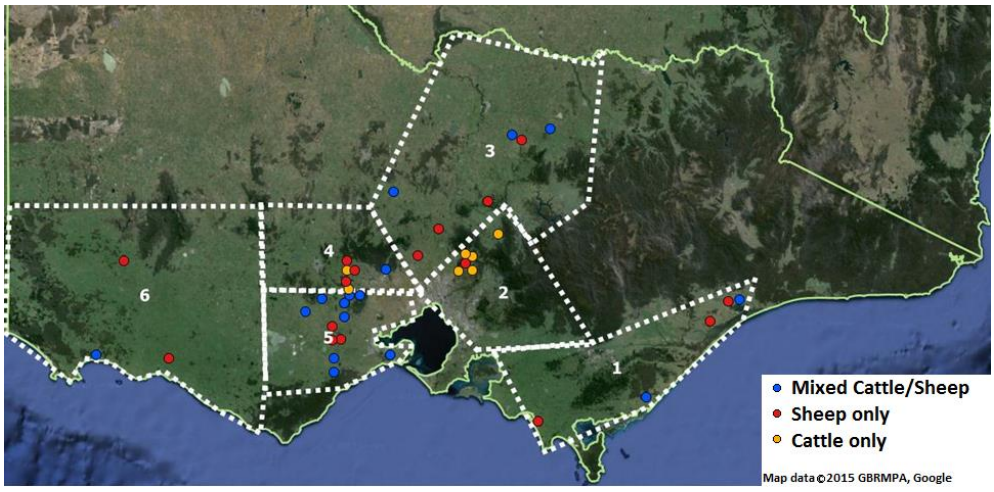

Fig. 1 Location of the 37 farms participating in the pilot investigation.

Data was collected for 16 months during the pilot phase (Aug 2014 to Nov 2015), after which an updated reporting format was used for another 13 months until Dec 2016. The revised format had an open-ended list of sub-syndromes that were derived from the free-text responses for each broad syndrome during the pilot phase. These increased the specificity of the data and allowed an estimate of confidence or uncertainty in the identification of a syndrome. For example, lameness of sheep had the sub-syndromes of footrot, foot abscess, infective arthritis, scabby mouth (parapoxvirus) and 'other' added.

Table 7. Syndromes used in a pilot investigation of farmer observations of disease

Disease syndrome	Example
Deaths	Deaths in lambing ewes
Reduced production or ill-thrift	Weaner “ill-thrift”
Gut or mouth signs	Scours
Lameness or limb signs	Foot abscess
Reproductive failure	Stillbirths and abortions
Nervous system signs	Staggers
Respiratory signs	Coughing
Skin or eye signs	Pinkeye
Urinary tract signs	Red urine
Other	Any other disease event

Each report included details of species affected, breed and stock class, clinical signs of disease, suspected causes and level of veterinary involvement. In total, 801 reports were received over the 28-month study period, describing disease events in around 142,000 sheep and 5000 cattle. This data has been analysed with a focus on mortality events in ewes and weaner sheep, as well as the participation and compliance of the reporting farmers. This analysis has confirmed the feasibility and usefulness of collecting farmers’ observations to assist in understanding disease occurrence in pasture-based livestock, and it is hoped that this will form the basis of a larger scale surveillance program in future (‘LANDI Phase 2’).

To investigate the attitudes of farmers towards disease events and veterinarians, three focus group discussions were held in late-2016 with sheep farmers from different regions of Victoria. These discussions were designed to reflect the ‘Theory of Planned Behaviour’ model of human decision-making. Transcripts from these focus groups were analysed using qualitative methods to determine the factors most affecting farmers’ likelihood of calling a vet and the major barriers to veterinary intervention on sheep farms. These has generated new information that will assist the development of passive surveillance strategies, with an emphasis on improving the likelihood of detecting unusual and emerging diseases.

A descriptive and preliminary network analysis of the patterns of sheep trading and other sheep movements was completed using data provided by Agriculture Victoria, then further detailed network analysis was undertaken. Investigating networks of livestock movements contributes to understanding the risk of infectious disease spread between different geographic areas, which can then inform where surveillance effort and resources such as a syndromic reporting system is focussed. Three consistent geographic clusters of sheep movement have been identified, informing the Victorian Government’s ongoing disease control programs and surveillance strategies.

