The One Health Approach to Q Fever Prevention and Control in South Australia

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27 May 2021 Md Rezanur Rahaman

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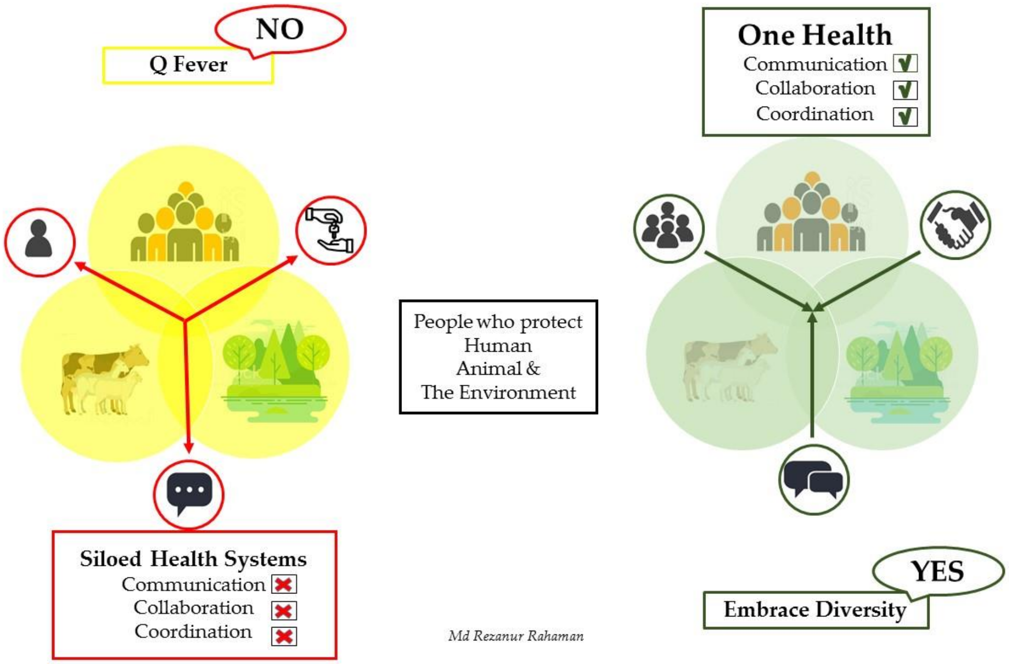
Keywords

- Animal and veterinary science
- *Coxiella burnetii*
- Epidemiology
- General practitioner
- Knowledge, attitudes and practices
- Livestock
- Multi-sectoral
- Occupational
- One Health
- Perspectives
- Prevention and control
- Q fever
- Qualitative research
- South Australia
- Spatial
- Stakeholder
- Vaccination
- Zoonosis

Abstract

Graphical abstract



Background

Q fever is a zoonotic disease, transmissible from animals to humans, and has potential for community outbreaks. Despite the availability of a human vaccine, Australia continues to bear a substantial burden of Q fever among at-risk populations such as abattoir workers, livestock farmers, and wildlife workers. A One Health approach, which engages cross-sectoral collaboration among human, animal and environmental health sectors and creates mutually benefiting outputs for all, is an appropriate framework to consider for Q fever prevention and control.

Q fever epidemiology is complex because of the involvement of multiple species in disease transmission, presence of ticks in the environment that constantly serve as a vector transmitting *Coxiella burnetii* between wildlife and livestock, and the proximity and interactions of humans to animals through an array of practices including farming, meat processing or even shooting. Given the extent of agricultural practices humans are involved with, there may be associations between livestock densities and spatial clustering of human cases. However, evidence concerning the spatial relationship between cattle, sheep and goat populations and human Q fever cases is still relatively scarce. Given the inherent occupational risks of Q fever for unvaccinated animal and veterinary science students and livestock farmers, assessment of their perspectives on Q fever prevention using a One Health framework is important because evidence suggests that they are at risk, however, little is known about the extent of that risk. Finally, exploring Australian general practitioners' (GPs') and broader health systems' preparedness for Q fever prevention through the analysis of multi-stakeholders' perspectives on the constituents of an effective systemic approach to disease prevention and the potential affordances of a One Health framework may attract considerable interest for guidelines and recommendations for policy.

Aims

The thesis is divided into six studies each with specific aims. Study 1, a literature review, aimed to assess whether components of One Health have been utilized for Q fever prevention and control in Australia and internationally. Study 2 aimed to analyze Q fever notification data in order to define at risk groups based on occupation and possible exposure in South Australia (SA). In this study, the association between notified Q fever cases and the spatial and temporal distribution of cattle, sheep and goats in SA was examined. Studies 3 and 4 aimed to assess the knowledge, attitudes and practices about Q fever and its prevention among university animal and veterinary science students, and livestock farmers in SA, while study 5 compared and contrasted the varying perceptions of Q fever and its prevention between students and farmers. Finally, study 6 aimed to explore multi-stakeholders' perspectives for identifying barriers and enablers of a One Health approach to Q fever prevention and control. An overall aim was to examine Q fever control and prevention approaches in SA, and to explore the enablers and barriers of adopting a One Health approach in order to provide policy recommendations and guidelines.

Methods

Study 1 involved a literature review of published studies on Q fever that utilized one or more components of a One Health approach. Study 2 was an epidemiological review of Q fever notifications between January 2007 and December 2017 obtained from the Communicable Disease Control Branch, SA Department for Health and Wellbeing (CDCB, SA Health). Notification rates and incidence rate ratios were calculated. Additionally, spatial mapping of Q fever notifications was undertaken using livestock density data and the locations of abattoirs and saleyards in SA. Studies 3 and 4 were an online survey of animal and veterinary science students enrolled at the University of Adelaide (UoA), and members of Livestock SA representing cattle, sheep and goat farmers in SA to gauge their perceptions about Q fever and its prevention. Descriptive analysis and logistic regression were used in studies 3 and 4. Study 5 collated the open responses from studies 3 and 4 concerning suggested strategies for Q fever prevention. Thematic analysis was performed to identify emerging themes. Study 6 included semi-structured interviews among participants drawn from four stakeholder groups including GPs and veterinarians who play a key role in Q fever surveillance; SA Health and SafeWork SA representatives who have roles and responsibilities concerning Q fever policy and guidelines; researchers from UoA and the

University of Queensland concerning evidence and current preventative practice; and representatives from Livestock SA and NSW farmers whose suggestions are instrumental for industry specific tailored recommendations. A qualitative approach was undertaken to analyze emerging themes concerning Q fever diagnosis, notification, and control and prevention including vaccination.

Results

In study 1, seven major themes were elicited from the literature review including human risk assessment, human and animal serology, integrated human-animal surveillance, vaccination for at-risk groups, environmental management, multi-sectoral collaboration, and education and training as important components of a One Health approach.

In study 2, 167 Q fever cases were reported in SA during 2007–2017, and rates (1.52/100,000) were higher among males (72%) aged 21–40 years, with 22% of notifications recorded in a suburb containing an abattoir. Commonly reported occupations were livestock farmers (35%), abattoir workers (20%) and individuals with no known occupational risks (15%). Eight cases (5%) reported prior vaccination for Q fever. Annual goat, cattle and sheep counts were highly correlated with each other ($P < 0.001$), but none of them, or the total number of livestock were associated with Q fever notifications ($P \geq 0.370$).

In study 3, 46% of animal and veterinary science students reported limited knowledge of Q fever. Most respondents (96%) reported moderate-high level exposure to high-risk animals. Among animal science students who reported vaccination status, 61% were not vaccinated for Q fever. Identified barriers to vaccination included cost, time and access to healthcare with strategies aimed at promoting awareness, improving healthcare access and subsidized and mass vaccination.

In study 4, 80% of livestock farmers who completed the survey had been farming for ≥ 20 years, with sheep and beef cattle their primary stock. The majority of farmers (71%) had good knowledge of Q fever, and 97% were aware of availability of a human vaccine. Despite 95% of farmers acknowledging that the vaccine was effective against Q fever, 42% remained unvaccinated. Identified barriers to vaccination included poor access to a trained doctor and time and cost related to vaccination. Subsidized vaccination and improved awareness were considered to be important strategies for promoting vaccine uptake.

In study 5, similar barriers and strategies were highlighted although the main themes identified differed between students and farmers. While students were more focused on the issues around cost, farmers emphasized the importance of the vaccination and were concerned about having access to an accredited GP and GPs' knowledge about Q fever.

In study 6, six major themes emerged including understanding Q fever burden, effective surveillance, the role of general practitioners and other stakeholders, barriers and enablers of vaccination, an integrated approach, and increased Q fever awareness. Participants highlighted that the role of GPs is instrumental in diagnosing Q fever, reporting of Q fever cases to CDCB, and treatment and prevention through health promotion and vaccination. However, the stakeholders also reported that GPs possessed limited knowledge and awareness of Q fever, and believed that leadership was required from SA Health to foster communication, collaboration, and the inclusion of GP networks within an inter-sectoral approach.

Conclusions and recommendations

While reviewing the literature, significant variation was noted in the practices of a One Health approach to Q fever prevention. Nevertheless, most studies highlighted multi-sectoral collaboration as the key to successful Q fever prevention programs. Higher Q fever rates among young males highlighted a workforce with a high turnover of staff, a transient workforce and possibly under vaccinated, which was consistent with abattoir workers' profiles, suggesting value of vaccinating this group. Individuals who developed Q fever after vaccination raised concerns about waning immunity or vaccine efficacy, requiring longitudinal studies to assess the degree of immunity conferred by the vaccine.

Animal and veterinary science students possessed limited knowledge about Q fever transmission. Their adherence to biosecurity guidelines, a One Health principle, could potentially reduce zoonosis including Q fever transmission. Universities should promote Q fever vaccination among both animal and veterinary science students with possible subsidies. Despite livestock farmers possessing good knowledge about Q fever, biosecurity measures were poorly practiced, and hence adherence to these practices may reduce their chance of contracting the disease. Government and industry partnerships are recommended to promote Q fever awareness, train GPs, subsidize vaccination, and increase its uptake among livestock farmers.

Updating medical curricula could potentially enhance clinical understanding for health practitioners. It is prudent to suggest that SA Health should lead the existing zoonosis working group while encouraging active participation from all relevant stakeholders fostering inclusiveness and less power disparity. Further research is required to identify potential options around funding and data sharing between departments for seamless delivery of Q fever prevention services. Although a One Health framework is not devoid of challenges, opportunities for implementation will enhance Q fever prevention programs' effectiveness.

Publications during candidature

Publications contributing to this thesis

Published

1. Rahaman MR, Milazzo A, Marshall H, Bi P. Is a One Health approach utilized for Q fever control? A comprehensive literature review. *International Journal of Environmental Research and Public Health*. 2019;16:730.

2. Rahaman MR, Milazzo A, Marshall H, Bi P. Spatial, temporal, and occupational risks of Q fever infection in South Australia, 2007–2017. *Journal of Infection and Public Health*. 2020;13:544-51.

3. Rahaman MR, Milazzo A, Marshall H, Chaber A-L, Bi P. Q fever vaccination: Australian animal science and veterinary students' One Health perspectives on Q fever prevention. *Human Vaccines & Immunotherapeutics*. 2021;17:1374-81.

4. Rahaman MR, Marshall H, Milazzo A, Crabb D, Bi P. Q fever prevention and vaccination: Australian livestock farmers' knowledge and attitudes to inform a One Health approach. *One Health*. 2021;12:100232.

Submitted for publication

5. Rahaman MR, Burgess T, Marshall H, Milazzo A, Chaber A-L, Crabb D, Bi P. Q fever prevention: perspectives from university animal science and veterinary students and livestock farmers. Submitted to *The Australian Journal of Rural Health* (ID ─ AJRH-02-2021-0029).

6. Rahaman MR, Hodgetts K, Milazzo A, Marshall H, Chaber A-L, Crabb D, Bi P. Q fever prevention in Australia: general practitioner and stakeholder perspectives on preparedness using a One Health approach. Submitted to *The Medical Journal of Australia* (ID – mja21.00558).

Other publications

Published

7. Rahaman MR, Alroy KA, Van Beneden CA, Friedman MS, Kennedy ED, Rahman M, Balajee A, Muraduzzaman AKM, Shirin T, Flora MS, Azziz-Baumgartner E. Etiology of severe acute respiratory infections, Bangladesh, 2017. *Emerging Infectious Diseases*. 2021;27:324-26.

Unpublished and unsubmitted work written in manuscript style

8. Rahaman MR, Dear K, Milazzo A, Marshall H, Satter SM, Rahman M, Varghese BM, Tong MX, Bi P. Short-term effects of climate variability on childhood diarrhoea in Bangladesh: multi-site time-series regression and meta-analysis. *Ready to submit*.

9. Rahaman MR, Dear K, Milazzo A, Marshall H, Satter SM, Rahman M, Bi P. Climatic factors and rotavirus infections among children under five years old in Bangladesh: time-series analysis. *Manuscript drafted*.

Presentations during candidature

International conferences

1. Rahaman MR, Milazzo A, Marshall H, Bi P. Livestock and its related occupations in spatial clustering of Q fever in South Australia, 2007–2017. The 31st Annual Conference of the International Society for Environmental Epidemiology (ISEE), 25–28 August 2019 | Utrecht, the Netherlands | *Poster discussion*.

2. Rahaman MR, Burgess T, Milazzo A, Marshall H, Chaber A-L, Crabb D, Bi P. Do Australian livestock farmers perceive Q fever prevention differently from animal science and veterinary students? Accepted virtual congress, World Congress of Epidemiology (WCE) 2021, September 2021 | *Oral long presentation*.

3. Rahaman MR, Milazzo A, Marshall H, Satter SM, Rahman M, Bi P. Intra-country climate variability and geographical distribution of diarrhoea among children under five in Bangladesh. The 32nd Annual Conference of the ISEE, 20–27 August 2020 | Virtual Conference | *Oral presentation*.

4. Rahaman MR, Milazzo A, Marshall H, Satter SM, Rahman M, Bi P. Climatic factors and rotavirus infections among children under five years old in Bangladesh: time-series analysis. The 32nd Annual Conference of the ISEE, 20–27 August 2020 | Virtual Conference | *E-poster presentation*.

National conferences

5. Rahaman MR, Milazzo A, Marshall H, Chaber A-L, Bi P. South Australian veterinary students' One Health perspectives on Q fever prevention. Communicable Diseases Control Conference 2019, 19–21 November 2019 | Canberra, Australia | *Long oral presentation*.

6. Rahaman MR, Milazzo A, Marshall H, Crabb D, Bi P. One Health perceptions of Q fever among South Australian livestock farmers. Communicable Diseases Control Conference 2019, 19–21 November 2019 | Canberra, Australia | *Rapid-fire presentation*.

7. Rahaman MR, Milazzo A, Marshall H, Chaber A-L, Bi P. Q fever perceptions among South Australian animal science and veterinary students. Australian Public Health Conference 2019, 17–19 September 2019 | Adelaide, Australia | *Long oral presentation*.

Local conferences

8. Rahaman MR, Milazzo A, Marshall H, Bi P. Is a One Health approach utilized for the prevention of Q fever? SA State Population Health Conference, 1 December 2018 | Adelaide, Australia | *Oral presentation*.

9. Rahaman MR, Milazzo A, Marshall H, Bi P. Q fever epidemiology, and its spatial and occupational risks in South Australia, 2007–2017. The 13th Florey Postgraduate Conference 2019, 24 September 2019 | Adelaide, Australia | *Poster presentation*.

10. Rahaman MR, Milazzo A, Marshall H, Satter SM, Rahman M, Bi P. Short-term effects of meteorological conditions on risk of rotavirus infection in children under five years of age in Bangladesh. The 14th Florey Postgraduate Conference 2020, 30 September 2020 | Virtual Conference | *Poster presentation*.

Awards and achievements during candidature

Title	Category	Institution	Year
1. Invited Global Talent	Global Talent Program	Department of Home Affairs, Australia	2021
2. Research Fellow ─ MAE, Academic Level B	Full-time Employment	The Australian National University	2021–2024
3. Nominated Training Developer	ADB Technical Assistance for COVID-19 Vaccine Rollout	The Australian National University	2021
4. Adelaide Graduate Award	Award	The University of Adelaide	2020
5. ISEE 2020 Virtual Conference Travel Award	Scholarship	ISEE 2020 Virtual Conference Organizing Secretariat	2020
6. International Health Special Interest Group Travel Scholarship	Scholarship	Public Health Association of Australia (PHAA)	2019
7. The Hospital Research Foundation Travel Grants	Scholarship	The Hospital Research Foundation	2019

8. Walter & Dorothy Duncan Trust Board Conference Travel Grant	Scholarship	Walter & Dorothy Duncan Trust	2019
9. Konrad Jamrozik Student Scholarship	Scholarship	PHAA	2019
10. The University of Adelaide International Wildcard Scholarship	Scholarship	The University of Adelaide	2017–2021
11. TEPHINET Global Media Coverage on Publication in *Emerging Infectious Diseases*.	Media Coverage	TEPHINET	2021

Notes. MAE: Master of Philosophy in Applied Epidemiology; ADB: The Asian Development Bank; TEPHINET: Training Programs in Epidemiology and Public Health Interventions Network.

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Dedication

My son Jaasan Rahaman (07.08.2013–29.10.2014)

&

Global citizens who have died from COVID-19 and those who may continue to do so

Abbreviations and acronyms

ABS	Australian Bureau of Statistics
ACRRM	Australian College of Rural and Remote Medicine
AMIC	Australian Meat Industry Council
AVA	Australian Veterinary Association
AWR	Australian Wildlife Rehabilitator
C. burnetii	*Coxiella burnetii*
CDCB	Communicable Disease Control Branch
CI	Confidence Interval
DEW	Department for Environment and Water
DoH	Department of Health
DVM	Doctor of Veterinary Medicine
EHRG	Environment and Health research Group
GP	General Practitioner
HREC	Human Research Ethics Committee
IRR	Incidence Rate Ratio
IRSAD	Index of Relative Socio-Economic Advantage and Disadvantage
KAP	Knowledge, Attitudes and Practices
NQFMP	National Q Fever Management Program
NSW	New South Wales
OR	Odds Ratio
PCR	Polymerase Chain Reaction

PE	Primary Exposure
PIC	Property Identification Code
PIRSA	Department of Primary Industries and Regions
QFS	Q Fever Fatigue Syndrome
RACGP	Royal Australian College of General Practitioners
RR	Risk Ratio
SA	South Australia
SA Health	SA Department for Health and Wellbeing
SAVS	School of Animal and veterinary sciences
SEIFA	Socio-Economic Indexes for Areas
UoA	University of Adelaide

1

Chapter 1 ─ Introduction

1.1 Preface

This chapter provides an overview of Q fever including public health significance, global and Australian burden of disease, prevention measures and epidemiological trends in Australia. Further to that, a relatively novel framework a One Health approach will be introduced. Finally, highlights concerning the continued challenges for Q fever prevention, knowledge gaps and project justification, research aims and objectives and an outline of the thesis structure will be presented.