One refereed paper has already been published from this work (Pfeiffer et al 2015) and a second paper was submitted in March 2018 (Pfeiffer 2018). Two other papers are in preparation and will be

submitted after the PhD thesis is submitted for examination, which is expected to occur by the end of July 2018. Currently, the chapter headings for the thesis are:

- Animal health surveillance design for imperfect disease reporting conditions: A review
- Participation of Australian sheep and beef farmers in syndromic disease reporting
- Epidemiology of adult ewe mortality in southern Australia: findings from a syndromic surveillance system
- Epidemiology of weaner sheep mortality in southern Australia: findings from a syndromic surveillance system
- How do sheep farmers respond to disease events? A qualitative investigation of the perceived role of veterinarians
- Sample size considerations for livestock movement networks
- Temporal and spatial characteristics of sheep movement in Victoria, Australia: A social network analysis

Conference attendance and talks given as part of the PhD program are summarised below:

- Pfeiffer CN, Firestone SM, Campbell AJD, Larsen JWA, Stevenson MA. The impact of sample size on understanding disease dynamics in livestock movement networks. *Proc. FVAS Postgraduate Symposium*, University of Melbourne, Werribee, November 2014: 27.
- Pfeiffer CN, Firestone SM, Campbell AJD, Larsen JWA, Stevenson MA. The impact of sample size on understanding disease dynamics in livestock movement networks. *Proc. Society Veterinary Epidemiology and Preventive Medicine*, Ghent, Belgium, March 2015: 146-160.
- Pfeiffer CN, Firestone SM, Campbell AJD, Larsen JWA, Stevenson MA. The right sample size for network analysis. *Proc. Aust & NZ College of Veterinary Scientists Epidemiology Chapter*, July 2015: 14.
- Pfeiffer CN, Campbell AJD, Firestone SM, Stevenson MA, Larsen JWA. Can farmers' observations become surveillance data? *Proc. Aust & NZ College of Veterinary Scientists Epidemiology Chapter*, July 2015: 39.
- Pfeiffer CN, Campbell AJD, Firestone SM, Stevenson MA, Larsen JWA. Using farmer observations for disease surveillance. *Proc. Mackinnon Project Seminar*, University of Melbourne, Werribee, September 2015: Session 6.
- Pfeiffer CN, Campbell AJD, Firestone SM, Stevenson MA, Larsen JWA. Participation of sentinel farmers in syndromic surveillance. *Proc. CRC Post-Graduate Conference*, Manly, November 2015: 13.
- Pfeiffer CN, Stevenson MA, Firestone SM, Larsen JWA, Campbell AJD (2015). Timeliness of farmers' responses in a monthly syndromic surveillance system. *Proc. FVAS Postgraduate Symposium*, University of Melbourne, Parkville, December 2015: 11.
- Poster presentation: Pfeiffer CN, Campbell AJD, Firestone SM, Stevenson MA, Larsen JWA (2015). Assessing engagement of sentinel farmers in syndromic surveillance reporting. Conference of the International Society for Veterinary Epidemiology and Economics, Yucatan, Mexico, November 2015.
- Pfeiffer C, Suter R, Firestone S, Campbell A, Larsen J, Stevenson M (2016). Dealing with network, spatial and missing data: Sheep movement in Victoria. *Proc Aust & NZ College Vet Sci Epidemiology Chapter*, July 2016: 61.

- Pfeiffer CN, Campbell AJD, Larsen JWA (2016). Using farmers' observations to estimate endemic disease prevalence. *Proc Aust Sheep Vet*, Dubbo, September 2016: 103-110.
- Suter R, Pfeiffer CN (2016). Movements of Victorian sheep, from the sheep Mob-based Movement database. *Proc Aust Sheep Vet*, Dubbo, September 2016: 150-153.
- Pfeiffer CN, Campbell AJD, Larsen JWA (2016). Weaner sheep mortality can be monitored by collecting farmers' observations. *Proc CRC Post-Grad Conference*, Manly, November 2016: 14.
- Pfeiffer CN, Firestone SM, Campbell AJD, Larsen JWA, Stevenson MA (2017). Which farmers to ask? Methods for identifying timely and reliable respondents for syndromic surveillance of farmers' observations. *Proc 3rd International Conference on Animal Health Surveillance*, Rotorua, NZ, 1-5 May 2017: 157-160.
- Pfeiffer C, Duncan K, Larsen J, Campbell A (2017). Ewe mortality in Southern Australia: data from the farmer's perspective. *Proc 9th International Sheep Veterinary Congress*, Harrogate, UK, 22-26 May 2017.
- Suter R, Pfeiffer C (2017). An analysis of the movements of sheep in Victoria, Australia. *Proc 9th International Sheep Veterinary Congress*, Harrogate, UK, 22-26 May 2017.
- Pfeiffer C, Firestone S, Stevenson M, Larsen J, Campbell A (2017). When do sheep farmers call the vet? *Proc AVA Conf*, Melbourne 4-9 June 2017.

5 Discussion

This project addresses a challenge for Australia's livestock industries – a reduced number of veterinary and farm management consultants with a detailed knowledge of the farm as a system. This situation has arisen because of gradual withdrawal by State Departments of Agriculture from extension services, with the proposal that the training and provision of skilled consultants should be managed directly by industry. However, many consultants were previously trained and developed their skills in Departments of Agriculture, and so the question arises "Who will develop the farm management consultants in future?". These are often referred to as 'expert generalists', and serve as a source of critical advice and appraisal of new information, both at a farm and industry level.

Sheep and beef farms need good advice to grow and develop their farming businesses. However, there is now less expertise and a reduced capacity to train farm advisors. This project aimed to address this training deficit, offering a comprehensive training program for veterinary consultants through the highly successful model developed by the Mackinnon Project (see Section 8.3 for a summary of Mackinnon 'alumni'). This group, located within the Faculty of Veterinary and Agricultural Sciences (FVAS) at Werribee, has been training veterinarians and successfully operating a whole farm consultancy service for the sheep and beef industries since 1982.

Three Sheep and Beef Industry residents completed their residency training from 2015-2018 with the support of the MLA Donor Company and the industry sponsor, The Scobie and Claire Mackinnon Trust. Two residents commenced in April 2015; Tabita Tan (a 2004 Murdoch University veterinary graduate) and Elsa Glanville (a 2014 University of Melbourne DVM graduate). Both followed the training model outlined in the project proposal, being enrolled half-time in two Masters courses at the University of Melbourne. Each of these post-graduate degrees, the Master of Veterinary Studies (MVS) and Master of Veterinary Science (MVSc), is 18 months for a full-time candidacy and so their part-time post-graduate candidacy was consistent with the 3-year residency training program.

The MVS is a clinical (consultancy and fieldwork) degree, whereas the MVSc is a research degree. Both candidates completed and passed the requirements for the MVS degree with honours. They have also completed the field work and submitted their theses for their respective research degrees – 'A pilot study of the seroprevalence of Q fever in cattle, sheep and goats in Victoria' (Dr Tabita Tan) and 'The effect of Ovilis Campyvax® on maiden ewe reproduction on four Victorian sheep farms' (Dr Elsa Glanville; awarded an Honours pass in March 2018).

The third resident was Dr Caitlin Pfeiffer, a 2011 veterinary graduate from the University of Melbourne. She enrolled in a full-time PhD with the University of Melbourne in March 2014, and was included in the Residency Program as an adjunct to her PhD studies in April 2015. She did not enrol in the parallel Masters courses. However, she completed most of the core clinical and consultancy training activities provided through the MVS program, although this was reduced in the analysis and writing up phase of her PhD thesis in 2017-18. Caitlin helped co-ordinate a major disease surveillance project, the Local Area Networks for Disease Information ('LANDI'), led by A/Prof John Larsen, from 2014-2017. This was a key component of her PhD research project – 'A farm-based observational approach to disease surveillance'.

An important component of this work was the development and assessment of a syndromic disease surveillance system based upon famers' observations. For this work, 39 Victorian farmers provided monthly reports about animal health events on their farms, using 10 syndromic categories. This pilot program operated until December 2016. Using this data she analysed the prevalence of mortalities of weaner sheep and ewes, reporting these findings in papers presented at the Australian Sheep Veterinarians conference in September 2016 and International Sheep Veterinary Congress in the United Kingdom in May 2017. She also undertook an analysis of how reliably and consistently farmers reported events on their farms, including whether they sought veterinary assistance during significant disease events. The results from these analyses were presented at the 3rd International Conference on Animal Health Surveillance at Rotorua in May 2017 ('Identifying timely and reliable respondents for syndromic surveillance of farmers' observations') and the Australian Veterinary Association's annual conference in June 2017 ('When do sheep farmers call the vet?').