1.2 Q fever

Q fever, which originated from the term "query fever",[1] is caused by the obligate intracellular bacterium *C. burnetii*, first described in 1937 among abattoir workers in Brisbane, Australia.[1,2] *C. burnetii* is present worldwide except in New Zealand and Antarctica.[3,4] The organism exists in a range of intermediate hosts including livestock,[5] wildlife,[6,7] companion animals,[1,8] and ticks.[1,9] *C. burnetii* withstands harsh environmental conditions such as heat and desiccation, and in the spore form can survive for years.[1,10,11] Involvement of multiple species together with environmental stability of *C. burnetii* makes Q fever an ongoing burden for a country with significant health and economic implications.[11-13]

Q fever is a zoonotic disease as it occurs through the transmission of *C. burnetii* from animal reservoirs to humans.[1] Transmission is predominantly through the airborne route; however other modes of spread have also been documented including consumption of unpasteurized milk and milk products,[14] blood transfusion,[15] and rarely sexual transmission.[16] The clinical spectrum of Q fever is extremely variable spanning an acute influenza-like illness to serious health issues such as endocarditis.[17] One of the most common chronic sequelae is post Q fever fatigue syndrome (QFS),[18,19] which can be debilitating for some people experiencing severe fatigue.[20] Mental illness including mood disorders such as depression following chronic sequelae have been reported.[19]

1.3 Disease burden

Although *C. burnetii* is present worldwide, the burden of Q fever varies across regions and even among countries in the same region.[21] In Europe, for instance, the annual incidence of Q fever varies from two cases per million persons in England and Wales to 500 cases per million persons in France.[17,22,23] On the other hand, the Netherlands had experienced the largest Q fever outbreak in history with over 4,000 cases between 2007 and 2010.[19] The United States' annual incidence is similar to England and Wales with over two cases per million persons.[23] In Oceania, New Zealand remains free from Q fever with Australia bearing substantial burden of an annual incidence peaking to 50 cases per million persons.[21]

Certain occupational groups carry the burden of Q fever in Australia. The most commonly reported occupations are ones that have contact with animals including abattoir workers,[18,24] livestock farmers,[25,26] wildlife workers,[6] veterinarians and veterinary nurses,[27] and animal and veterinary science students.[28,29] Contracting Q fever through occupational exposure has implications at the personal and industry level. While the former includes physical and mental health issues and chronic sequelae associated with diagnosis of Q fever, the latter concerns compensation claims incurred in meat and livestock industries due to loss of worktime.[30] Considering the inflation rates of currencies, an Australian review estimated compensation claims to approximate A$4.3 million per annum from acute illness.[21] However, real costs around chronic Q fever are difficult to estimate because of its nature, for example, QFS is often long-term, vaguely defined, and associated costs are poorly recorded.[30]

1.4 Q fever prevention and vaccination

Characteristics of *C. burnetii* including survival in harsh environments,[11] presence of the bacterium in multiple species (livestock,[31] dogs and cats,[1] kangaroos and wallabies,[32] and ticks[33,34]) coupled with complexities in diagnosing the disease in humans[1] poses challenges for Q fever prevention. Limited public health capacity to vaccinate an extensive reservoir, agricultural practices exposing humans to ongoing susceptibility, and occupational related risk to Q fever indicates the need for non-specific and specific preventative measures. Non-specific measures include health education for the public, at-risk populations and health practitioners;[35] and hand hygiene, mask wearing, use of gloves and protective clothing particularly during high-risk activities such as handling birth fluids;[36] while the specific measure is vaccination of humans and animals.[37-39]

Notable public health interventions in Australia concerning Q fever prevention have included: mandatory notification since 1977,[40] licensure of the human vaccine for Q fever "Q-Vax®" since 1989,[24] and the subsidized National Q Fever Management Program (NQFMP) between 2001 and 2006.[41] The first phase of the NQFMP targeted abattoir workers and shearers while the second one extended to farmers and their families.[41] The results showed a substantial decrease in Q fever notifications across Australia,[41] particularly among abattoir workers.[42] However, cessation of the NQFMP has resulted in inadequate Q fever control and notifications have increased since 2007, which reinforces the need for a sustainable subsidized vaccination program.[43]

Vaccination of animal populations has been the practice in some countries. For example, the Netherlands implemented a mandatory small ruminant vaccination program during the community Q fever outbreak in 2009.[19,39] However, due to biosecurity concerns on imported vaccines, Australia has never used an animal vaccination despite efforts to import the inactivated Phase I livestock vaccine from France during a Victorian farm outbreak in 2012–2014.[38] Unlike the Netherlands with a relatively defined animal population (farm animals), it may be less possible or at least extremely resource intensive to attempt vaccination of

Australian livestock and wildlife due to the extensive animal reservoir. This leaves the most viable specific disease prevention measure of vaccination for at-risk human populations.[38,44]

1.5 Epidemiological trend for Q fever in Australia

Despite the highly efficacious Q-Vax®,[45] and the effective NQFMP,[41] Q fever notifications in Australia have not reduced substantially post-NQFMP period.[43] Q fever notifications pre-NQFMP were higher in abattoir workers compared to livestock workers. On the other hand, there was an overall reduction in Q fever notification during the vaccination program, but an increase in cases among livestock workers compared to abattoir workers post-NQFMP.[42,46] While relatively fewer notifications have been reported among abattoir workers indicating the effectiveness of the NQFMP, increased reporting among livestock workers highlight complexities in the occupational epidemiology of Q fever.[42]

There are several reasons for this change in the epidemiology of Q fever in Australia. The most convincingly hypothesized one is less uptake of the vaccine among non-abattoir workers, particularly farmers living in regional areas,[41,47] and limitations of the short-term NQFMP intervention to carry out sustainable changes.[43,48] In addition, other challenges for Q fever prevention include the inability to vaccinate animal reservoir, environmental sustainability of *C. burnetii*, and geographical remoteness of farming communities which have contributed to inadequate disease control among rural populations.[11,43,47] Acknowledging these limitations, a One Health approach with human vaccine as an integral component would provide a stronger framework to manage the challenges related to Q fever prevention in Australia.

1.6 One Health approach

While the most simplistic notion of a One Health approach is to have human, animal and environmental health systems working together, a thoughtful definition may involve recognizing the interconnectedness of different sectors and allowing system changes for creating mutually beneficial outputs to protect the health of all species.[21,49,50] System change is not easy and requires understanding the complexities in the emergence of a zoonotic disease.[49] Therefore, an effective approach to managing zoonoses including Q fever may require better understanding of multiple factors, and their interconnectedness that serves as a pathway for emerging diseases. This can be achieved through inter-sectoral communication, stakeholder participation, and data sharing using a common platform.[21,49] An integrated health system may help generate positive outputs e.g., healthy species as an offset to emerging diseases, which are often outcomes of a siloed health system.

An example of an integrated system while responding to the recently emergent COVID-19 pandemic is the establishment of a high level One Health expert collaboration led by the World Health Organization (WHO) with representation from the Food and Agriculture Organization of the United Nations (FAO), the World Organisation for Animal Health (OIE), and the United Nations Environment Programme (UNEP).[51] One Health collaboration is very timely and relevant for reminding us of the practical reality and the need for multi-sectoral collaboration, particularly in addressing zoonotic diseases.

In Australia and internationally, there has been successful application of a One Health approach in controlling Q fever outbreaks.[38,52-54] A well-known example adopted in Victoria, Australia consisted of intensive screening and vaccination of humans, and the management of contaminated materials including animal excrement.[38] Although the Victorian example demonstrates the public health response to a Q fever outbreak, interdisciplinary control and prevention measures including human vaccination, attempt at vaccinating farm animals and environmental decontamination highlights the One Health nature of the response. All these measures effectively controlled the outbreak in the Victorian goat farm. The Netherlands application was different in its scope and mandatory measures included animal notification, animal vaccination, waste management, bulk milk monitoring, breeding restriction and animal culling.[38,53,54] It is proposed that a One Health approach should be considered outside of an outbreak investigation, that is, applications of the framework to broader Q fever control and prevention approaches. Following that recommendation, in Australia, several observational studies have recently been conducted within a One Health framework.[25,28,29] These studies utilized a holistic approach of understanding Q fever epidemiology, the role of animal reservoirs and risks to humans, assessing at-risk occupations' preparedness for disease prevention, and identifying the barriers and enablers of implementing interventions through the analysis of stakeholder perspectives.

1.7 Continued challenges

Despite discernible successes of a One Health approach to Q fever prevention, particularly in outbreak investigations, the characteristics of *C. burnetii* still pose a continued challenge to healthcare systems.[55] One challenge is the diagnostic complexities,[1,13,56] which is a key determinant of underreporting of Q fever. As Q fever may remain asymptomatic in 60% of cases,[36,57] affected individuals are unlikely to seek medical care and hence are not counted in the human surveillance system requiring notification from general practitioners (GPs) and the laboratory.[38,58] Concerning surveillance, another challenge is the geographical heterogeneity in Q fever reporting, which may be influenced by proximity of wildlife to human populations, heavy environmental contamination due to livestock and wild animals, and geographical remoteness of at-risk populations and their limited access to GPs.[47] In addition, limited evidence is available on the spatial distribution of livestock and its association with human cases.[59]

Suboptimal knowledge and awareness about Q fever among at-risk populations such as abattoir workers and farmers, lack of adherence to preventative measures, and poor uptake of human vaccination are some identified challenges.[25,60-63] Knowledge and awareness of Q fever among health providers such as GPs and veterinarians including animal and veterinary science students is also key to successful disease prevention through the practice of biosecurity interventions and human vaccination, which was reportedly low in several studies.[28,61,64-66] Finally, a system factor that often prohibits the implementation of Q fever preventative measures is the lack of inter-sectoral communication and coordination rooted in a siloed health system.[25,43,49] In keeping with these challenges this thesis identified knowledge gaps highlighted below and a framework combining a number of studies to address them is proposed.

1.8 Knowledge gaps and project justification

Current literature on Q fever highlights limitations in understanding Q fever epidemiology, particularly about human notifications and their link with the spatiotemporal distribution of livestock animals. Although some studies have classified at risk populations based on their occupations, state specific data in SA was not available. Furthermore, no Australian study has examined the links of Q fever cases with livestock densities, therefore, this research analyzed notification data and linked them with spatial distribution of cattle, sheep and goats. While interpreting results from this study, a causal interpretation should be cautioned as an ecological fallacy of an incorrect assumption at an individual level based on group data,[67] may accidentally be introduced with potential public health implications.

Information on at risk populations' knowledge, attitudes and practices (KAP) concerning Q fever prevention and control was limited requiring further studies among commonly reported at-risk occupational groups such as livestock farmers and also university animal and veterinary science students as explored in this research. Analysis of Australian health providers' including GPs and veterinarians' perspectives has not been carried out to understand their Q fever preventative practices including biosecurity interventions and human vaccination. Finally, the feasibility and perceptions of adopting a One Health approach, its possible challenges and opportunities have not been explored within a multi-stakeholder framework. In order to address the identified gaps in the literature this research was conducted using six different studies.

Study 1 (Chapter 2) encompassed a major literature review examining the utilization of a One Health approach to Q fever prevention and control in Australia and internationally. This was performed to define the scope and methodologies for this research, and a manuscript arising from this work was published in February 2019.[21] An update to the literature since 2018 (when the published review was conducted) has been incorporated in Chapter 2 to provide recent evidence on a One Health approach to Q fever prevention.

Study 2 (Chapter 4) involved the analysis of Q fever notification data reported in SA across 2007 to 2017, and examined the spatiotemporal relationship of notifications with livestock densities over the same period and was published in October 2019.[29]

Study 3 (Chapter 5) examined university animal and veterinary science students' knowledge and attitudes on Q fever, and practices related to its prevention and control and was published in September 2020.[28]

Study 4 (Chapter 6) assessed livestock farmers' knowledge and attitudes on Q fever, and practices related to its prevention and control and was published in March 2021.[25]

Study 5 (Chapter 7) explored university animal and veterinary science students' and livestock farmers' perspectives on Q fever prevention and control using a qualitative framework and is currently under review in *The Australian Journal of Rural Health*.

Study 6 (Chapter 8) explored the feasibility and perceptions of adopting a One Health approach to Q fever prevention and control, and its possible challenges and opportunities. Key stakeholders' policy perspectives were examined through a series of semi-structured interviews and is currently under review in *The Medical Journal of Australia*.

1.9 Aims and objectives

Aims

The overall aim of this research was to examine Q fever control and prevention approaches in South Australia (SA) and to explore the enablers and barriers of adopting a One Health approach in order to provide policy recommendations and guidelines.

Objectives

In order to achieve the overall aims, six key objectives were identified pertaining to five studies except the literature review. Objectives 1 and 2 were linked to study 2, and objectives 3–6 for the corresponding studies 3–6.

1. To analyze Q fever notification data in order to define at risk groups based on occupation and possible exposure in SA (Study 2).

2. To examine the association between notified Q fever cases and spatial and temporal distribution of cattle, sheep and goats in SA (Study 2).

3. To assess the KAP about Q fever and its prevention among university animal and veterinary science students in SA (Study 3).

4. To investigate the KAP about Q fever and its prevention among livestock farmers in SA (Study 4).

5. To compare and contrast the varying perceptions of Q fever and its prevention between university animal and veterinary science students and livestock farmers in SA (Study 5).

6. To explore multi-stakeholders' perspectives for identifying barriers and enablers of a One Health approach to Q fever prevention and control in SA (Study 6).

1.10 Thesis outline

The thesis is the format of a PhD by publication comprising of ten Chapters (Figure 1.1). Following this introduction outlining the background, rationale and aims of the research, Chapter 2 provides a review of the literature on the utilization of the components of a One Health approach to Q fever prevention and control. The published review is supplemented by an update to the literature since this review was conducted in 2018. Chapter 3 sets out the overall methodological framework used to address each of the specific research questions. Chapter 4 examines the spatial, temporal and occupational epidemiology of notified Q fever cases between 2007 and 2017 in SA. Chapters 5 and 6 examine the KAP of Q fever and its prevention among university animal and veterinary science students and livestock farmers in

SA. Chapter 7 compares and contrasts the varying perceptions of Q fever and its prevention between students and farmers. Chapter 8 explores multi-stakeholders' perspectives on the barriers and opportunities of a One Health approach to Q fever prevention and control in SA. While Chapter 9 provides the discussion of the key findings outlining the significance, limitations and challenges faced during the conduct of this research, Chapter 10 concludes this thesis with specific recommendations, policy implications, future research directions and concluding remarks.

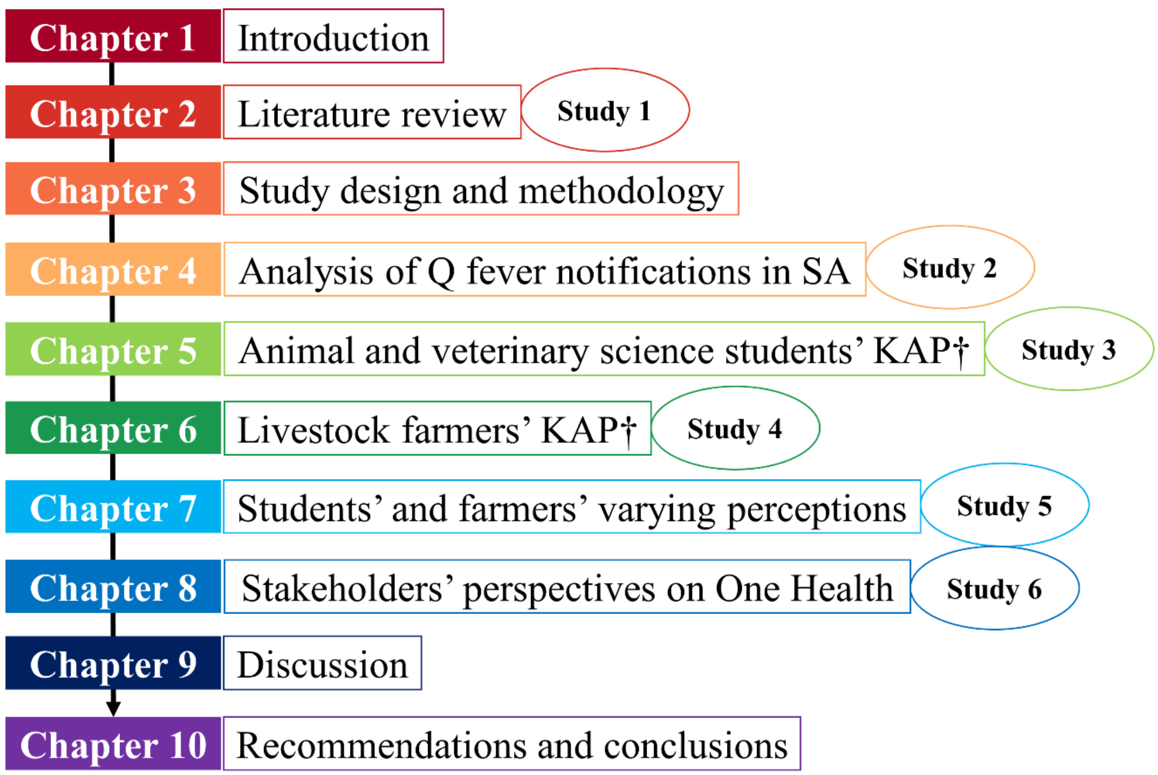

Figure 1.1 Schematic presentation of the thesis structure.

†KAP: Knowledge, attitudes and practices.

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2

Chapter 2 – Is a One Health approach utilized for Q fever control? A comprehensive literature review

2.1 Preface

This chapter is broadly divided into two parts: the first being a literature review encompassing published studies on the utilization of a One Health approach to Q fever prevention until 13 June 2018 and is presented in section 2.2–2.3. The second part consists of an updated literature review of studies published from 14 June 2018 to 4 May 2021 and is presented in section 2.4. As the earliest One Health study on Q fever prevention was published in 2009, the published literature review presented in this chapter (2009–2018), as well an update (2018–2021) provides the most up-to-date and comprehensive synthesis of the utilization of a One Health approach to Q fever prevention and control.

2.2 Statement of authorship

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Publication Status	☑ Published ☐ Submitted for Publication	☐ Accepted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
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Principal author

Name of Principal Author (Candidate)	Md Rezanur Rahaman		
Contribution to the Paper	Conducted the literature review, conceptualized and drafted the manuscript and incorporated feedback.		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	10 May 2021

Co-author contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Rahaman MR, Milazzo A, Marshall H, Bi P. Is a One Health Approach Utilized for Q Fever Control? A Comprehensive Literature Review. *Int J Environ Res Public Health*. 2019;16:730.

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Review

Is a One Health Approach Utilized for Q Fever Control? A Comprehensive Literature Review

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Abstract: Q fever, a zoonotic disease transmitted from animals to humans, is a significant public health problem with a potential for outbreaks to occur. Q fever prevention strategies should incorporate human, animal, and environmental domains. A One Health approach, which engages cross-sectoral collaboration among multiple stakeholders, may be an appropriate framework and has the underlying principles to control Q fever holistically. To assess whether components of One Health for Q fever prevention and control have been applied, a comprehensive literature review was undertaken. We found 16 studies that had practiced or recommended a One Health approach. Seven emerging themes were identified: Human risk assessment, human and animal serology, integrated human–animal surveillance, vaccination for at-risk groups, environmental management, multi-sectoral collaboration, and education and training. Within the multi-sectoral theme, we identified five subthemes: Policy and practice guidelines, information sharing and intelligence exchange, risk communication, joint intervention, and evaluation. One Health practices varied between studies possibly due to differences in intercountry policy, practice, and feasibility. However, the key issue of the need for multi-sectoral collaboration was highlighted across most of the studies. Further research is warranted to explore the barriers and opportunities of adopting a One Health approach in Q fever prevention and control.

Keywords: Q fever; zoonotic disease; prevention and control; environmental; One Health; multi-sectoral

1. Introduction

Q fever, a zoonotic disease transmitted from animals to humans, is a significant public health problem worldwide. It is mostly occupationally acquired, and despite the availability of a vaccine for human use, at least in Australia, some countries continue to bear a substantial disease burden [1,2]. The annual incidence of Q fever notifications in the USA ranges from 0.28 to 2.40 cases per million persons. The reported incidence in England and Wales is similar to that in the USA. However, the annual reported incidence in Australia is higher with 15–49 cases per million persons [3].

The high incidence of infection in humans together with potential for spread through animal movements, magnitude of animal and human involvement, suboptimal national preparedness for outbreak control, and diagnostic challenges make Q fever control an important international public health priority [4,5]. Furthermore, infection in animals is associated with abortion storms particularly in goats, livestock culling, and reduced milk and meat production [6]. Reduced livestock production combined with human health costs derived from clinician visits, laboratory testing, hospital admission, and lost productivity signifies the impact of Q fever warranting an international response [6,7].