As part of the MVS program, the residents received training in veterinary whole-farm consultancy relevant to the sheep and beef industries. This included seminars, farm visits, and clinical work led by senior Mackinnon staff and external experts. In the first year (2015) formal training included a farm management economics subject (AGRI30033) delivered by Prof Bill Malcolm, co-author of 'The Farming Game' (Malcolm, Makeham and Wright, 2005), animal disease investigation training delivered by Dr Tristan Jubb, a biostatistics training course run by the University of Melbourne Statistical Group, a Certificate IV course in 'Workplace training and assessment' (required to deliver programs to farmer groups, including Bestwool/ Bestlamb and Lifetime Ewe), and modules of the Masters of Veterinary Public Health (MVPH) program co-ordinated by Prof Mark Stevenson and Dr Simon Firestone from the FVAS Epidemiology unit (summarised in Table 2). In 2015, Dr Tan also completed a Post-graduate Masters in Livestock Health and Production through the Royal Veterinary College, University of London.

In Year 2 (2016), internal Mackinnon seminars were given on trace elements in grazing livestock, drought feeding, using the GrazFeed™ decision support tool and worm control in sheep and cattle. All Residents attended a biostatistics training course run by the University of Melbourne Statistical

Group, and a Statistical Modelling course presented by Dr Ian Dohoo, an internationally recognised veterinary epidemiologist. Case report seminars were presented on 'Investigation into the premature birth of weak neonates in a Merino flock' (Tan) and 'A detailed neurological assessment of post-partum recumbent ewes' (Glanville).

In Year 3 (2017), a two-day seminar was delivered to the residents and other junior Mackinnon consultants on the use of the GrassGro™, an important decision support tool that simulates grazing enterprises, and a half-day seminar on Animal Welfare issues. Tabita Tan attended a workshop on 'Accounting for bias and confounding in data', again delivered by Dr Ian Dohoo, and Drs Tan and Pfeiffer obtained their memberships of the Epidemiology Chapter of the Australian and New Zealand College of Veterinary Scientists by examination in 2015 and 2017, respectively. Elsa Glanville continued to build her expertise in sheep reproduction, including conducting pre-joining ram and ewe evaluations, comprehensive investigations into poor scanning and lamb marking percentages and presenting talks to farmer groups, including Bestwool at Hamilton and the Southwest Victoria Prime Lamb group.

In addition to their own research projects and clinical work, the residents were actively involved in the design and conduct of other research activities conducted by the Mackinnon group including:

- The LANDI disease surveillance project supported by the Victorian Sheep & Goat and Cattle Compensation Funds from 2014-Jan 2017 (all residents)
- Investigation of balanitis in beef bulls (MLA project BAHE 0227; TT & EG);
- A serological survey of the prevalence of toxoplasmosis in Victorian ewe flocks (sponsored by Coopers Animal Health; EG);
- Improving small ruminant health in the central dry zone of Myanmar (ACIAR-funded project with Dr Angus Campbell; EG);
- Assessing the efficacy of an autogenous vaccine against pneumonia of goats caused by *Mannheimia haemolytica* (sponsored by Nuchev P/L with A/Prof John Larsen; TT);
- Assessment of the benefits to reproductive efficiency of a commercial mineral supplement (Multimin™) in meat flocks (funded by Virbac Animal Health with John Larsen; TT & EG);
- The effect of stocking density and mob size on lamb marking percentages (TT with Dr John Webb Ware), and

The residency training program has produced three highly skilled and competent veterinary consultants, all of whom intend remaining involved in the sheep and beef industries for the foreseeable future, and so the benefits from this program will accrue for the next 25-30 years. Two residents have found placements within the Mackinnon Group, from which they will be able to continue their contributions to the grazing industries during the next phase of their careers.

6 Conclusions/recommendations

The residency training program has produced three highly skilled and competent veterinary consultants, all of whom intend remaining involved in the sheep and beef industries for the foreseeable future. Two residents have found employment within the Mackinnon Group from which they will be able to continue their contributions to these industries during the next phase of their careers.

One issue that emerged at the end of the program was the need for flexibility to allow different completion times for the research degrees, including a final practicum examination for the MVSc (clinical). Despite an undesirably long period initially spent negotiating the contract, hence a delayed start to the program, the consultancy training was completed as planned within the 3-year timeframe and consistent with the milestones in the contract for the MLA Donor Company grant. However, a different rate of progress with each of the research projects (field work, analysis and writing up), plus the different individual circumstances of each candidate (eg. requirement for personal and sick leave), meant that two of three research degrees were not completed by the scheduled end date for contract (Jan 2018). Fortunately, an extension to the final milestone date was agreed, until June 2018, and this enabled a second of the three residents to submit her thesis before the residency project officially ended.

In addition to the completion and final reporting of the project, this has practical ramifications for the continued payment of financial support (stipends). Under University arrangements, research degrees can be extended for up to 6 months full time (or equivalent time pro-rata for part-time candidates). This meant that considerable planning and careful administration of the budget was needed, but fortunately sufficient funds for the payment of stipends to the candidates during their extensions were available.

An agreement to contribute a similar level of funding for a second phase of the Residency Training program has been given by the industry sponsor, The Scobie and Claire Mackinnon Trust. At this stage two firm expressions of interest in this next round of residency training have been received, and one new resident will commence in Semester 2, 2018. A second candidate has been offered a place, but cannot commence until 2019. If a suitable third candidate can be identified then another application for funding will be submitted to the MLA Donor Company for training, from 2019-2021 ('Beef and Sheep Industry Veterinary Residency Program – Phase 2').

7 Bibliography

Malcolm LR, Makeham J and Wright V (2005) The Farming Game – Agricultural Management and Marketing (2nd edition). (Cambridge University Press, New York. ISBN 13 978 0 521 53755 1)

Pfeiffer CN, Firestone SM, Campbell AJ, Larsen J W, Stevenson MA (2015) Sample size considerations for livestock movement network data. *Preventive Veterinary Medicine* **122**,399-405.

Pfeiffer C, Campbell A, Larsen J, Stevenson M, Firestone S (2018) Using farmers' observations for animal health syndromic surveillance: identification and importance of timely and reliable respondents. *Preventive Veterinary Medicine* (submitted 9 Mar 2018).

8 Appendices

8.1 Theses

1. Glanville EJ (2018) 'The effect of Ovilis Campyvax® on maiden ewe reproduction on four Victorian sheep farms.' MVSc thesis, University of Melbourne, Australia.
2. Tan TS (2018) 'A pilot study of the seroprevalence of Q fever in cattle, sheep and goats in Victoria.' MVSc thesis, University of Melbourne, Australia (submitted for examination 8 June 2018).

3. Pfeiffer C (2018) 'A farm-based observational approach to disease surveillance'. PhD thesis, University of Melbourne, Australia (in preparation).