On average, an acute Q fever infection can cost a patient 7.5 days off work [6]. In an Australian study the cost of compensation claims from Q fever was estimated to be >A$3 million per annum, which today is approximated at A$4.3 million per annum, given inflation rates of the Australian dollar over 15 years [8]. Though immunization can largely abate these costs, screening of prior immunity through serology and skin tests, followed by vaccination if non-immune, is associated with high costs (≈A$300), and these costs are often responsible for lower immunization rates among at-risk occupational groups such as abattoir workers and farmers [9,10].

Considering the human-animal interface of zoonotic diseases, a One Health approach provides a strong framework in dealing with the economic challenges associated with Q fever [2,11–13]. One Health holistically engages human, animal, and environmental health professionals in collaborating nationally and globally for the pursuit of healthy living of humans and organisms [14]. Coordination and collaboration includes improving human surveillance, instituting animal surveillance and ensuring data sharing and intelligence exchange between veterinary and public health agencies, establishing communication, improving clinicians' knowledge and attitude toward Q fever management, strengthening laboratory facilities, improving veterinary control measures, environmental monitoring, human and animal sero-surveillance, and access to screening and vaccination [11,15].

The aim of this review was to examine whether a One Health approach to Q fever control was applied and to identify gaps in practice and recommendations. One Health components that were considered for this review include human and animal serological surveys; knowledge, attitude, and practices among practitioners and farmers; One Health literature reviews; ecological correlations using multi-sectoral data; and outbreak investigations involving human, animal, and environmental domains.

2. Materials and Methods

2.1. Search Strategy

In order to identify all published studies on Q fever that utilized one or more components of a One Health approach, a systematic literature search was conducted in CINAHL, Embase, PsycINFO, PubMed, Scopus, and Web of Science databases until 13 June 2018. Searches were restricted to English language only. A logic grid using indexing languages (Emtree, MeSH) and/or keywords was developed for each database (see Table S1—Supplementary file for detailed search strategy). Keywords such as "Q fever" and "One Health", their synonyms and closely associated words were used. Additionally, references cited in the included studies were pearled for possible relevance. Because a limited number of studies applied a One Health approach to Q fever, the literature search was extended to include conference abstracts and proceedings.

2.2. Eligibility Criteria

Studies that met one of the following two criteria were included:

- Studies that described the practice of one or more components of One Health in Q fever prevention and control;
- Studies that did not practice but recommended a One Health approach to Q fever prevention and control.

Excluded studies were those not having a One Health practice and/or recommendation focus in Q fever control. Books and book chapters were also excluded.

2.3. One Health Practice, Recommendation, and Observed and Expected Outcomes

Studies including serological surveys, outbreak investigations, ecological correlation, and systematic reviews that adopted a One Health approach from the outset were considered as practice. In contrast, published literature that recommended this approach for Q fever control was considered as recommendation. As highlighted in Table 1, One Health practices resulted in observed outcomes whereas recommendations were made with expected outcomes.

Table 1. Characteristics of the studies that used one or more components of One Health in Q fever prevention and control.

Study and Location	Study Type	One Health	Observed and/or Expected Outcomes	Comments
[16] South Africa	Cross-sectional	**Practiced** ▪ Risk factor survey among farmers, herders and veterinary staff ▪ Human serology **Recommended** ▪ Education and training related to zoonosis for human health and veterinary practitioners	▪ Q fever included in the differential diagnosis of febrile illnesses ▪ Positive Q fever serology demonstrated ▪ Educated clients for better disease prevention	▪ Diagnostic challenges related to febrile illnesses identified ▪ Small sample size and non-random selection of participants limit generalizability of the results

[17]
Europe/Belgium
	Systematic review	**Practiced**
		▪ Risk factors reviewed:
		  ▪ Occupational factors e.g. farmers, abattoir workers
		  ▪ Husbandry factors e.g. goat farming
		  ▪ Environmental factors e.g. infected livestock transportation
		Recommended
		▪ Q fever monitoring in high incidence countries
		▪ Collaboration across disciplines
			▪ One Health is a model for Q fever control addressing complex interactions between the reviewed factors
			▪ Promote optimum health of humans, animals and environment
				▪ One Health focus was drawn from the Netherlands experience, which may fail to appreciate the subtleties of Q fever epidemiology that determine possible control options in other countries

Table 1. *Cont.*

Study and location	Study type	One Health	Observed and/or expected outcomes	Comments
[18] Côte d'Ivoire	Cross-sectional	**Practiced** ■ Risk factor survey in rural farming communities ■ Human and animal serology **Recommended** ■ Educate community about zoonosis by combining public health and animal health	■ Positive Q fever serology at the farm and community level ■ Reduced human exposures to Q fever	■ No association between animal abortions and Q fever seropositivity contradicting findings in other studies e.g. Netherlands' outbreak
[19] Africa/Tanzania	Review	**Recommended** ■ Global zoonosis surveillance system ■ Strengthen national core capacities ■ Interventions targeted at Q fever source e.g. livestock vaccination ■ Community trust, engagement and collaboration	■ Impromptu response to endemic zoonosis ■ Coordinated response to future disease threats ■ Reduction of animal abortions and human Q fever cases ■ Less fragmentation, less inequalities for sustainable development	■ Stakeholders meet, interact, share experiences and embark on agreed upon decisions

Table 1. *Cont.*

Study and location	Study type	One Health	Observed and/or expected outcomes	Comments
[20] Spain	Cross-sectional	**Practiced** ▪ Wild and domestic ruminant serology **Recommended** ▪ Multidisciplinary studies required	▪ Positive *C. burnetii* antibodies in wild and domestic ruminants ▪ First evidence of antibodies in European wildcats ▪ *C. burnetii* epidemiology at human-livestock-wildlife interface will be better understood	▪ Inclusion of human serology would have provided a strong One Health practice and helped further understanding of Q fever epidemiology in Spain
[21] Kenya	Cross-sectional	**Practiced** ▪ Risk factor survey among randomly selected households ▪ Human and cattle serology ▪ Spatial correlation of cattle and human seropositive samples **Recommended** ▪ Livestock markets be targeted for Q fever control interventions (e.g. animal serology and vaccination)	▪ *C. burnetii* exposure was heterogeneous ▪ Cattle brought from livestock markets had highest seroprevalence ▪ Human and cattle seroprevalence was not associated ▪ Reduction of *C. burnetii* shedding in previously exposed animals	▪ Studying only cattle limits extrapolation of results to settings such as the Netherlands where small ruminants are the main reservoir ▪ Without full explanation of socio-cultural factors, it is premature to conclude certain ethnic groups had increased exposure risks

Table 1. *Cont.*

Study and location	Study type	One Health	Observed and/or expected outcomes	Comments
[22] Netherlands	Ecological correlation	**Practiced** ▪ Netherlands' outbreak analyzed Q fever notification data, farm data and climate data **Recommended** ▪ Ecological research on outbreak associated data	▪ Q fever notification was correlated with environmental conditions, e.g. wind current and humidity ▪ Spatially planned farming	▪ An estimated 8% of Q fever cases was notified in 2009 outbreak. This, in part limited the authors' conclusion of the causal associations between human notifications and environmental predictors
[23] Kenya	Cross-sectional	**Practiced** ▪ Knowledge, attitude and practices survey among medical, veterinary and wildlife workers, and farmers **Recommended** ▪ Provide healthcare professionals updated Q fever knowledge ▪ Strengthen multi-sectoral collaboration ▪ Community sensitization	▪ Q fever knowledge was low among most participants (94% human health providers had little or no knowledge) ▪ Effective control of Q fever ▪ Help community members prevent Q fever	▪ How stakeholders' knowledge contributes to a One Health collaboration, and why this multi-sectoral approach is important is not discussed

Table 1. *Cont.*

Study and location	Study type	One Health	Observed and/or expected outcomes	Comments
[24] Australia	Outbreak investigation	**Practiced** ▪ Multidisciplinary epidemiological investigation and animal serology ▪ Skin and serological testing for workers, subsequent vaccination ▪ PCR testing of aborted materials, vaginal swabs, environmental samples ▪ General measures e.g. biohazard sign erection ▪ Site surveillance launched ▪ Health education ▪ Management of farm environment e.g. manure management **Recommended** ▪ Mandatory vaccination for all occupational contacts ▪ Further research to identify possible interstate introduction of Q fever ▪ Validation of IFA ▪ Livestock vaccination	▪ Comprehensive risk assessment techniques and consensus control measures developed ▪ Workers protected by HEPA* filters ▪ Goats identified as likely source of the outbreak ▪ Controlled human cases without source control ▪ Could not prevent infections in workers' family members ▪ Ongoing farm environmental contamination due to intensive breeding and milking goats demonstrated ▪ Presumably these public health measures controlled the outbreak ▪ Prevent acute Q fever cases ▪ Traditionally held views that interstate importation of *C. burnetii* to Victoria may be established ▪ Livestock and wildlife prevalence of *C. burnetii* could be established ▪ Reduced environmental shedding	▪ Key similarities with the Dutch outbreak include outbreak source, both occurred at goat farm; use of human vaccination; and application of a One Health approach. Differences include magnitude of the outbreaks, livestock vaccination was not used in the Australian outbreak because of manufacturing biosecurity concerns

Table 1. *Cont.*

Study and location	Study type	One Health	Observed and/or expected outcomes	Comments
[25] Netherlands	Ecological correlation	**Practiced** ▪ Q fever notification data, veterinary and farm data analyzed ▪ Largest farm visited, and farmers interviewed on risk factors ▪ Atmospheric dispersion model used **Recommended** ▪ Consider farms with history of *C. burnetii* infection as potential source of human outbreaks ▪ Use meteorological forecast data	▪ Largest goat farm had abortion waves, bulk tank milk and almost all samples positive for *C. burnetii* – considered as the most likely source ▪ Several unsafe farm practices related to manure and removal of birth products ▪ Likely period of infection and airborne propagation shown ▪ These could guide future Q fever control strategies	▪ Largest goat farm caused a smaller outbreak in 2008, with a larger community outbreak following year ▪ Public health and veterinary health professionals should work together on an alert mechanism to identify any potential human Q fever outbreaks ahead of time
[26] Africa/Tanzania	Feature/Review	**Recommended** ▪ Syndromic surveillance and targeted collection of diagnostic materials e.g. aborted products ▪ Improved communication across sectors ▪ Regional data on Q fever burden is essential	▪ Better linking etiology and epidemiology of *C. burnetii* in humans and animals ▪ Early detection of possible human outbreaks ▪ Identification of key intervention points ▪ Cost-effective interventions ▪ Early diagnosis, prompt treatment and better control strategies ▪ Q fever becomes a global disease control priority	▪ One Health approach provides a holistic management perspective in a cost-effective fashion and is most viable option to minimize misdiagnosis, assess zoonotic impacts and utilize disease control methods

Table 1. *Cont.*

Study and location	Study type	One Health	Observed and/or expected outcomes	Comments
[27] Lao People's Democratic Republic (Laos)	Review	**Practiced** ▪ Summarized 8 pig associated zoonoses, their risks and impacts **Recommended** ▪ Improved diagnostic approaches ▪ Strengthen disease surveillance systems ▪ Interdisciplinary collaboration and research	▪ Misdiagnosis and underreporting were common ▪ Reduced diagnostic errors and improved notification ▪ Designing socially and culturally appropriate control methods	▪ Focusing only on pigs led the scope of wide range of zoonotic reservoirs remained unexplored. Inclusion of a range of reservoirs could have offered a stronger case scenario of advocating for a One Health approach ▪ Unique aspect is emphasizing socio-cultural determinants of zoonoses

[28] Africa/Chad	Conference proceedings/Review	**Practiced**
		▪ Summarized "One Health" studies among mobile farmers
		  ▪ Linked human and animal health studies
		  ▪ Summarized human and animal intervention (e.g. vaccination) studies
		  ▪ Combined human and animal serological studies
		Recommended
		▪ Integrated zoonotic surveillance using cell phone for mobile farmers to be established
		▪ Social and anthropological studies
			▪ Livestock vaccination coverage higher than human vaccination in farming communities
			▪ Better access to care for mobile farmers and their families
			▪ Camel breeding associated with human *C. burnetii* seropositivity
			▪ Demographic and disease surveillance and control methods for mobile populations
			▪▪ Social and cultural complexities of zoonotic infections will be understood
				▪ One Health programs were shown to be efficient (e.g. joint vaccination) and acceptable (e.g. health assessment using mobile phone). Public health and veterinary interventions which are coordinated, accessible, resource saving and based on community needs are successful

Table 1. *Cont.*

Study and location	Study type	One Health	Observed and/or expected outcomes	Comments
[29] USA	Outbreak investigation	**Practiced** ▪ Multidisciplinary outbreak investigation by veterinarians, public health nurses, medical doctors, epidemiologists and Q fever and reference diagnostic laboratories ▪ Risk factor survey and human serology ▪ Ruminants' milk, vaginal swab, placenta, manure and environmental samples were tested **Recommended** ▪ Health education and change in farm practices	▪ Extent and epidemiology of this outbreak was determined ▪ Livestock contact had strong association with Q fever ▪ Goat and cattle samples were positive for *C. burnetii* ▪ Birthing areas had highest concentration of *C. burnetii* ▪ Prevent future *C. burnetii* transmission ▪ Reduce lost productivity and ensure better livelihoods	▪ A good example of applying One Health approach to Q fever ▪ Personal communications were established with principal author, detail information sourced and incorporated ▪ Moreover, this conference abstract was published in a slightly different way in 2016 as cited in reference [30]
[31] Netherlands	Review	**Recommended** ▪ Dispute between human health providers and veterinarians be dissolved ▪ Better diagnostic methods ▪ Livestock vaccination	▪ Better Q fever control through agreed measures ▪ Improved Q fever notifications ▪ Reduced human exposure through prevention of animal abortions	▪ Communication gap between human and animal health sectors was identified in an outbreak investigation, although it was believed that both sectors were working together. One Health as a method of bridging that gap needs practical interactions rather than written words ▪ Only goat as reservoir was discussed without considering other species e.g. sheep and cattle

Table 1. *Cont.*

Study and location	Study type	One Health	Observed and/or expected outcomes	Comments
[32] USA	Review	**Practiced** ■ Multidisciplinary diagnostic facilities ■ Quick result production ■ Less communication pitfalls among stakeholders ■ Public-private partnerships ■ Joint investigation of Q fever cases ■ Human and animal serology **Recommended** ■ Vector borne disease control requires human, animal and vector surveillance	■ Sample testing from a range of sources ■ Stewardship and collaborations ■ Coordinated local responses against diseases and threats ■ Positive Q fever serology demonstrated ■ Shared resources and expertise ■ Animals and humans are protected	■ Local, state and federal levels involving public and private partnerships that combine human, animal and ecological sectors helps minimize resource exhaustion in control of zoonotic diseases

* HEPA: High-efficiency particulate arrestance; IFA: Immunofluorescence assay.

3. Results

Sixteen studies (15 full publications and 1 conference abstract) from 2009 to 2018 were included in this review. The earliest One Health study was published in 2009. A PRISMA flow diagram as shown in Figure 1 illustrates the study selection process. Four types of studies were included in this review: Cross-sectional study (*n* = 5), ecological study (*n* = 2), outbreak investigation (*n* = 2), and review (*n* = 7). Most studies were conducted in Africa (*n* = 7) and Europe (*n* = 5). While all cross-sectional studies were conducted in these regions, outbreak investigations were carried out in Australia (*n* = 1) and the USA (*n* = 1). Figure 2 shows the distribution and design of the studies. A summary of the studies including their location, study type, whether One Health approach was practiced and/or recommended, observed and/or expected outcomes, and comments on their strengths and weaknesses is given in Table 1.

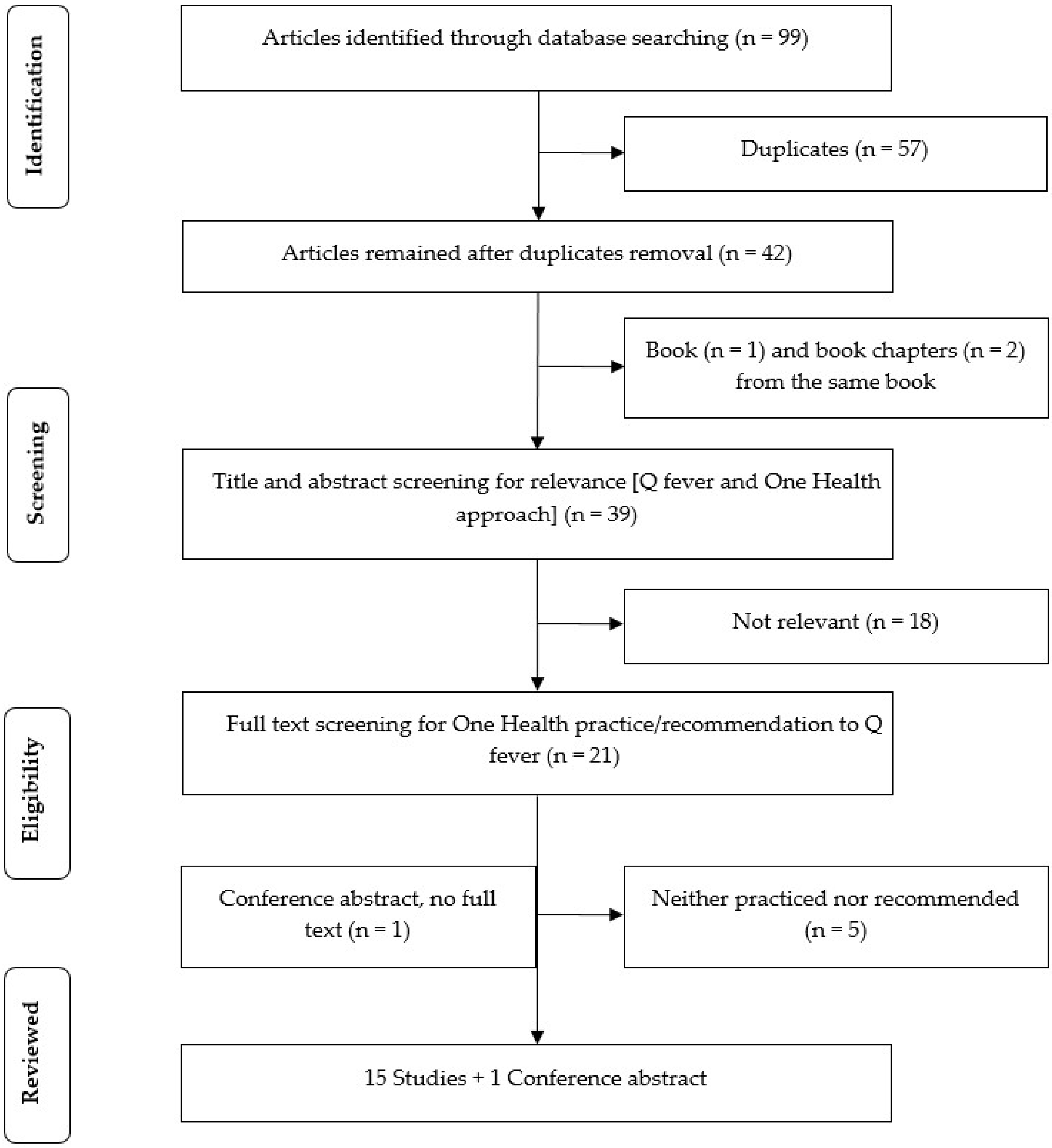

Figure 1. PRISMA flow diagram of the study selection process.

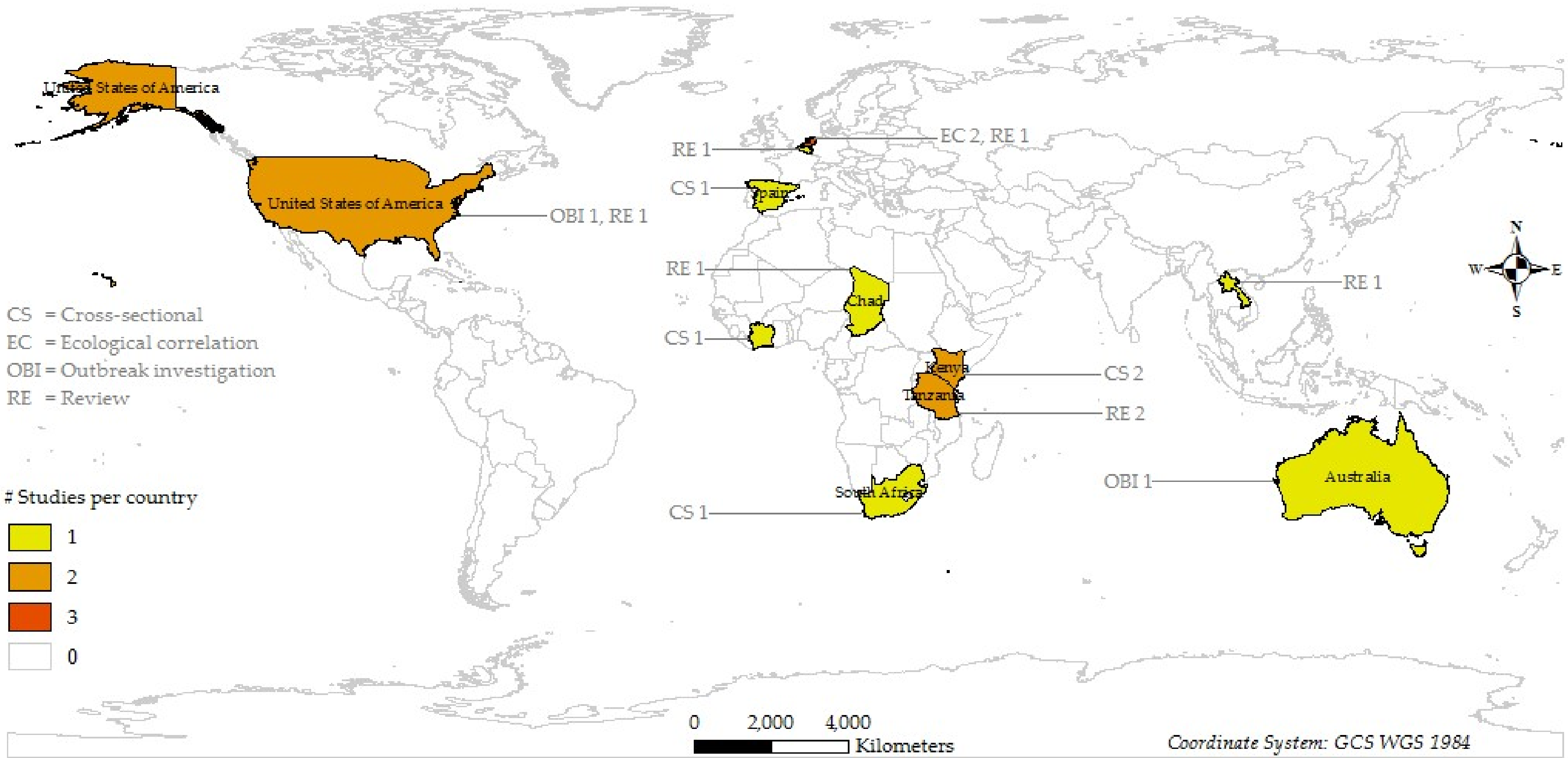

Figure 2. Distribution of studies that used a One Health approach to Q fever by location and study design.

The major themes elicited from this review were human disease risk, human and animal serology, integrated surveillance, vaccination, environmental management, multi-sectoral collaboration, and education and training.

3.1. Q Fever Risks to Humans

Human disease risks were examined by nine studies. Occupational risks included working in abattoirs; veterinary practices; farming, particularly goat farming; and transporting of infected livestock [17]. In the two Q fever outbreaks, livestock contact with manure and birth products was associated with human disease (RRs = 2.7 and 5.65) [24,29]. Additionally, in the USA, family members with frequent livestock contact (RR = 4.8) and in Australia those working in the office or close to the dairy without air filters (RR = 5.49) were found to be associated with Q fever. Proximity, defined as living within 1 kilometer of a farm with infected animals, was a risk factor in the Netherlands Q fever outbreak (RR = 46) [25]. These results suggest that occupational and environmental factors are pivotal in Q fever transmission.

3.2. Human and Animal Serology

3.2.1. Human

Serological testing was carried out in seven studies. Of the seven studies, two performed human serology, one animal serology, and four both human and animal serology. In South Africa, 28/73 (38%) non-malarial febrile patients and 39/64 (61%) farmers, herders, and veterinary workers were *Coxiella burnetii* IgG positive [16]. In a Q fever outbreak in Australia, 32 (31%) individuals had unknown/no screening results. Of the remaining 72 cases with available results, 42 (58%) had positive Q fever serology [24]. In another outbreak in the USA, 81/135 (60%) persons had positive Q fever serology [29,30]. Contrary to the high seroprevalence among these occupational groups, the seroprevalence in a Kenyan community (n = 2049) was 2.5% [21].

3.2.2. Animal

Animal serological studies found that 13.9% of cattle, 12.4% of goats, and 9.4% of sheep were *C. burnetii* seropositive in West Africa [18]. In Kenya, 10.5% of cattle, and 15% of goats in the Australian outbreak were seropositive [21,24]. A Spanish study found 22%–33% of European wildcats, Spanish ibex, and domestic sheep, and less than 2% of other species were seropositive [20]. These results underscore the importance of human and animal serology in quantifying Q fever risks and designing targeted control measures.

3.3. Integrated Q Fever Surveillance

Seven studies have shown that an integrated animal–human surveillance system by veterinary and public health authorities offers better disease monitoring than siloed surveillance systems [5,19,24–28,32,33]. Bond et al. [24] used integrated surveillance during their outbreak investigation in Australia and kept it under operation after the investigation was over. An integrated surveillance system can address multiple similar zoonoses simultaneously with the existing workforce. For example, appropriately trained farmers can use a syndromic approach such as animal abortions for considering Q fever, brucellosis, leptospirosis, and borreliosis and reporting this to veterinarians and human health authorities. This cost-effective surveillance system provides regional zoonotic data that can be used for global zoonotic disease surveillance priorities as shown in Figure 3 [19,26,27]. Integrated surveillance systems should have an integrated diagnostic facility where samples from a range of sources including human, animal, and environmental are tested guiding coordinated decision making and responses (see Figure 3) [32]. Unfortunately, an integrated Q fever surveillance system has rarely been implemented, except in a few circumstances such as in the San Diego County laboratory that has coordinated diagnostic facilities [32].

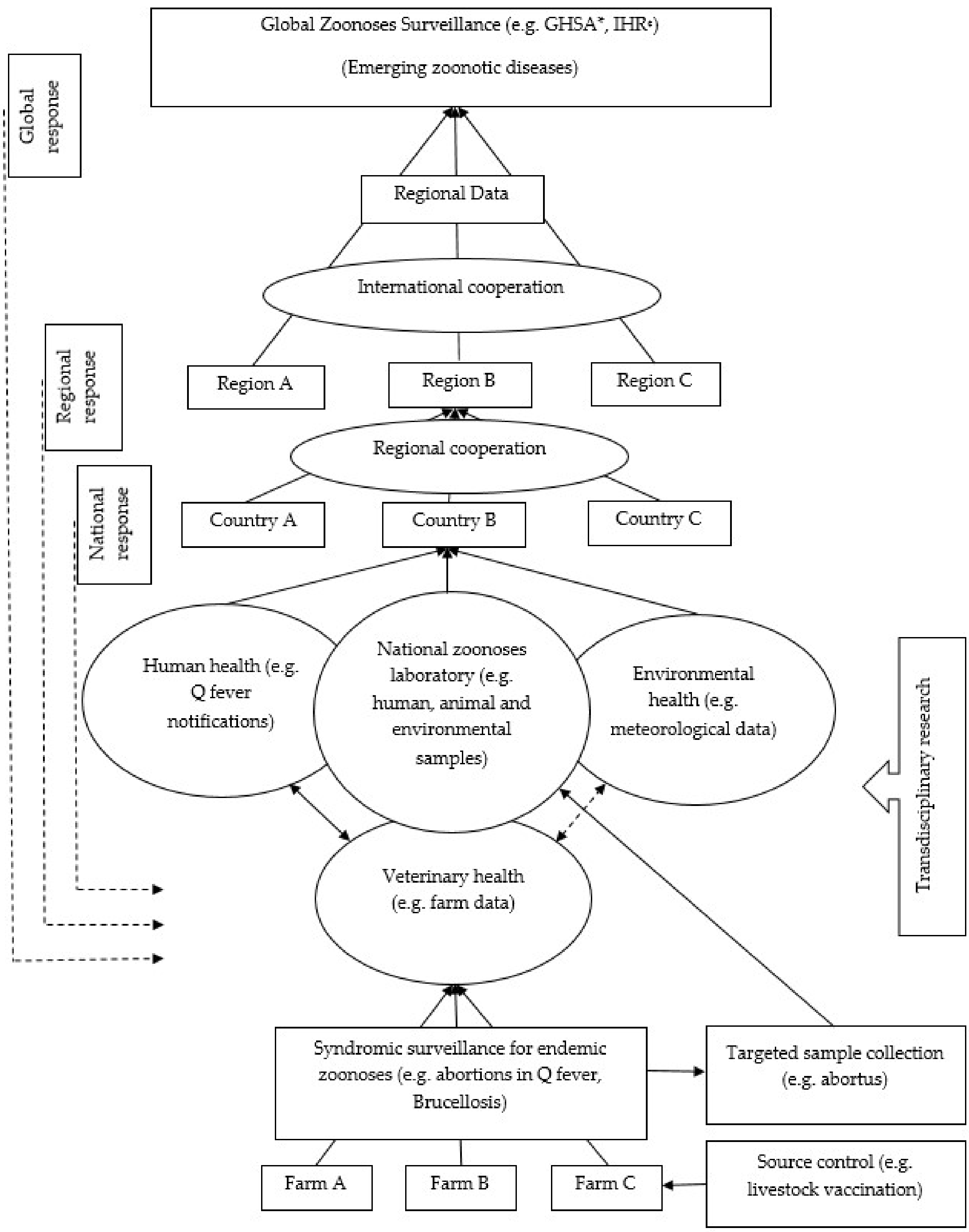

Figure 3. Schematic illustration of a One Health global zoonoses surveillance system. Conceptualized from [19,26,27,32]. * GHSA: Global Health Security Agenda; ¢ IHR: International Health Regulations.

3.4. Vaccination

Vaccination was practiced and/or recommended in five studies, of which four recommended livestock vaccination. Human vaccination was extensive in the Australian outbreak and was effective in reducing human cases [24]. The authors recommended mandatory human vaccination for those having occupational contact with livestock. In contrast, livestock vaccination is a cost-effective intervention because it provides human health benefits through source control [19,31]. This can be carried out at farm levels or at livestock markets where *C. burnetii* contamination is high [19,21]. However, the available livestock vaccine is limited because of its biosecurity risks [24]. In the Australian outbreak investigation, these risks were considered and livestock were not vaccinated, as was the case in the Netherlands outbreak [24]. No study has shown the efficacy of livestock vaccination or the quantified associated biosecurity risks.

3.5. Environmental Management

Six studies practiced environmental management toward Q fever prevention and control including environmental sample testing (*n* = 2), environmental data analysis (*n* = 3), and an environmental risk factor review. Twenty eight (61%) of the 46 swab samples taken from the vagina and birth products of goats were *C. burnetii* positive in the Australian outbreak. However, air and bedding samples from the farm were not positive [24]. In the USA outbreak, 17%–26% of goat samples, 2%–7% of cattle samples, and the bulk tank milk filters were positive for *C. burnetii*. Though fecal samples were negative, 8/26 (31%) of the environmental samples including birth products, carcass, and manure were positive [30]. Environmental measures in the Australian outbreak investigation included manure storage in litter sheds, followed by composting and removal; immediate removal of aborted materials; and notifying goat buyers about the Q fever status of farms [24]. For an efficient Q fever control, an integrated surveillance system coupled with an environmental management component is warranted.

3.6. Multi-Sectoral Collaboration Including Joint Research

Of the 16 studies, 13 (81%) directly discussed a multidisciplinary approach to Q fever control. Given the complex interactions between animals, humans, and the environment, a cross-disciplinary approach to Q fever control is required [17,26]. The results for this theme are categorized under the five subthemes discussed in the following sections.

3.6.1. Policy and Practice Guideline Development

Nationally, Q fever control guidelines should be developed for health practitioners, industries, and their employees. For example, Simpson et al. [16] recommended an update of the conventional febrile treatment guidelines to include zoonoses such as Q fever. Countries also need to formulate specific agriculture- and husbandry practice-related policies at the national level [17]. While globally, the World Health Organization's priority zoonotic diseases need to be revisited to include endemic zoonoses [27]. In terms of practice, guidelines and strategies to reduce human transmission were developed for patients, practitioners, and communities in the Australian and USA outbreaks [24,29]. Dunne and Gurfield [32] in their review showed how human and animal health laboratories were unified for testing a range of samples and coordinated decision-making. However, public health policies on Q fever control are limited except for those developed during outbreaks.

3.6.2. Information Sharing and Intelligence Exchange

Eleven (69%) studies discussed this subtheme. Knowledge of human, animal, and environmental domains provides opportunities for regular and planned interactions among stakeholders. This in turn builds trust, stewardship, and empowerment whereby disease control strategies are formulated through shared information and intelligence [16,17,19]. Moreover, such interaction opens the scope for transdisciplinary research that helps our understanding of the epidemiological and sociocultural complexities of Q fever [20,26,27]. For example, the Netherlands community Q fever outbreak in 2009 was also associated with a smaller outbreak in 2008. This recurrence was identified through the analyses of cross-disciplinary data [25]. Furthermore, sharing information and intelligence had demonstrated benefits in controlling both the Australian and USA outbreaks [24,29]. A joint diagnostic facility is, amongst others, a model par excellence because it offers greater access to information required for coordinated actions, as it is the functional endpoint of multiple related disciplines [32].

3.6.3. Risk Communication

Five studies discussed risk communication. At the community level, risk information needs to be disseminated by both human- and animal-health authorities to increase the credibility of health messages. Credible messages may encourage individuals to refrain from risk behaviors such as sharing sleeping areas with livestock [16,23]. Likewise, risk communication through public–private partnerships reduces communication pitfalls and is cost effective [32]. In both the Australian and USA outbreaks, multidisciplinary risk assessment improved communication across stakeholders and helped formulate agreed risk reduction guidelines [24,29].

3.6.4. Joint Intervention

Joint interventions, such as human and animal vaccination through cross-sectoral collaboration, provide superior disease control choices over a single approach [19,24]. These interventions are resource saving, devoid of duplication, and free from communication barriers [19]. In their outbreak investigation, Bond et al. [24] adopted this approach by including human vaccination, general biosecurity measures, and public health interventions.

3.6.5. Evaluation

Periodic evaluation is crucial when a disease control program is implemented for possible adjustment of the program components [18]. However, program evaluations are not reported, and therefore studies are needed in future.

3.7. Education and Training Including Community Engagement

Six studies discussed this theme: Practitioners' education and training (n = 2), community education and engagement (n = 3), and both (n = 1). Q fever knowledge was very limited among healthcare providers in Kenya. Most of them had no or poor knowledge about the disease, its transmission and treatment [23]. Medical and veterinary practitioners need updated knowledge about Q fever, risks of transmission, diagnosis, and management to educate their clients on how to prevent zoonotic diseases [16,30]. Likewise, community members, particularly at-risk populations, should be targeted for audiovisual educational promotion on how to reduce their zoonotic risks [18]. Educating the community is an integral part of zoonosis control as it provides individuals with informed choices for practicing risk reduction strategies. Additionally, this offers a socially purchased benefit of community trust and engagement [19,23]. If education providers are trustworthy, target groups take ownership of the zoonosis prevention process. An example is the educational campaigns for workers' families in the Australian outbreak response whereby general practitioners were requested to promote optional vaccination among them [24].

4. Discussion

This review summarizes contemporary published evidence on using a One Health approach for Q fever prevention and control. Although Q fever is ubiquitously distributed [1,34], the contexts, magnitudes, and risks are not homogeneous. Therefore, One Health components and practices varied between studies. For example, the origin of the outbreak and delayed institution of an investigation were similar in the Australian and the Netherlands outbreak. However, Netherlands' investigation was bigger in magnitude, culled animals, restricted ruminant breeding, and made animal notification mandatory [24,35]. Although an outbreak investigation per se may be less appropriate to generalize, all practices in this review contribute to a strong generic One Health model for Q fever prevention and control.

Despite the fact that Q fever infection may occur without occupational exposure, such as sporadic cases living in proximity to infected animals, our review has identified common occupational groups at risk including farmers, abattoir workers, and veterinarians [17,36]. However, apart from Bond et al. [24]

no other studies acknowledged the occupational risks and advocated for mandatory vaccination of occupational contacts, most likely because the vaccine is only registered for use in Australia. Furthermore, the Australian investigation also addressed the environmental transmission through promoting vaccination among people living in the vicinity [24]. These findings emphasize that the extrapolation of vaccination practices is required to avoid further outbreaks.

Human vaccination is 97%–100% efficacious when given outside the natural incubation period [37–39]. However, high screening and vaccination costs and access to general practitioners are often viewed as challenges [9,40]. Some studies have shown that unlike human vaccination, animal vaccination is cost effective as it reduces shedding of the bacterium in animals, environmental contamination, and the likelihood of disease transmission to humans [19,31]. From a One Health perspective, concurrent human–animal vaccination at livestock markets would offer one of the best Q fever prevention strategies. It reduces *C. burnetii* contamination in animals and allows mass vaccination of farmers who perceive cost and access to care as barriers [9,19,21]. However, given that the available livestock vaccine has manufacturing biosecurity concerns, caution must be exercised in the event a concurrent vaccination program at livestock markets is planned.

Human serology plays an important role in quantifying Q fever burden. High seroprevalence among occupational groups in this review is similar to that of goat farmers in the Netherlands [41] and may indicate that Q fever prevention should target occupational contacts. Unlike this, low population seroprevalence is consistent with the Netherlands and USA national rates that makes the general population a less appropriate target for interventions [21,30,41]. In contrast, as animals are asymptomatic carriers [42], their serology can identify species that have previously been infected and can have some role in identifying flocks or herds where *C. burnetii* is endemic. However, it has been shown that there is no association between antibody response and shedding of the organism [18], which represents the true public health risk.

Given that Q fever is under-diagnosed and underreported, human surveillance is the most reliable option for burden estimation [43,44]. Animal surveillance is important because human outbreaks are preceded by animal infections that may manifest with abortions, warning public health professionals to activate an alert mechanism [33,34,45]. The integration of the two surveillance systems could reduce communication pitfalls, save resources, and provide zoonotic data for national and global coordination [19,26,27,32]. Although in the Netherlands an integrated surveillance system was instituted, it was challenged by inadequate coordination and lack of trust and stewardship between stakeholders [31]. Enserink [31] therefore argued that for the functionality of an integrated surveillance system stakeholders need to resolve all possible inter-sectoral disputes beforehand.

Another major domain of One Health is the environment that allows host–reservoir interactions, propagates disease transmission, and deserves meticulous consideration in Q fever control [17]. The fact that soon after shedding *C. burnetii* settles in dust, becomes aerosolized, and infects humans makes environmental management a key factor in disease control [7,46]. Such management practices varied between settings. For example, the Australian and the Netherlands outbreaks practiced manure management while the latter restricted humans and transports [24,35]. These measures were key to the successful control of both outbreaks [24,35] and, therefore, deserve inclusion in Q fever prevention and control practices.