8.2 Presentations at conferences given as part of the residency program

1. Pfeiffer CN, Firestone SM, Campbell AJD, Larsen JWA, Stevenson MA (2015). The impact of sample size on understanding disease dynamics in livestock movement networks. *Proc Society Vet Epid Prev Med*, Ghent, Belgium, March 2015: 146-160.
2. Pfeiffer CN, Campbell AJD, Firestone SM, Stevenson MA, Larsen JWA (2015). Can farmers' observations become surveillance data? *Proc Aust & NZ College Vet Sci Epidemiology Chapter*, July 2015: 39.
3. Pfeiffer CN, Firestone SM, Campbell AJD, Larsen JWA, Stevenson MA (2015). The right sample size for network analysis. *Proc Aust & NZ College Vet Sci Epidemiology Chapter*, July 2015: 14.
4. Pfeiffer CN, Campbell AJD, Firestone SM, Stevenson MA, Larsen JWA (2015). Assessing Engagement of Sentinel Farmers in Syndromic Surveillance Reporting. *Int Soc Vet Epi Economics,* Yucatan, Mexico Nov 2015.
5. Pfeiffer CN, Campbell AJD, Firestone SM, Stevenson MA, Larsen JWA (2015). Participation of sentinel farmers in syndromic surveillance. *Proc CRC Post-Grad Conf*, Manly, November 2015: 13.
6. Pfeiffer C, Suter R, Firestone S, Campbell A, Larsen J, Stevenson M (2016). Dealing with network, spatial and missing data: Sheep movement in Victoria. *Proc Aust & NZ College Vet Sci Epidemiology Chapter*, July 2016: 61.
7. Pfeiffer CN, Campbell AJD, Larsen JWA (2016). Using farmers' observations to estimate endemic disease prevalence. *Proc Aust Sheep Vet*, Dubbo, September 2016: 103-110.
8. Suter R, Pfeiffer CN (2016). Movements of Victorian sheep, from the sheep mob-based movement database. *Proc Aust Sheep Vet*, Dubbo, September 2016: 150-153.
9. Tan T, Firestone S, Larsen J, Stevenson M. The seroprevalence of Q-Fever in sheep, goats and cattle in Victoria (2016). *Int Congress Tropical Disease and Malaria*, Brisbane 18-22 Sep 2016: 404.
10. Pfeiffer CN, Campbell AJD, Larsen JWA (2016). Weaner sheep mortality can be monitored by collecting farmers' observations. *Proc CRC Post-Grad Conf*, Manly, November 2016: 14.
11. Tan T, Firestone S, Larsen J, Stevenson M (2016). The seroprevalence of Q-Fever in sheep, goats and cattle in Victoria. *Proc One Health Ecohealth Conference*, Melbourne 3-7 Dec 2016: 121.
12. Glanville E, Campbell A, Larsen J (2016). The seroprevalence of *Toxoplasma gondii* in Victorian ewe flocks, and the associated risk factors. *Proc One Health Ecohealth Conference*, Melbourne 3-7 Dec 2016: 703.
13. Pfeiffer CN, Firestone SM, Campbell AJD, Larsen JWA, Stevenson MA (2017). Which farmers to ask? Methods for identifying timely and reliable respondents for syndromic surveillance of farmers' observations. *Proc 3rd International Conference on Animal Health Surveillance*, Rotorua, NZ, 1-5 May 2017: 157-160.
14. Glanville EJ, Larsen JWA, O'Brien D, Campbell AJD (2017). A randomised controlled field trial of Campyvax® vaccine on ewe reproductive output on four Victorian sheep farms. *Proc 9th International Sheep Veterinary Congress*, Harrogate, UK, 22-26 May 2017
15. Glanville EJ, Larsen JWA, Webb Ware JK, Campbell AJD (2017). Benefits of detailed neurological assessment in an investigation of post-lambing recumbency in extensively

managed ewes. *Proc 9th International Sheep Veterinary Congress*, Harrogate, UK, 22-26 May 2017.

16. Pfeiffer C, Duncan K, Larsen J, Campbell A (2017). Ewe mortality in Southern Australia: data from the farmer's perspective. *Proc 9th International Sheep Veterinary Congress*, Harrogate, UK, 22-26 May 2017.
17. Glanville EJ, Campbell AJD, Hanks J (2017). Practical interventions to improve small ruminant production in the Central Dry Zone of Myanmar: drenching and supplementary feeding. *Proc 9th International Sheep Veterinary Congress*, Harrogate, UK, 22-26 May 2017.
18. Suter R, Pfeiffer C (2017). An analysis of the movements of sheep in Victoria, Australia. *Proc 9th International Sheep Veterinary Congress*, Harrogate, UK, 22-26 May 2017.
19. Pfeiffer C, Firestone S, Stevenson M, Larsen J, Campbell A (2017). When do sheep farmers call the vet? *Proc AVA Conf*, Melbourne 4-9 June 2017.
20. Tan T, Firestone S, Larsen J, Stevenson M (2017). The seroprevalence of Q fever in sheep, goats and cattle in Victoria, ANZ College Vet Scientists, Science Week 6-8 July 2017.