Multi-sectoral collaboration is the central theme of this review. Although a majority of studies explicitly emphasized a multi-sectoral and collaborative approach, very few outbreak responses applied this in practice [11,32]. In the USA and Australian outbreaks, both countries lacked prior policies for collaboration. One reason is the enduring bureaucracies and disputes between veterinary, public health, and environmental sectors that hinder countries formulating and implementing the multi-sectoral policies identified by Enserink [31] in the Netherlands outbreak. This disintegration needs to be resolved ahead of time whereby heterogeneous stakeholders cooperate and collaborate on a homogenous platform. In reality, many countries are yet to have intellect and skill sharing that provides cross-sectoral data, ensures continued vigilance, and expedites timely response should an event surge [32].

Several studies have identified that inter-sectoral collaboration is the building block of joint risk communication. If risk communication to the community is conducted by different authorities individually, it is likely to confuse the community [19]. On the contrary, when joint risk communication is carried out, individuals feel that authorities are trustworthy and self-motivate themselves to follow health messages [16]. Moreover, joint risk communication could be a milestone for reforming a fragile health system [19]. It mediates the success of joint interventions by assisting individuals in making informed decisions. An example is the joint vaccination in Chad for mobile farmers' children and their livestock. This intervention was cost effective and more importantly set a milestone for veterinary and public health coordination [28]. However, joint intervention is not limited to joint vaccination only as is observed in the Australian outbreak investigation where human vaccination was coupled with several public health actions [24].

Considering the complexities of practice where One Health programs are used, evaluation becomes mandatory for accommodating changes deemed necessary as the evidence evolves [47]. However, our review did not identify any such program evaluation. Finally, education and training of health practitioners and at-risk groups are crucial in shaping their attitude and practice related to Q fever prevention. Practitioners' knowledge makes them vigilant as a high level of suspicion is required for Q fever diagnosis, given its inapparent clinical course [35,48,49]. Similarly, at-risk populations' knowledge helps them refrain from practicing high-risk behaviors [8,19,23,50].

5. Conclusions

This review presents an up-to-date evidence base for controlling Q fever in a One Health approach. One Health programs need to be based on human, animal, and environmental domains. These programs are highly context specific and their success depends on their flexibility to incorporate required changes. Emerging themes may be employed alone or in a combination of different One Health programs based on intercountry policy, practice, and feasibility. However, as long as the holistic underpinning of the multi-sectoral collaboration is preserved, programs are likely to function well. Further research into the barriers and opportunities of adopting a One Health approach to Q fever prevention and control is warranted.

Supplementary Materials: The following resource is available online at http://www.mdpi.com/1660-4601/16/5/730/s1, Table S1: Logic grids showing subject headings and keywords used for searching databases until 13 June 2018.

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2.4 Update to the literature

As it has been nearly three years since the published literature review was conducted, an update to include recent publications seemed timely and important.

2.4.1 Search strategy and eligibility criteria

All published studies between 14 June 2018 and 4 May 2021, on the utilization of a One Health approach to Q fever prevention and control were systematically searched in CINAHL, Embase, PsycINFO, PubMed, Scopus, and Web of Science databases. As in Figure 2.1, the same search strategy and eligibility criteria were used in the published literature review presented in this chapter (Appendix D.1).

2.4.2 Results

Eighteen studies between 2018 and 2021 were included in this updated literature review. One third of studies (6/18, 33%) were conducted in Australia, and four (67%) of them were studies from this PhD research. A list of reviewed studies is presented in Table 2.1.

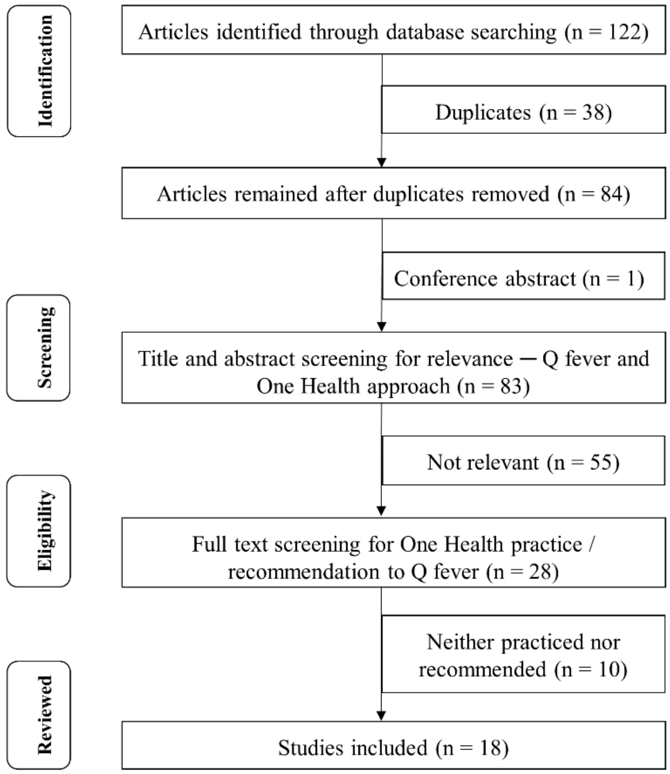

Figure 2.1 PRISMA flow diagram of the study selection process (literature review update).

Table 2.1 Characteristics of the studies that used one or more components of One Health in Q fever prevention and control.

Study and location	**Study type**	**One Health**	**Observed and/or expected outcomes**	**Comments**
[1] Australia	Cross-sectional	**Practiced** ▪ KAP survey among animal and veterinary science students **Recommended** ▪ Adherence to biosecurity guidelines while in contact with animals ▪ Universities should subsidize vaccination for both animal and veterinary science students	▪ Students possessed suboptimal knowledge about Q fever ▪ The majority of students reported exposure to livestock ▪ 61% animal science students were unvaccinated for Q fever ▪ Reduce zoonotic risks ▪ Higher vaccination coverage	▪ Inform Q fever vaccination policy, particularly for animal and veterinary science students

[2] Australia	Cross-sectional	**Practiced** ▪ KAP survey among livestock farmers **Recommended** ▪ One Health partnership between government and industry is required	▪ Livestock farmers possessed good understanding of Q fever ▪ 42% farmers were unvaccinated ▪ Higher immunization coverage through funded vaccination programs	▪ One Health partnership may promote Q fever awareness, ensure subsidies, and address low vaccination rates
[3] Australia	Cross-sectional	**Practiced** ▪ Survey of Australian wildlife rehabilitators (AWRs) ▪ Testing for IgG, IgA and IgM antibodies against *C. burnetii* **Recommended** ▪ Despite that AWRs are currently recommended for vaccination, they should be targeted through awareness programs	▪ AWRs are twice as likely to be exposed to *C. burnetii* than Australian general population ▪ Only 8% of AWRs were vaccinated for Q fever ▪ Increase uptake of Q fever vaccination	▪ Need for targeted prevention approaches including vaccination
[4] Ethiopia	Cross-sectional	**Practiced**	▪ Human seroprevalence ─ 29% males vs 24% females	▪ High seroprevalence of Q fever in livestock and

		▪ Human and cattle, sheep, goats and camels serology for Q fever **Recommended** ▪ Further collaborative research on Q fever	▪ Animal seroprevalence ─ 56% camels, 49% goats, 29% sheep and 10% cattle ▪ Identify health priorities and negotiate interventions	humans highlights the need for medical practitioners' vigilance and preventative interventions
[5] Australia	Epidemiological review	**Practiced** ▪ Analysis of human Q fever notification data ▪ Spatial analysis of human Q fever cases and livestock densities **Recommended** ▪ One Health research involving data from public health, veterinary and environmental disciplines is required	▪ Abattoir workers are a vulnerable group at high risk ▪ Livestock densities may be unrelated with spatial clustering of human Q fever cases in SA ▪ Better understanding of spatial and environmental epidemiology of Q fever	▪ State level analysis merits replication of similar interstate epidemiological reviews involving data from multiple disciplines
[6] France	Cross-sectional	**Practiced** ▪ Human serology ─ cattle farmers, livestock veterinarians, and general adult population (blood donors)	▪ Seroprevalence ─ 56% cattle farmers, 89% veterinarians, and 13% blood donors	▪ Cattle farming poses Q fever risks to occupational groups, and general population in Q fever endemic areas

[7] Australia	Cross-sectional	**Practiced** ▪ Dogs and cats serology and qPCR testing of whole blood, reproductive tissue or vaginal/preputial swab ▪ Survey of pet owners on behavioral and husbandry risk factors for exposure to *C. burnetii*	▪ Seroprevalence ─ 26% dogs and 13% cats ▪ Highest seroprevalence noted within 150 kilometers of an earlier human Q fever outbreak ▪ *C. burnetii* was not detected in qPCR in tested samples	▪ Non-detection of *C. burnetii* DNA from healthy dogs and cats suggests they may not be an important reservoir
[8] Sao Tome Island	Cross-sectional	**Practiced** ▪ Human serology ▪ Sequence analysis of ticks **Recommended** ▪ Further epidemiological studies are required	▪ Human seroprevalence ─ 7% ▪ Despite *C. burnetii* was not found in ticks, *Coxiella*-like endosymbionts were detected in almost all ticks ▪ Confirm the etiology and prevalence of Q fever in humans and animals	▪ Understand the differential diagnoses of certain unexplained febrile illnesses in the study site
[9] Dutch-German border region	Cross-sectional	**Practiced** ▪ Dutch human seroprevalence was estimated fitting an exponential	▪ Seroprevalence ▪ Outbreak farm's township, 16%	▪ Cross-border collaborative prevention measures are required to reduce cross-

		gradient to the geographical distribution of notified Q fever cases ▪ German seroprevalence was estimated from a sample of blood donors ▪ Association between seroprevalence and distance from the outbreak farm's township was assessed by regression analysis	▪ Overall in Dutch area, 4% ▪ Overall in German area, 1% ▪ Mean seroprevalence declined with increasing distance from the outbreak farm	border transmission of Q fever
[10] The Netherlands	Ecological correlation	**Practiced** ▪ The transmission of *C. burnetii* between infected and susceptible goat farms was characterized by estimating a spatial transmission kernel ▪ Infected farm to neighboring residents transmission was also characterized	▪ Transmission risk from farm to farm, and farm to residents declined with distance	▪ Visualization of transmission patterns through risk maps may offer further One Health insights for Q fever prevention
[11] Italy	Cross-sectional	**Practiced** ▪ Cattle and sheep serology ▪ Review of notified human Q fever cases	▪ Seroprevalence ─ sheep vs cattle ▪ Animal-level, 38% vs 12%	▪ Despite that the study did not identify any infection source, this study highlights circulation of *C. burnetii* in the human-

		Recommended ▪ Integrated animal-human surveillance is required to understand *C. burnetii* circulation in livestock and human populations	▪ Herd-level, 87% vs 69% ▪ Predominantly sheep but also cattle were involved in *C. burnetii* circulation in the area ▪ 5/7 confirmed human notifications had at least one exposed herd within 5 kilometer buffer ▪ Understand human zoonotic potential and design appropriate control measures	animal interface and may help design One Health measures to disease prevention including integrated surveillance
[12] Australia	Review	**Recommended** ▪ Multi-sectoral collaboration should benchmark all One Health practices despite contextual differences may	▪ Successful and sustainable public health interventions ▪ Explore barriers and opportunities of a One Health approach	▪ Despite the ubiquitous distribution of Q fever, variable disease burden, epidemiological understanding, and

		occur while practicing other components of this framework ▪ Further One Health research warranted		national preparedness for disease prevention, One Health practices may vary by country/region. However, as long as multi-sectoral approach benchmarks a One Health practice a program is likely to succeed
[13] Africa	Systematic review	**Recommended** ▪ Building laboratory capacity for zoonosis surveillance and prevention is necessary ▪ Inter-disciplinary research with data integration is required for further understanding and prevention of zoonoses	▪ Reduction in zoonotic disease burden	▪ Africa lacks data on zoonotic diseases. As zoonoses have major human and animal health implications a coordinated approach with veterinary and public health data sharing is needed.
[14] India	Cross-sectional	**Practiced** ▪ Human and animal serology	▪ Seroprevalence	▪ An epidemiological insight into *C. burnetii*

		▪ Milk samples tested for *C. burnetii* antibodies ▪ Vaginal swab, animal feed, environmental sample, and ticks were PCR tested for *C. burnetii*	▪ Dairy cattle ─ milk, 27% and serum samples, 30% ▪ Human contacts, 84% ▪ Ticks and sera from farm workers tested negative	transmission in human-animal interface in India
[15] Sub-Saharan Africa	Review	**Recommended** ▪ Zoonoses prevention strategies should target both humans and animals	▪ Better disease prevention outcomes compared to siloed human health interventions	▪ Optimal health for all species is attainable through a collaborative One Health approach to disease prevention
[16] South Africa	Cross-sectional	**Practiced** ▪ Human serology ▪ Surveyed on animal exposure/risk factors **Recommended** ▪ Clinicians with an understanding of zoonotic risk factors may inform safe clinical practice in South Africa	▪ Seroprevalence ─ 27% ▪ Attending cattle inspection facilities (dip tanks) was a risk factor for Q fever ▪ Sound therapeutic management of febrile patients, and targeted interventions	▪ Cattle inspection facilities should be targeted for building awareness and Q fever prevention in South Africa

[17] India	Cross-sectional	**Practiced** ▪ Human, animal and environmental samples tested for the presence of *C. burnetii* using PCR and ELISA	▪ Seroprevalence ─ ▪ Humans, 46% ▪ Goat samples, overall 14%	▪ Circulation of *C. burnetii* in goats and its implication for human health in India
[18] Belgium/The Netherlands	Review	**Recommended** ▪ A One Health framework should be used to deal with the emergence of zoonotic diseases due to human activities, particularly agricultural practices	▪ Q fever provides an interesting model for the application of a One Health approach to its prevention	▪ Q fever is best prevented holistically due to its widespread involvement in humans and animals

Notes. qPCR: quantitative polymerase chain reaction; ELISA: Enzyme-linked immunosorbent assay; IgG/A/M: Immunoglobulin G/A/M.

2.4.3 Overall comments

Overall, findings from studies presented in this literature update are similar to those in the published paper. Identified major themes across both reviews include risk assessment, serology, Q fever vaccination, environmental management and a multi-sectoral approach.[19] This update highlights that a One Health approach is recognized as an appropriate framework for Q fever prevention and control in Australia and internationally. While the published review captured 16 studies across nine years (2009–2018) including a conference abstract, the literature update has included 18 studies across three years (2018–2021), which is more than a three-fold increase per year. Contrastingly, the published review identified studies that applied a One Health approach to Q fever prevention and control including outbreak investigations.[20,21] While the literature update included cross-sectional studies and reviews, which may not be a direct application of One Health, it has generated evidence concerning the need for targeted vaccination, and the seroprevalence of *C. burnetii* identified for the first time in India.

An important observation from published and updated components of the review is the integration of the agricultural sector in Q fever risk assessment including animal serology, animal and environmental sampling, surveying risk factors, and ecological correlations. However, few studies have examined the impact of Q fever in the agricultural industry. Despite the evidence favoring a One Health approach, a lack of studies directly practicing this framework for Q fever prevention, particularly in Australia, highlights the need for adopting One Health for zoonosis prevention across the three domains. This recommendation is data driven and scientifically sound as presented throughout this thesis, and supported by stakeholders' perspectives. The literature update provides evidence that a One Health approach has been practiced, but mainly within research and academia rather than on the ground. In light of this, it is timely to assess the framework's suitability for Q fever prevention and control incorporating system change in partnership among human, animal and environmental disciplines.

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3

Chapter 3 ─ Study design and methodology

3.1 Preface

This chapter begins with an overview of the study setting (section 3.2). Section 3.3 outlines the research questions used to address the identified research gaps, and section 3.4 provides an overall framework of the study. Section 3.5 describes the study design, and data sources, collection and management. Finally, section 3.6 highlights the analytical approach used in this research and section 3.7 outlines associated ethical clearances.

3.2 Study setting

This research has been conducted in SA (Figure 3.1), although participants were recruited for study 6 from New South Wales (NSW) and Queensland (QLD). In the 2016 Census, SA had an approximate population of 1.7 million.[1] The number of Q fever notifications is highest in QLD, NSW and Victoria followed by SA.[2] This research has been conducted as part of the Environment and Health Research Group (EHRG) of the University of Adelaide (UoA),[3] with support from a number of coordinating organizations. These include the Communicable Disease Control Branch, SA Department for Health and Wellbeing (CDCB, SA Health),[4] the Department of Primary Industries and Regions (PIRSA),[5] Livestock SA ─ a not-for-profit organization representing cattle, sheep and goat producers in SA,[6] and the School of Animal and veterinary sciences (SAVS), UoA ─ the only school providing veterinary education in the state.[7]

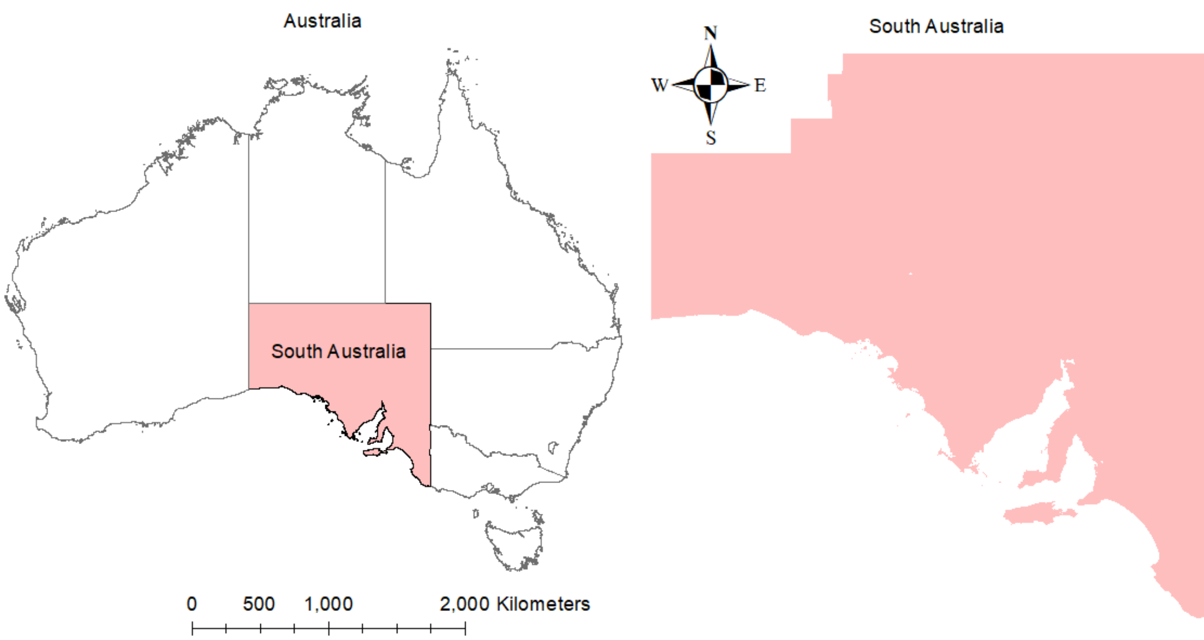

Figure 3.1 Map of South Australia, the study setting.

3.3 Research questions

In order to achieve the aims of this research and address the highlighted research gaps presented in Chapter 1, this thesis has used mixed methods (quantitative and qualitative) to explore three broad research questions illustrated in Figure 3.2 and linked to studies 2–6. The first study is a literature review on the utilization of a One Health approach to Q fever prevention and control. Study specific research questions are presented in section 3.3.1–3.3.4.

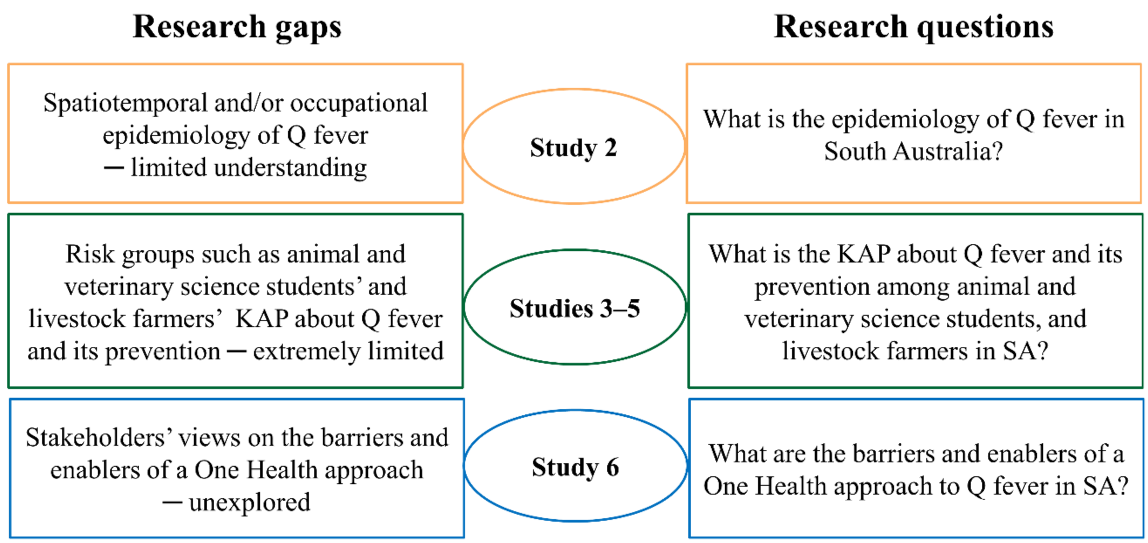

Figure 3.2 Identified research gaps and corresponding research questions.

KAP: Knowledge, attitudes and practices.

3.3.1 Study 1

Is a One Health approach utilized for the prevention and control of Q fever in Australia and internationally?

3.3.2 Study 2

What is the spatiotemporal and occupational epidemiology of Q fever in SA between 2007 and 2017? Are spatial livestock densities associated with clustering of human Q fever cases in SA?

3.3.3 Studies 3–5

What is the level of knowledge, attitudes and practices about Q fever and its prevention among university animal and veterinary science students and livestock farmers in SA? Do university animal and veterinary science students perceive Q fever and its prevention approaches differently than livestock farmers in SA?

3.3.4 Study 6

What are the barriers and enablers of adopting a One Health approach to Q fever prevention and control in SA? How do stakeholders perceive the constituents of an effective systemic approach to Q fever? Are GPs and the broader health system prepared to prevent and control Q fever within an inter-sectoral framework fostering communication and collaboration?

3.4 Framework of the overall study

To address the overall aims and proposed research questions identified through a review of the literature (study 1), this thesis is divided into three group(s) of studies including an epidemiological review of notified Q fever cases (study 2), cross-sectional surveys among university animal and veterinary science students and livestock farmers (studies 3–5), and stakeholder interviews (study 6) (Figure 3.3). Study 2 used Q fever notification data and annual records of cattle, sheep and goats in SA across 2007 to 2017 to understand the epidemiology of Q fever and explore the relationship between livestock densities and Q fever notifications in SA. Study 3 used responses from a cross-sectional survey among university animal and veterinary science students to elicit their KAP about Q fever and its prevention. Study 4 used responses from a cross-sectional survey with livestock farmers to gauge their perceptions of Q fever and its prevention. While study 5 compared and contrasted the varying perceptions of Q fever and its prevention between students and farmers through thematically analyzing the open responses obtained via the two cross-sectional surveys, study 6 used qualitative data from stakeholder interviews for identifying barriers and enablers of a One Health approach to Q fever prevention and control (Figure 3.3).

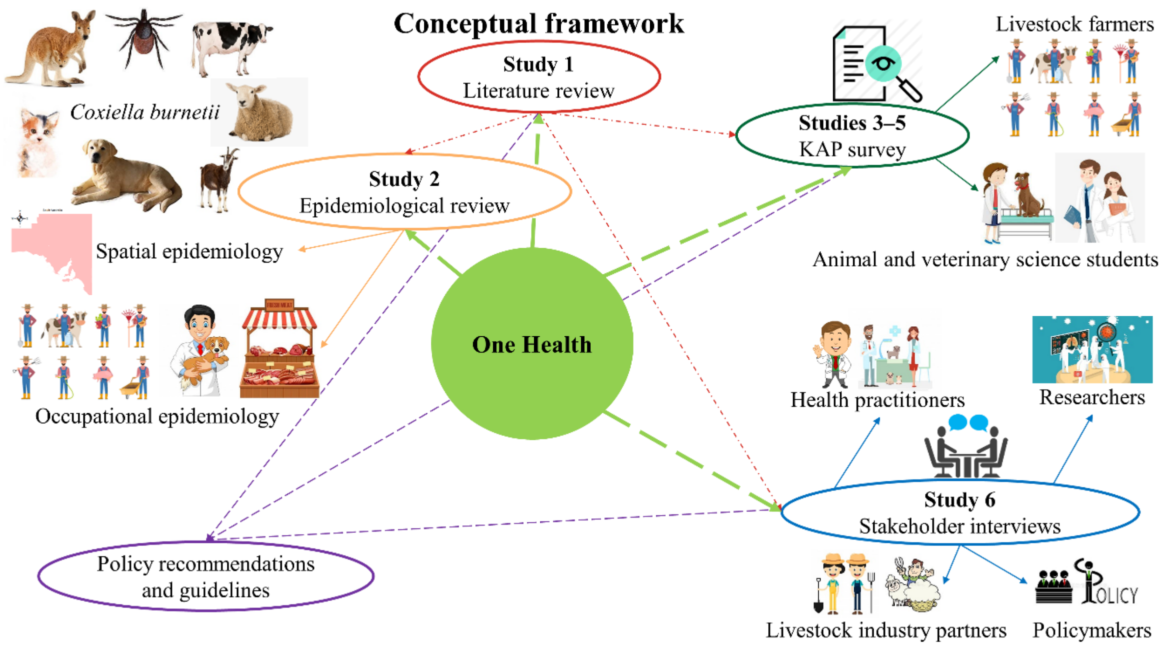

Figure 3.3 Conceptual framework of this research.

KAP: Knowledge, attitudes and practices.

Legend

Solid arrows indicate study components. Dash-dotted red arrows highlight how the literature review informed study designs to address identified research gaps. Dashed purple arrows indicate how study findings may contribute to policy formulation and recommendations. Thick dashed green arrows show the underlying One Health framework used in each of the studies.

3.5 Study design, and data sources, collection and management

This thesis presents mixed method research involving quantitative analysis of Q fever notification and livestock data in study 2, and survey data obtained in studies 3 and 4. Qualitative methods were used for studies 5 and 6 through the thematic analysis of the survey open responses and interview data.[8] The methods, analyses and results for individual studies are described in detail either in the published article or in the submitted manuscript presented in respective chapters and will not be repeated here. Rather this section will broadly outline the study design, recruitment process, data collection and the analytical approach taken to address the research questions.

3.5.1 Q fever notification data

Under the *South Australia Public Health Act 2011*,[9] medical practitioners and laboratories are mandated to report notifiable diseases to the CDCB, SA Health which is responsible for conducting state wide surveillance. Laboratory confirmed Q fever cases reported to the CDCB, SA Health between January 2007 and December 2017 were included in the analysis. De-identified Q fever notifications were sourced with the variables presented in Table 3.1.

Table 3.1 Q fever notification data.

Variable	Explanation
Notification date	Date of first notification to CDCB
True onset date	Date of first symptoms stated by doctor on notification
Calculated onset date	Earliest date of symptoms, laboratory notification or medical notification
Laboratory confirmation date	Date of positive laboratory testing
Doctor notification date	Date medical notification received
Age	Age in years
Sex	Male or female
Primary work status	Employed, unemployed, retired, student
Primary occupation	General employment category
Occupation description	Title of occupation
Hospitalized	Yes, no, unknown
PE type	Residential, employment or travel exposure
Vaccinated for Q fever	Yes, no, unknown
Vaccination date	Date recorded for vaccination
Residential suburb	Usual place of residence
Postcode	Residential postcode
PE suburb	Most likely place of exposure

Note. PE: Primary exposure.

3.5.2 Livestock data

Under the *Livestock Act 1997*,[10] livestock property registration is mandatory to maintain a register of the locations of livestock, and property owner or manager's contact details. Data about property owners, property information, livestock species on the property and the number of livestock on the property are recorded in the registry by the property identification codes (PICs).[11] Livestock count is recorded on 1 January each year. Using livestock registry data the number of cattle, sheep and goats per PIC zone in SA was obtained from PIRSA across the study period 2007–2017.

3.5.3 Survey of Q fever knowledge, attitudes and practices among animal and veterinary science students

In 2019, an online survey was employed among animal and veterinary science students of the SAVS, UoA. The questionnaire (Appendix A) sought information on participants' sociodemographic characteristics, knowledge of Q fever, attitudes towards and practices related to Q fever prevention and control, policies and guidelines they were required to follow, and barriers and enablers of vaccination. The questionnaire was substantiated against the survey tool used for surveying the Australian veterinary workforce.[12] A pilot survey was conducted among researchers of the EHRG and the questionnaire was refined accordingly.

The target population consisted of first, second and third year students enrolled in Animal Behavior and Bachelor of Animal Science (BSc Animal Science) program, and first to sixth year students enrolled in the Doctor of Veterinary Medicine (DVM) program. Students were recruited with assistance from the SAVS using an invitation email and a once only reminder email.

In 2018, SAVS had an approximate enrolment of 650 students across all degree programs,[13] hence, the required sample size was calculated to be 242 using the below formula.

$$\text{Sample size} = \frac{\dfrac{z^2 \times p(1-p)}{e^2}}{1+\left(\dfrac{z^2 \times p(1-p)}{e^2 N}\right)}$$

Here, z = z-score = 1.96, p = proportion that has the response of interest i.e., “have you heard of Q fever” (50%) = 0.5*, confidence interval (CI = 95%) and e = margin of error (5%) = 0.05, and N = size of the population = 650.[14]

3.5.4 Survey of Q fever knowledge, attitudes and practices among livestock farmers

In 2019, an online survey seeking similar information to animal and veterinary science students, was distributed among registered members of Livestock SA, the coordinating agency for this survey.[6] The questionnaire (Appendix A) was substantiated against tools used in a study assessing farmers’ knowledge of Q fever and its prevention in NSW.[15]

Registered cattle, sheep and goat producers in SA were recruited with the help of Livestock SA using a variety of mechanisms including newsletters, stock journals, Facebook page, website, direct emails and a once only reminder email to individual members. In 2018, Livestock SA had 3,500 registered members, and the calculated sample size was 347 using the above formula.

Here, except N = 3,500, all other parameters including p = 0.5* remained the same.

*For the purpose of calculating the sample size for both surveys, the proportion that has the response of interest i.e., “have you heard of Q fever” was considered at least 50%.

3.5.5 Interviews with stakeholders

Study 6 aimed to answer specific research questions through a series of semi-structured interviews using a pragmatic framework.[16-18] Between July and October 2020, representatives from four broad categories of stakeholder groups were interviewed via online video conferencing. Stakeholders included GPs and veterinarians; SA Health and SafeWork SA representatives; researchers from UoA and the University of Queensland; and representatives from the farming industry including Livestock SA and NSW farmers as suggested by Livestock SA. A semi-structured interview schedule (Appendix A/Chapter 8) was used and included the following topics:

- Knowledge of Q fever, its transmission and occupational risks
- Beliefs, attitudes and practices about Q fever prevention and control in the industry
- A One Health approach to Q fever: challenges and opportunities
- Q fever surveillance (human, animal and integrated), barriers and enablers
- Barriers and enablers of vaccination and immunization policy
- Key partners for policy implementation

GPs were recruited through the EHRG team network, the Australian College of Rural and Remote Medicine (ACRRM), the Royal Australian College of General Practitioners (RACGP), and the Primary Health Networks and Rural Clinical School newsletters. Veterinarians were recruited utilizing the existing collaboration with the SAVS. SA Health and SafeWork SA representatives were recruited through the EHRG research team network as the EHRG works in partnerships with SA Health and SafeWork SA. Researchers were recruited through the EHRG team network, and with assistance from colleagues in the SAVS. Industry stakeholders were recruited utilizing the existing collaboration with Livestock SA.

An invitation email containing details about the study along with the participant information sheet and consent form was sent to the identified stakeholders seeking their interest to participate (Appendix B/Chapter 8). A once only follow up email was sent to participants one week following the initial email if no response was received from them. Upon receiving participants' expression of interest, a meeting was scheduled according to participants' preferences and an online video conferencing invitation sent. Informed written consent was obtained via emails before the commencement of interviews. At the time of interviews, consent was reconfirmed verbally and interviews were recorded with permission.

3.6 Analytical approach

This research adopted a mixed method approach to answering identified research questions.[18] This thesis involved both concurrent and sequential collection of quantitative and qualitative data. Such an integrated approach helped develop instrument, triangulation and data transformation while adding scientific rigor to the research methodology. The following sections provide an overview of the analytical framework, and the publications and submitted manuscripts in each chapter provide a detail account of the analysis.

3.6.1 Analysis of Q fever notification and livestock data

A descriptive epidemiological analysis was performed using variables including age, gender, occupation, hospitalization, median delays in care seeking, vaccination for Q fever and the postcode of residential and primary exposure (PE) suburbs. Frequency, chi square tests and incidence rates per 100,000 population were calculated for each of the listed variables.

Assuming the data was not overdispersed for a small Q fever notification dataset, Poisson regression was carried out using notification count as outcome while age, gender, occupation, vaccination status and residential and PE suburbs as exposure of interests. Subgroup specific population estimates for each of the exposure variables were sourced from the Australian Bureau of Statistics (ABS) Census reports.[19] Annual average densities for cattle, sheep and goats per square kilometer were calculated using ArcGIS and spatially mapped with human Q fever notifications. As livestock counts were recorded by PIC zone and Q fever notifications by postcode, spatial join was performed on the corresponding shape files while examining their spatial correlations. Abattoirs and saleyards located in SA were also mapped using XY coordinates and postcodes sourced from the Aussie Farms Repository.[20] Details of analyses including spatial join is described in Chapter 4.

3.6.2 Quantitative analysis of survey data ─ animal and veterinary science students and livestock farmers

Four types of analytical approaches were used: 1) descriptive analysis of participants' demographic characteristics; 2) Fisher's exact tests to examine the association between participants' self-reported Q fever knowledge and prevention practices, perceptions about Q fever transmission, and vaccination promotion strategies; 3) univariate logistic regression to calculate the effect estimates for Q fever prevention practices by participants' self-reported knowledge, vaccination status, and stock type and size for farmers; and 4) multivariate logistic regression to estimate participants' odds of being vaccinated against Q fever for predictors including perceptions about the vaccine, vaccination barriers, and disease impacts.

Although participants' knowledge of Q fever was sought on a four-level Likert scale ─ a great deal, some, little and nil knowledge, responses were collapsed into a binary variable as 'a great deal or some knowledge', and 'little or nil knowledge' to reduce between group variability of the number of respondents. Responses to exposure to specific animals were collected using a five-level Likert scale and for the same reason eventually rescaled into four-levels: exposed 'always/often' = 'high exposure', exposed sometimes = moderate exposure, exposed rarely = low exposure, and never exposed = nil exposure. Similar rescaling was applied to a five-level Likert scale for responses to Q fever prevention practices with the eventual binary outcome: practice 'always/often/sometimes' = 'yes', and practice 'rarely/never' = 'no'. Responses for multivariate model predictors were collected on a five-level agreement scale and rescaled into three levels as 1) 'strongly agree/agree' = 'agree', 2) neither agree nor disagree, and 3) 'disagree/strongly disagree' = 'disagree'.

Additionally, spatial relationship was examined between livestock farmers' postcode of usual place of residence and corresponding 1) Socio-Economic Indexes for Areas (SEIFA) obtained from the ABS,[21] and 2) land cover/vegetation class obtained from the Department for Environment and Water (DEW).[22] Further details pertaining to analytical methods and corresponding results is covered in Chapters 5 and 6.

3.6.3 Qualitative analysis of survey data ─ animal and veterinary science students and livestock farmers

Open responses obtained from cross-sectional surveys among animal and veterinary science students and livestock farmers were thematically analyzed following the Braun and Clarke framework.[8] The analysis was guided by the research questions including how university students and livestock farmers perceived Q fever, how such perceptions influenced their attitudes to vaccination, and what barriers and enablers they identified that could inform vaccination policy? The analysis was conducted in six steps and is detailed along with the major themes discussed in the submitted manuscript presented in Chapter 7.

3.6.4 Qualitative analysis of interview data ─ stakeholders

Interviews were de-identified and assigned to a unique participant number at completion, and transcribed verbatim. Interviews were thematically analyzed and the inductive analytical process was guided by interview topics listed in section 3.5.5. Details of thematic analysis and major themes are discussed in the submitted manuscript presented in Chapter 8.

3.6.5 Statistical packages

All statistical analyses were performed using STATA version 15.[23] Geographic mapping was carried out using ESRI's ArcGIS version 10.5.1.[24]

3.7 Ethics approval

This research required several ethics approval (Appendix C). An approval for study 2 was obtained from the Human Research Ethics Committee (HREC), SA Health (*HREC/18/SAH/47*), and a site-specific assessment (project authorization) from the CDCB (*SSA/18/SAH/71*). Studies 3–5 required approval from the UoA HREC (*H-2019-040*). For study 6, a separate approval was obtained from the SA Health HREC (*HREC/20/SAH/8*), and corresponding site-specific assessment (project authorization) from the CDCB (*SSA/20/SAH/63*).

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4

Chapter 4 ─ Spatial, temporal, and occupational risks of Q fever infection in South Australia, 2007–2017

4.1 Preface

This chapter contains the second of six articles contributing to this thesis. This article has been published in *Journal of Infection and Public Health* and aims to describe the epidemiology of Q fever notifications in SA, to identify the association between Q fever infection and occupational exposure, and to detect the possible spatial and temporal correlation between Q fever and livestock density from 2007 to 2017.

Australia bears substantial burden of Q fever, yet no studies have been conducted into its epidemiology in SA. Besides, despite recent evidence suggesting association between livestock density and spatial clustering of Q fever cases, no Australian study has investigated Q fever notifications' spatial and temporal relationship with livestock densities. This article provides the evidence base for spatial, temporal and occupational epidemiology of Q fever in SA. In addition, findings have shown that spatial livestock densities in SA may not be related with human Q fever clustering, warranting further research involving interstate and multidisciplinary data including climatic and other environmental data.

4.2 Statement of authorship

Title of Paper	Spatial, temporal, and occupational risks of Q fever infection in South Australia, 2007–2017.	
Publication Status	☑ Published ☐ Submitted for Publication	☐ Accepted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	Rahaman MR, Milazzo A, Marshall H, Bi P. Spatial, temporal, and occupational risks of Q fever infection in South Australia, 2007–2017. *J Infect Public Health*. 2020;13:544-51.	