8.3 Consultants and grazing industry scientists trained by the Mackinnon Group (1982-2018)

8.3.1 Master of Veterinary Studies (MVS – Diseases and Management of Agricultural Animals)

1. Cameron, Simon (1985). The role of nutrition, shelter and genotype in the prevention of neonatal losses in sheep.
2. Abbot, Kym (1986). Management evaluation on grazing properties in South Australia with particular reference to financial analysis.
3. Neithe, Geoff (1986). Opportunities for implementation of herd health and production programs in the Northern Territory.
4. Nilon, Paul (1986). Nutritional ill-thrift in weaner sheep: causes and management options.
5. Brightling, Anthony (1986). A review of State sheep lice control strategies for Victoria.
6. McGregor, Peter (1987). Improving cattle health and production management services on the North Coast of New South Wales.
7. Watts, Tim (1987). A review of permanent oestrogenic infertility in sheep and its effect on the profitability of merino wool enterprises.
8. Sackett, David (1987). Sheep flock health and production management programs.
9. Allworth, Bruce (1988). Control and eradication of footrot.
10. Daniel, Geoffrey (1988). The importance of soil erosion when deciding upon farm stocking rate.
11. Rolls, Peter (1988). Drought - nutrition and management.
12. Jordan, David (1988). An evaluation of control programs for gastro-intestinal nematodes of sheep in New South Wales
13. Roberts, Daniel (1988). A review of Footrot in Australian sheep flocks and a study of the factors associated with a farm being affected by Footrot in four shires in Western Australia.
14. Nicholas, Masten (1989). Opportunities to improve the profitability of four properties in Southern New South Wales.
15. Carr, Anthony (1989). Time of lambing: importance, extension and implementation.

16. Trengove, Colin L (1991). Opportunities to improve farm profitability through genetic improvement of Merino sheep.
17. Irving, Rosemary F (1991). Factors which influence the selection of time for shearing on a property in Gippsland.
18. Taylor, Richard P (1991). Ram breeding for the commercial woolgrower.
19. Webb Ware, John (1992). Control of Gastrointestinal parasitism in sheep flocks in eastern Australia.
20. Maclean, Murray F (1992). Practical aspects of changing from autumn to spring lambing.
21. Salmon, Elizabeth M (1992). Genetic and economic gains from the use of artificial insemination and multiple ovulation and embryo transfer.
22. Williams, Scott H (1993). The effect of farm management practices on wool quality and income from wool.
23. Power, Megan E (1993). Pasture renovation in north east Victoria.
24. Thompson, Graham K (1993). Prickly acacia infestation of the Mitchell grasslands.
25. Cox, Jonathan W (1995). Breeding bulls in a commercial beef cattle herd.
26. Counsell, David C (2000). Wool price risk management.
27. Tan, Tabita Su-En (2018). In conjunction with MVSc (clinical), Mackinnon Residency program.
28. Glanville, Elsa J (2018). In conjunction with MVSc (clinical), Mackinnon Residency program.

8.3.2 Master of Veterinary Science (MVSc)

1. Grant, Ian M (1984). Evaluation of a flock health and production programme in commercial flocks in south-west Victoria.
2. Ridge, Sally E (1994). Evaluation of an absorbed enzyme-linked immunosorbent assay for bovine Johne's disease and application of the assay to Johne's disease control in Victoria.
3. Niven, Paul G (2000). The integration of grazing management with anthelmintic treatment to control trichostrongylid infections of sheep.
4. Swaney, Susan (2004). Internal parasite infections of Merino sheep grazed at two stocking rates.
5. Buckley, David (2005). The economic response to seasonal rainfall and the value of seasonal rainfall forecasts on Australian farms.
6. De Cat, Sandra (2007). The over-wintering ecology of *Lucila cuprina* in south-eastern Australia.
7. Tyrell, Leah (2013). Comparison of Programs for the Control of Blowfly-Strike in Merino sheep in South-Eastern Australia.
8. Kirk, Beata (2016). Internal Parasitism and Production in Prime Lamb Flocks.

8.3.3 Doctor of Philosophy (PhD)

1. Donnelly, John R (1983). The productivity of breeding ewes grazing on lucerne or grass-clover pastures.
2. Spath, Ernesto JA (1984). Calving date and hypomagnesaemic tetany in beef cattle.
3. Larsen, John WA (1997). The pathogenesis and control of diarrhoea and breech soiling ('winter scours') in adult Merino sheep.
4. Campbell, Angus D (2007). The effect of time of shearing on wool production and management of a self-replacing merino flock.
5. Stanger, Kelly J (2017). Bacterial enteritis in young Merino sheep.