Principal author

Name of Principal Author (Candidate)	Md Rezanur Rahaman		
Contribution to the Paper	Designed the study, analysed the data, drafted the manuscript and incorporated feedback.		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	10 May 2021

Co-author contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Adriana Milazzo		
Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	10 May 2021

Name of Co-Author	Helen Marshall		
Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	10 May 2021

Name of Co-Author	Peng Bi		
Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	10 May 2021

4.3 Publication

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Spatial, temporal, and occupational risks of Q fever infection in South Australia, 2007–2017

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ABSTRACT

Background: The burden of Q fever on at risk population groups in Australia is substantial, despite the availability of a vaccine. Our objectives were to: (a) describe the epidemiology of notified Q fever cases in South Australia (SA), (b) identify if Q fever infection is associated with occupational exposure, and (c) detect the possible spatial and temporal association of Q fever with livestock density.
Methods: Laboratory confirmed Q fever notifications from January 2007 to December 2017 were obtained from the SA Health Department. Q fever notification rates and incidence rate ratios were calculated for gender, notification year, age group, occupation category, and primary exposure suburb. Spatial mapping and analysis of Q fever notifications was undertaken using livestock data, and abattoirs and saleyards located in SA.
Results: During the study period 167 Q fever cases were notified. Males predominated (72%), with higher rates observed in the 21–40 year age group (1.52/100,000), and eight cases (5%) reported prior Q fever vaccination. Most frequently listed occupation categories were livestock farmers (35%), and abattoir workers (20%), but in 15% of cases, there was no known occupational risk. Highest notifications (22%) were recorded in the suburb containing an abattoir. The number of goats, cattle and sheep was not associated with Q fever notifications.
Conclusions: Q fever predominance among males in their twenties and thirties may indicate vaccination under-coverage among the young workforce possibly due to high turnover of workers. Q fever among those vaccinated raises concerns about vaccine efficacy or potential waning immunity. Our findings are consistent with previous studies highlighting abattoir workers as a high-risk occupational group because of its transient workforce, and low vaccination coverage. Q fever notifications in SA may be unrelated with spatial livestock density. Further One Health research involving veterinary, public health and environmental data is required.

Introduction

Q fever infection is transmissible from animals to humans, and it exists in many countries, particularly amongst certain occupational groups who have contact with animals and animal products [1,2]. *Coxiella burnetii*, the causative bacterium, is present in a range of reservoirs, particularly goats, cattle and sheep [3]. Infected animals shed the bacteria in their urine, faeces, and in larger quantities in birth products [4]. Soon after shedding, the bacterium becomes aerosolized in the environment and may infect humans through inhalation of contaminated dust and aerosols [3,5]. In humans Q fever infection commonly manifests as a self-limiting febrile illness, but may remain sub-clinical as well [2]. Asymptomatic infections pose diagnostic challenges to clinicians and could be a major driver of Q fever underreporting with its higher probability in low incidence geographical regions [6,7]. It has been estimated that for every Q fever case, two further cases are likely to be underreported [8].

Unlike the United States (U.S.), and the United Kingdom where the annual reported incidence of Q fever is low (0.04–0.24/100,000) [8,9], the reported incidence in Australia is higher (1.50–4.90/100,000) [10]. Higher incidence is in part because

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of increased notifications among persons who come in contact with livestock through their occupations, and is associated with significant workplace compensation claims [11,12]. In recognition of Q fever as an emerging public health problem, the Australian Government has been conducting Q fever surveillance through mandatory reporting since 1977 [13]. The government also funded vaccination nationally through the National Q Fever Management Program (NQFMP) from 2001 to 2006 [14]. The NQFMP was effective in reducing Q fever incidence by 20–50% until 2009 when the incidence had started to rise again. This rebounding incidence highlights the changing epidemiology of Q fever as reported in several Australian studies with more cases reported among farmers post-NQFMP compared to abattoir workers pre-NQFMP [15,16].

The complex epidemiology of Q fever underscores that multi-sectoral strategies may be required to control its transmission. A One Health approach engages cross-sectoral collaboration, data sharing and intelligence exchange among public health and animal health authorities and provides an effective means for Q fever control and prevention [17]. Such an approach was adopted in the Netherlands to deal with a community Q fever outbreak affecting more than 4000 people [18,19]. Veterinary control measures included bulk milk tank monitoring, small ruminant mandatory vaccination, pregnant animal culling and prohibition of farm expansion [19]. However, veterinary control measures per se were thought to be insufficient in preventing human cases, and like the NQFMP a subsidized vaccination program was nationally funded for high risk populations [18].

In Australia, there are limited studies concerning the epidemiology of Q fever. Amongst those published, studies are from areas with high Q fever incidence [1,14–16,20], and few studies in areas with low reported incidence [10,21,22]. On the contrary, there has been no published epidemiological reviews concerning Q fever infection in SA. Investigating occupational risks of Q fever, and relationship with Q fever notifications and livestock density in Australia is also limited. This study aims to describe the epidemiology of notified Q fever cases in SA, to explore the association of Q fever infection with occupational exposure, and their spatial and temporal correlation with livestock density from 2007 to 2017. Combined, this information will provide evidence for public health and animal health authorities for their coordinated actions to protect the vulnerable groups from Q fever infection utilizing a One Health approach.

Methods

Q fever notification data

Laboratory confirmed Q fever notification data in SA from 1 January 2007 to 31 December 2017 were obtained from the Communicable Disease Control Branch (CDCB), SA Health Department. We obtained information on date of illness onset, age, gender, hospitalization, vaccination status, postcode, residential suburb, primary exposure (PE) suburb, and occupation.

To estimate the burden in SA, Q fever notified cases per 100,000 population was calculated using 2016 and 2011 Australian census population estimates [23]. Age specific population estimates, yearly total populations, and suburban populations were sourced from Australian Bureau of Statistics census reports. Given the low number of notifications in SA over the study period, we calculated state level Q fever incidence rates, and later incidence rates by PE suburbs. Incidence Rate Ratios (IRRs) for Q fever notifications were calculated for selected sub-groups defined by gender, year of notification and age group. In our study occupations were classified into eight broad categories modified from an Australian study [1] and from nationally derived occupation classifications [24] (Table 2, Supplementary Table S1).

Livestock density

On 1st January each year, livestock count is recorded as the number of animals on farms by property identification codes (PIC), which is a mandatory registry code in SA containing information on the property, animal species, and the number of livestock [25]. Using PIC data we obtained the number of goats, cattle, and sheep for the study period. However, as SA does not have an animal surveillance system, Q fever infection in animals is unknown. There are 57 PIC zones and 10 PIC regions in SA, with PIC regions several times larger than zones containing one to nine PIC zone(s) (Fig. 1). In order to visually inspect the relationship between livestock numbers and human Q fever incidence per 100,000 population, we plotted Q fever incidence against goat, cattle, and sheep populations. Pearson's correlation was used to examine the association between annual livestock population and yearly Q fever incidence.

The average density of livestock species per square kilometre for each PIC zone across the 11 year study period was calculated using ArcGIS. In addition, in order to examine the pattern of overall livestock density, an 11-year combined goat, cattle, and sheep density per square kilometre was calculated.

Spatial mapping of Q fever cases

In all analyses, we included PE suburb because this is the most likely place where the person was exposed. Information on PE suburb is obtained from the medical notification or from interviews with the case by CDCB. Location of exposure includes the case's workplace or their residential suburb. If there is no information on exposure, the place of exposure is listed as the case's residential suburb. For this study period >90% of cases were interviewed with exposure information provided.

In order to examine the association between Q fever and livestock density, spatial join was performed on PE suburbs to PIC zones using ArcGIS. PE suburbs that fell completely within a PIC zone were assigned to the respective PIC zone number. However, PE suburbs which fell over one adjacent PIC zones were manually assigned to a PIC zone that contained the majority of the respective PE suburbs. Q fever notifications were mapped with livestock density for goats, cattle and sheep per PIC zone, for each year and for the overall study period. A total of 18 (11%) cases were excluded from spatial mapping because their associated PE suburb was recorded as interstate, overseas or unknown.

Q fever notifications were also mapped against the location of SA abattoirs and saleyards as potential places of exposure. Abattoirs are where slaughtering of livestock is carried out, while saleyards are livestock markets where trading takes place in the form of auctions [26]. Information on location, XY coordinates and postcodes for each abattoir and saleyards was sourced from the Aussie Farms Repository [26]. All were assigned to a PIC zone as per the method described for spatially assigning Q fever notifications from PE suburbs to PIC zones. This information was added to the maps as a separate layer in ArcGIS.

Risk occupations/regions for Q fever in SA

Poisson regression was used to calculate IRRs to compare Q fever incidence between selected occupation categories and SA regional PE suburbs with 95% confidence intervals (CI) and P values.

Statistical analyses were conducted using Stata version 15. Geographic mapping was applied using ESRI's ArcGIS version 10.5.1.

Results

Q fever notification data

There were 167 Q fever cases notified in SA between January 2007 and December 2017. Across the 11-year study period, annual

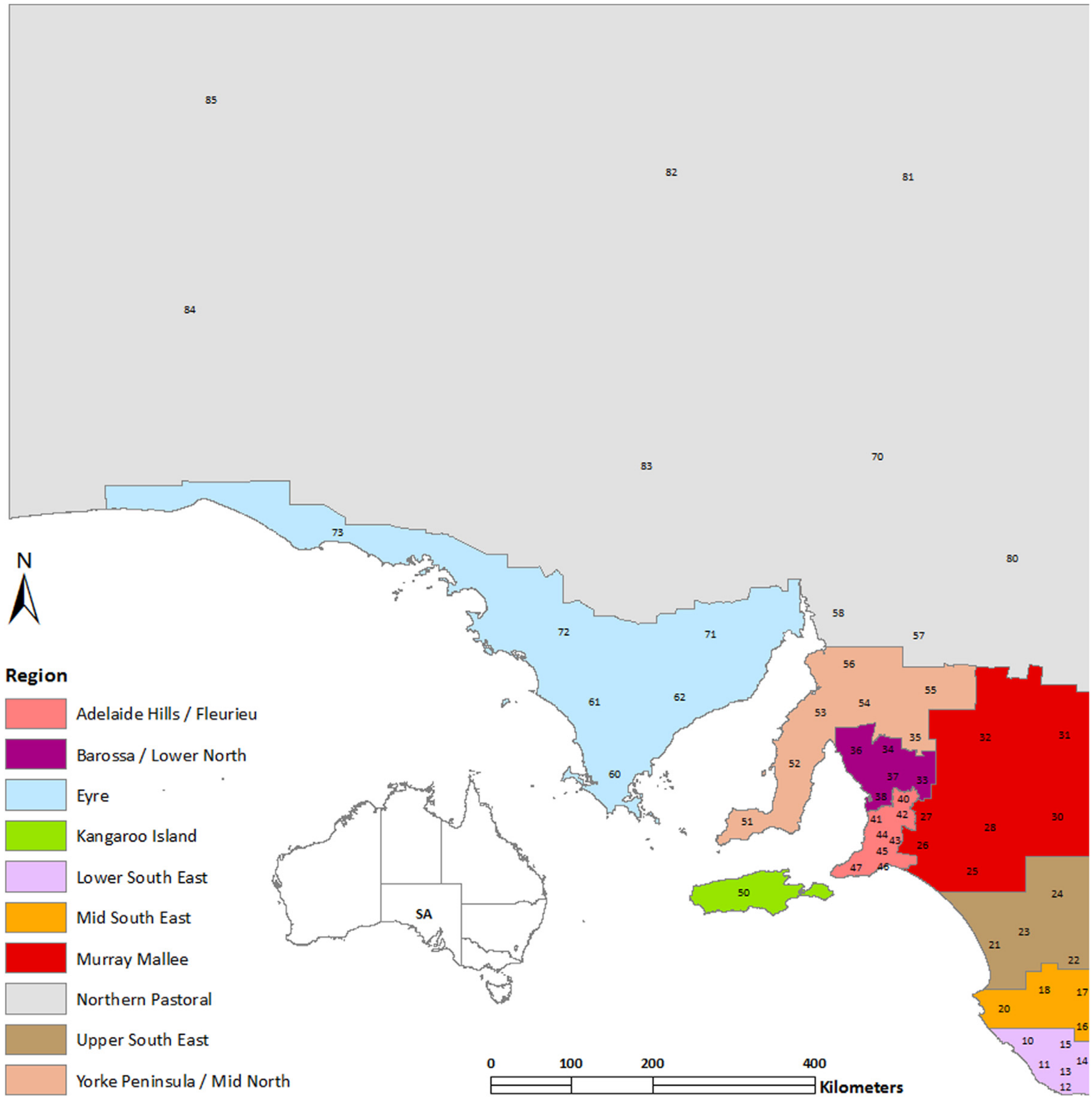

Fig. 1. Reference PIC regions, South Australia. Numbers indicate property identification code (PIC) zones. South Australia location is indicated as SA in the inset Australia map.

Q fever cases ranged from eight to 28, with the highest number reported in 2016. The mean annual notification rate was 0.92 per 100,000 population, with notification rates peaking at 1.63/100,000 in 2016 (Fig. 2). Cases associated with seasonality was not detected.

Of the 167 Q fever cases, 120 (72%) were male, and 70 (42%) were in the 21–40 year age group (Table 1). Q fever notification rates were almost three times higher among males (IRR 2.61, 95% CI 1.86–3.65) compared to females (Table 1). As opposed to the highest reported age group of 21–40 year-olds, Q fever incidence was 72% lower among persons >60 years (IRR 0.28, 95% CI 0.17–0.48). Of the 167 cases, eight (5%) reported prior Q fever vaccination. Just under half of all cases required hospitalization. Within occupational categories, the proportion of hospitalization ranged from 20% (healthcare workers) to 78% (transport workers) (Table 2). However, occupational category was not associated with cases being hospitalized, (Fisher's Exact $P = 0.156$).

Five PE suburbs had the highest number of Q fever notifications and accounted for 59 (35%) cases (Table 1). Two of these PE suburbs were in the Murray Mallee region, and three in the Northern Pastoral region. The PE suburb with the highest number of Q fever cases was from the Murray Mallee region and accounted for 22% of the total cases at a rate of 23.70/100,000 (Table 1). When PE suburbs were assigned to PIC zones, the top five PIC zones with the highest number of Q fever notifications accounted for 78 (47%) cases. Of these, 50 (64%) were reported from the Murray Mallee region containing two of the five PIC zones.

Primary exposure of cases occurred at work (49%), residence (38%), travel (4%), and for 9% it was unknown. The five major occupation categories were farmers who had contact with livestock, abattoir workers, no risk occupation, unknown occupation, and tradespersons or transport workers (Table 2).

Livestock density

Although cattle and sheep populations have increased proportionately, goat populations have shown a disproportionate increase over the study period, particularly since 2014 (Fig. 3). Annual goat, cattle and sheep counts were highly correlated with each other ($P < 0.001$), but none of them, or the total livestock population were associated with annual Q fever incidence in humans ($P \geq 0.370$).

Table 1
Characteristics of Q fever cases, South Australia, 2007–2017.

Characteristics	N (%[a])	Rate/100,000 person-years at risk	IRR (95% CI)[b]	P value
Gender				
Female	47 (28)	0.51	Ref.	–
Male	120 (72)	1.33	2.61 (1.86–3.65)	<0.001
Year of notification (2-year)[c]				
2007–2008	41 (25)	1.30	Ref.	–
2009–2010	20 (12)	0.62	0.48 (0.28–0.81)	0.007
2011–2012	18 (11)	0.55	0.42 (0.24–0.73)	0.002
2013–2014	27 (16)	0.80	0.62 (0.38–1.01)	0.054
2015–2016	41 (25)	1.20	0.93 (0.60-1.43)	0.728
2017	20 (12)	1.16	0.89 (0.52–1.53)	0.683
Age group				
0–20 years	13 (8)	0.30	0.20 (0.11–0.36)	<0.001
21–40 years[d]	70 (42)	1.52	Ref.	–
41–60 years	66 (40)	1.36	0.89 (0.64–1.25)	0.517
61 years or older	18 (11)	0.43	0.28 (0.17–0.48)	<0.001
Occupation category				
Farmer/contact with livestock	59 (35)	35.67	4.61 (2.89–7.36)	<0.001
Abattoir worker	34 (20)	17.57	2.27 (1.36–3.81)	0.002
No risk occupation[e]	25 (15)	7.73	Ref.	–
Tradesperson	9 (5)	7.83	1.01 (0.47–2.17)	0.974
Transport worker	9 (5)	5.87	0.76 (0.35–1.63)	0.479
Healthcare worker	5 (3)	5.56	0.72 (0.28–1.88)	0.501
Contact with animals other than livestock	3 (2)	53.90	6.97 (2.10–23.08)	0.001
Primary exposure suburb				
Murray Mallee regional suburb in PIC 27[f]	37 (22)	23.70	Ref.	–
Murray Mallee regional suburb in PIC 32	10 (6)	33.66	1.42 (0.71–2.86)	0.325
Northern Pastoral regional suburb in PIC 57	4 (2)	24.39	1.03 (0.37–2.89)	0.956
Northern Pastoral regional suburb in PIC 58	4 (2)	5.21	0.22 (0.08–0.62)	0.004
Northern Pastoral regional suburb in PIC 70	4 (2)	94.01	3.97 (1.41–11.13)	0.009

Notes: IRR, incidence rate ratio; CI, confidence interval; Ref., reference group for Poisson regression analysis.
[a] Percentages may not add up to 100 due to rounding. Person-years at risk was calculated by summing yearly total population for the respective sub-groups of each of the listed variables in SA across 11 study years.
[b] These are unadjusted IRRs, as population at risk estimates for subgroups defined by all five factors simultaneously were not able to be obtained from the available data.
[c] Year of notification was collapsed into 2-year intervals for a more stable model.
[d] The highest number of Q fever cases belong to this age group.
[e] We wanted to quantify the risks of Q fever in other occupations relative to this category.
[f] The highest number of Q fever notifications was reported from this suburb.

Table 2
Q fever notification by occupation, South Australia, 2007–2017.

Occupation categories	Number (%[a])	Hospitalized (%[b])	Reported occupations from notification data
Farmer/contact with livestock	59 (35)	26 (44)	Beef cattle farmer; dairy farmer; farmers and farm managers; farm hands; grazier; livestock farmers; mixed crop and livestock farmers; primary products inspector; shearer; sheep farmer; skilled agricultural workers; veterinarian; wool classer
Abattoir worker	34 (20)	11 (32)	Abattoir worker; boner; butcher; cleaner in meatworks; lecturer at TAFE, attends abattoirs and butchers to lecture[c]; meat and fish process workers; meatworks labourer; meat tradespersons; packer; slaughter person; slicer
No risk occupation[d]	25 (15)	12 (48)	Child care worker; community worker; construction project manager; importer/exporter; kitchenhand; other advanced clerical and service workers; performing arts support workers; sales consultant; school teachers; supervisor transport and despatching clerks
Unknown occupation[e]	23 (14)	16 (70)	Home duties; other; retired; unemployed
Tradesperson	9 (5)	3 (33)	Builder; construction tradespersons; electrical and electronics tradesperson; motor mechanic; tiler
Transport worker	9 (5)	7 (78)	Delivery driver; road and rail transport drivers; truck drivers
Healthcare worker	5 (3)	1 (20)	Enrolled nurses; medical laboratory technical officer; medical technical officer
Contact with animals[f] other than livestock	3 (2)	1 (33)	Park ranger; veterinary students

[a] Percentages may not add up to 100 due to rounding. Percent contribution in parenthesis is relative to the column total i.e., 167 cases.
[b] Percent contribution in parenthesis is relative to the row total i.e., number of cases in that occupation category.
[c] The likely exposure occurred at his workplace and therefore classified under abattoir worker.
[d] The occupation per se is not known to be a risk factor for Q fever and obtained dataset does not have specific detail on exposures.
[e] A primary occupation is not known and examples listed here are the occupation descriptions as recorded in the obtained dataset without specific detail on exposures.
[f] Important ones are dogs, cats, kangaroos and bandicoots.

Fig. 2. Q fever notification rates by year of notification, South Australia, 2007–2017.

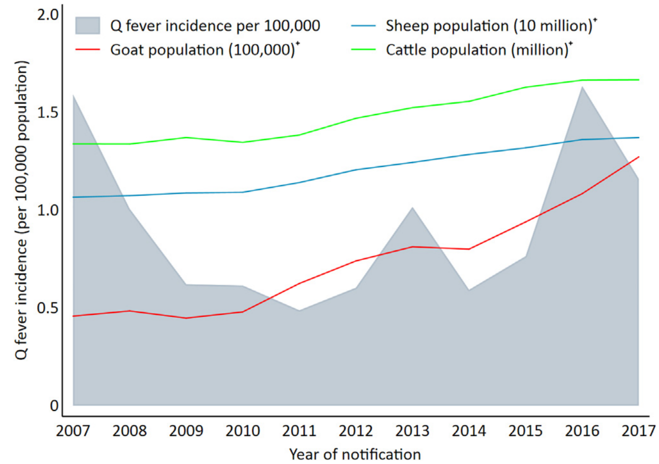

Fig. 3. Q fever incidence by livestock numbers, South Australia, 2007–2017. **+**Species denominators are different because of the relative differences in their annual population size.

The highest annual (Supplementary Fig. S1–6) and overall study period (Fig. 4) goat, cattle, and sheep density was respectively observed in Adelaide Hills/Fleurieu regional PIC, Lower South East regional PIC, and Mid-South East regional PIC. In comparison, the lowest annual goat and sheep density was observed in two Northern Pastoral regional PICs (Supplementary Fig. S1–6). However, the lowest annual cattle density was observed in Northern Pastoral regional PICs during 2007–2012 (Supplementary Fig. S1–3), and in the Eyre regional PIC during 2013–2017 (Supplementary Fig. S4–6).

Spatial mapping of Q fever cases

Spatial distribution was undertaken for 149 (89%) cases because for remaining cases the PE suburb was interstate, overseas or unknown. The highest number of Q fever notifications from one PIC was reported from the Murray Mallee region across all study years (Supplementary Fig. S1, S3–6), except the Barossa/Lower North in 2008 and 2010 (Supplementary Fig. S1 and S2), and the Lower South East in 2009 (Supplementary Fig. S2). Overall, the highest Q fever cases (n = 39) in one PIC occurred in the Murray Mallee region while the lowest was recorded in the Northern Pastoral region (Fig. 4).

The location of 40 meat abattoirs and four saleyards were plotted by their XY coordinates (Fig. 4 and Supplementary Fig. S1–6). The top three PIC regions with the highest number of abattoirs were Barossa/Lower North, Adelaide Hills/Fleurieu, and the Murray Mallee region. Of the 149 cases, 107 (72%) were reported from PE suburbs in regional PICs having at least one abattoir located in it. Of the four saleyards, two were located in Adelaide Hills/Fleurieu region, and one each in Lower South East and Barossa/Lower North region (Fig. 4 and Supplementary Fig. S1–6).

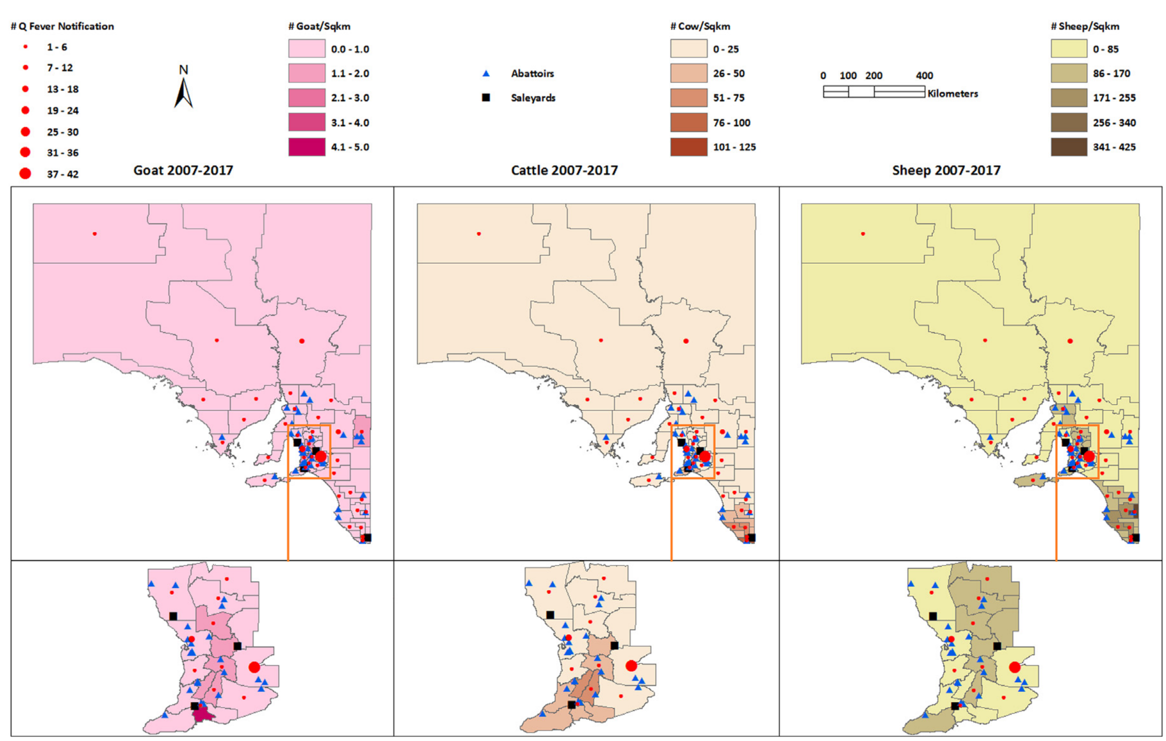

Fig. 4. Spatial relationship of Q fever notifications and livestock densities; location of abattoirs and saleyards, South Australia, 2007–2017.

Risk occupations/regions for Q fever in SA

Compared to Q fever cases who had 'no risk occupation', disease incidence was two times higher among abattoir workers (IRR 2.27, 95% CI 1.36–3.81), seven times higher among persons who had contact with animals other than livestock such as park rangers and veterinary students (IRR 6.97, 95% CI 2.10–23.08), and almost five times higher among farmers or persons who had contact with livestock (IRR 4.61, 95% CI 2.89–7.36) (Table 1). One Northern Pastoral regional suburb had four times the risk of Q fever (IRR 3.97, 95% CI 1.41–11.13), while another suburb in that region had 80% lower risk (IRR 0.22, 95% CI 0.08–0.62) compared to the reference Murray Mallee regional suburb (Table 1).

Discussion

This comprehensive epidemiological study explored the relationship between Q fever notification data and livestock data in SA, the state that has the third highest notification rates nationally [10]. We were also able to quantify occupational risks of Q fever.

Even though male preponderance in Q fever cases is consistent with other published studies [1,8,11,14,27,28], the age group with the highest incidence of Q fever notifications in our study was young adults in their twenties and thirties, compared to older adults reported elsewhere in Australia and in the U.S. [1,8]. Although the decrease in Q fever notifications among young adults between 2001 and 2010 is considered to be due to the direct effect of targeted vaccination through the NQFMP [15], our findings have several interpretations. One reason could be that Q fever vaccination coverage rate among young adults in SA is generally low, particularly among transient abattoir workers who are financially challenged and may not afford the cost of vaccination [29]. Evidence also suggests that transient workers are often involved in slaughtering of feral goats [29], which could potentially increase their risks of Q fever.

Contrary to initiatives from WorkSafe Victoria of enforcing mandatory vaccination for all abattoir workers [30], one study reported that SA meat processors generally do not offer routine vaccination to their employees [29]. We found that 95% of Q fever notifications in SA were not vaccinated indicating poor coverage among at-risk populations. Therefore, it is prudent to prioritize abattoir workers for targeted vaccination. Five of the eight cases who developed disease after Q fever vaccination had their vaccination status validated, and the time interval between vaccination and disease onset ranged from 83 days to 15 years post vaccination. This raises concerns about Q fever vaccine efficacy. Q fever vaccine Q-VAX® is manufactured by Seqirus Australia from inactivated *C. burnetii* Phase I Henzerling strain that offers cell mediated immunity [31]. It was proposed that vaccination related immunity lasts for at least five years [32]. However, two cases who developed Q fever within three years post vaccination suggests possible waning immunity or failure of a primary immune response to the vaccine. Revaccination is contraindicated because of the risk of hypersensitivity to the vaccine in those previously exposed to the organism [31].

Increased number of Q fever cases in SA reporting contact with livestock is consistent with published Australian and international literature [11,15,28,33]. This could be in part because of the lower than expected vaccination coverage among farmers during the second phase of NQFMP which attracted less subsidy than the first phase [5]. In addition to farmers and abattoir workers, unvaccinated veterinary students and park rangers that constituted the occupational group "contact with animals other than livestock" in our study possessed higher than expected risk of Q fever. This elevated risk should not be overlooked based on the number of notified cases during the study period, the finite population at risk and the calculated rates of Q fever also deserve careful consideration. Although Q fever vaccination is a prerequisite for students enrolled in veterinary degrees in Australia [34], and vaccination is currently recommended for park rangers [32], the three cases were not vaccinated. This situation warrants exploration of existing Q fever vaccination policy and practice, particularly related to at-risk groups who are currently recommended to be vaccinated such as abattoir workers, farmers, shearers, veterinary students, veterinarians and wildlife workers [32].

Even though evidence suggests that NQFMP was effective [14], the unexpected increase in Q fever notifications in SA in 2016 underscores the need for further epidemiological investigation. Contrary to an international study that found a relationship between the number of sheep flocks and Q fever [27], our study identified that livestock species, or total livestock populations, were not statistically associated with Q fever notifications in humans. Furthermore, the Murray Mallee regional suburb had the highest recorded Q fever notifications, but its associated livestock density was not high. However, the respective PIC zone contained an SA abattoir [35], which could potentially highlight the added risk of Q fever among abattoir workers.

Historical high incidence, transient workforce, relative unvaccinated status, and poor industry attention suggest that abattoir workers are still one of the highest at-risk occupational groups for Q fever infection. This supports the findings in our study, coupled with evidence that the majority of cases were reported from PIC zones with abattoirs. Although higher rates of Q fever notifications were reported from one Northern Pastoral regional suburb, its small population size deserves consideration. In contrast, the Murray Mallee regional suburb had a 37 times larger population with the highest notification numbers, as well as the location of several abattoirs. We suggest that the Murray Mallee region needs continued vigilance by state government and meat industry, and that mandatory vaccination is required for all abattoir workers in SA. However, for averting the economic and social implications of Q fever on a sustainable scale, commitment from government and industry should extend to fund vaccination of at-risk occupations, particularly farmers and park rangers, and ensure that all veterinary students are vaccinated prior to working with animals.

One of the key limitations of this study is the low number of notifications reported over the study period, which was further reduced by the exclusion of 18 cases from analyses. Underreporting of Q fever may have contributed to lower notification rates resulting in limited epidemiological analysis and interpretation. We were unable to produce adjusted rate ratios and we cannot rule out that there may be confounding in the calculated IRRs. The other major limitation was that the occupations reported for cases notified to CDCB did not align with the ABS categories for occupation. Although we endeavoured to include all related occupations and population size, under or over representation is a possibility. We also assumed that the worker population for each occupation category remained constant for the duration of the study period.

Although in Queensland Q fever notifications may have a seasonal pattern [20] which has also been shown in the U.S. [8] and Netherlands [28], our findings do not hold that postulation in SA, which is consistent with published literature on national level data in Australia [13]. However, in the large Q fever outbreak that occurred in the Netherlands, there was an association between environmental conditions such as *C. burnetii* airborne concentration and vegetation density, and disease notification [28,36,37]. Therefore, one future direction may include analysis of Q fever notifications in an interdisciplinary approach using veterinary data on bulk tank milk sample, and vaginal or environmental swabs for *C. burnetii*; meteorological data including relative humidity, temperature, and wind speed and direction; atmospheric dispersion modelling; and spatial covariates from the adjacent states of SA.

Conclusions

Q fever prevention requires a coordinated approach from all levels, including government and industry. Public health programs like NQFMP should be adopted nationally and at state levels periodically, and in collaboration with industries. In order to maximize program success, state level challenges and opportunities deserve contextual priority when conceiving public health programs. Our finding of no association between spatial livestock density and Q fever notifications does not restrict replication of such analysis in other high incidence Australian states and countries, as this will contribute evidence to the epidemiology of Q fever not only in Australia, but also worldwide. One Health research using data from several disciplines including public health, veterinary, and environmental is required before drawing any premature conclusion that Q fever is not associated with livestock density.

Author contributions

MRR, AM, HM and PB conceptualized and designed the study. MRR completed data analysis and drafted the manuscript. AM, HM and PB reviewed the manuscript. AM, HM and PB supervised the research.

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Competing interests

None declared.

Ethical approval

This research was approved by the SA Department for Health and Wellbeing Human Research Ethics Committee, HREC reference number: HREC/18/SAH/47 and endorsed by the University of Adelaide ethics committee.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jiph.2019.10.002.

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5

Chapter 5 ─ Q fever vaccination: Australian animal science and veterinary students' One Health perspectives on Q fever prevention

5.1 Preface

This chapter contains the third article contributing to this thesis. This article has been published in *Human Vaccines & Immunotherapeutics*. In 2019, an online survey was conducted among animal and veterinary science students enrolled at UoA to explore their perceptions about Q fever and prevention strategies. A substantial number of animal science students were unvaccinated for Q fever. Students identified costs and time associated with vaccination and access to healthcare as challenges for vaccination. They suggested that mass vaccination, subsidized vaccination and improving healthcare access were enablers for Q fever vaccination. Findings are a reminder that unvaccinated students are a priority for Q fever vaccination, and underscore that university policy for Q fever vaccination needs to consider subsidized vaccination for both animal and veterinary science students.

5.2 Statement of authorship

Title of Paper	Q fever vaccination: Australian animal science and veterinary students' One Health perspectives on Q fever prevention
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	Rahaman MR, Milazzo A, Marshall H, Chaber A-L, Bi P. Q fever vaccination: Australian animal science and veterinary students' One Health perspectives on Q fever prevention. *Hum Vaccin Immunother*. 2021;17:1374-81.

Principal author

Name of Principal Author (Candidate)	Md Rezanur Rahaman		
Contribution to the Paper	Designed the study, collected and analysed the data, drafted the manuscript and incorporated feedback.		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	10 May 2021

Co-author contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Adriana Milazzo		
Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	10 May 2021

Name of Co-Author	Helen Marshall		
Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	10 May 2021

Name of Co-Author	Anne-Lise Chaber		
Contribution to the Paper	Designed the study, collected the data and reviewed the manuscript.		
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Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	10 May 2021

5.3 Publication

Rahaman MR, Milazzo A, Marshall H, Chaber A-L, Bi P. Q fever vaccination: Australian animal science and veterinary students' One Health perspectives on Q fever prevention. *Hum Vaccin Immunother*. 2021;17:1374-81.

6

Chapter 6 – Q fever prevention and vaccination: Australian livestock farmers' knowledge and attitudes to inform a One Health approach

6.1 Preface

This chapter contains the fourth article contributing to this thesis published in *One Health*. In 2019, an online survey was conducted among members of Livestock SA representing cattle, sheep and goat farmers to explore their perceptions about Q fever and prevention strategies. Australian livestock farmers had a good understanding of Q fever. However, their knowledge of farm-level biosecurity measures was suboptimal. Livestock farmers suggested a coordinated approach to Q fever prevention programs including human vaccination. Findings are a reminder that livestock farmers would benefit from adherence to dust and aerosol transmission prevention practices. One Health partnership between government and industry is needed to promote Q fever awareness and address low vaccination rates among livestock farmers by funding vaccination programs.

6.2 Statement of authorship

Title of Paper	Q fever prevention and vaccination: Australian livestock farmers' knowledge and attitudes to inform a One Health approach	
Publication Status	☑ Published ☐ Submitted for Publication	☐ Accepted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	Rahaman MR, Marshall H, Milazzo A, Crabb D, Bi P. Q fever prevention and vaccination: Australian livestock farmers' knowledge and attitudes to inform a One Health approach. *One Health*. 2021;12:100232.	

Principal author

Name of Principal Author (Candidate)	Md Rezanur Rahaman		
Contribution to the Paper	Designed the study, collected and analysed the data, drafted the manuscript and incorporated feedback.		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	10 May 2021

Co-author contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Helen Marshall		
Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	10 May 2021

Name of Co-Author	Adriana Milazzo		
Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	10 May 2021

Name of Co-Author	Deane Crabb		
Contribution to the Paper	Designed the study, collected the data and reviewed the manuscript.		
Signature		Date	10 May 2021

Name of Co-Author	Peng Bi		
Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	10 May 2021

6.3 Publication

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Q fever prevention and vaccination: Australian livestock farmers' knowledge and attitudes to inform a One Health approach

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ABSTRACT

Background: Livestock farmers are at risk of Q fever, a zoonotic disease transmitted to humans from animals such as cattle, sheep and goats. Australia bears substantial Q fever burden, particularly among farmers. A One Health approach engages cross-sectoral collaboration among animal, human and environmental health and is the preferred framework for Q fever prevention.
Methods: Cattle, sheep and goat farmers were invited to participate in an online survey in 2019 to gauge perceptions about Q fever and its prevention. Participants were recruited via membership newsletters and social media. Descriptive analyses and logistic regressions were performed.
Results: A total of 351 farmers completed the survey. Most respondents (80%) had been farming for ≥20 years, with sheep and beef cattle their primary stock. 71% reported knowledge of Q fever, and 85% identified transmission through contaminated dust inhalation was highly likely. The majority of respondents (97%) were aware of Q fever vaccine, and 95% agreed it was effective in preventing disease, yet 42% remained unvaccinated. Reported barriers to vaccination included poor access to a trained doctor and time and cost related to vaccination. Most farmers (≥91%) believed that subsidized vaccination and improved awareness would promote higher uptake.
Conclusion: While Q fever knowledge among respondents was good, their practices related to airborne transmission prevention were poor. Livestock farmers would benefit from adherence to dust and aerosol transmission prevention practices. One Health partnership between government and industry is needed to promote Q fever awareness and address low vaccination rates among livestock farmers by funding vaccination programs.

1. Introduction

Coxiella burnetii causes Q fever zoonosis in humans with livestock being its principal reservoir [1,2]. Clinical manifestations span asymptomatic infections, acute disease, chronic Q fever and post Q fever fatigue syndrome [3,4]. Livestock farmers bear substantial burden of Q fever zoonosis [3,5].

Higher Q fever notifications among Australian livestock farmers in recent years [6] further support the importance of Q fever prevention for farmers. The U.S. Centers for Disease Control and Prevention (U.S. CDC) recommends non-specific Q fever prevention strategies including hand hygiene, wearing protective clothing and shoes, eye goggles and face shields, and respiratory protection using a facemask or N95 respirator when the risk of exposure is high such as handling birth fluid/placenta [4]. Vaccination as a specific disease prevention strategy significantly reduces Q fever incidence [7], and a human vaccine is registered only in Australia [8]. Despite this, high Q fever incidence among Australian livestock farmers indicates possible low uptake of vaccination [6], and/or inadequate practice of preventative measures.

Australia implemented its national Q fever immunization program during 2001–2006 among abattoir workers and farmers. An evaluation of the national program found that the vaccination was effective, but not at the desired level due to low uptake in the livestock sector [9]. Additionally, there is little evidence on whether Australian livestock

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farmers practice non-specific Q fever prevention measures [4]. Persistent burden of human Q fever cases in the livestock industry, following the nationally funded vaccination program in Australia highlights possible inadequacy with a single approach such as vaccination, and the need for a multifaceted disease prevention program involving key stakeholders including industry and at risk populations [2].

An integrated approach having multi-stakeholder representation is purported to provide an appropriate framework for Q fever prevention [1,10]. One Health is a framework that combines efforts from human, animal and environmental health sectors. A One Health approach has been piloted to prevent and control Q fever outbreaks internationally and in Australia [11–13]. Findings from these pilot studies set the ground for the large-scale application of One Health measures in the livestock industry. Piloting One Health principles in the Australian goat farm was an example where non-specific Q fever control measures were supplemented by the use of human vaccination [11]. However, countries not having an available human vaccine may benefit the most from a One Health approach utilizing non-specific measures such as environmental control and transmission prevention as shown in the U.S. goat and cattle dairy [12].

In line with the Australian goat farm example, we propose that a One Health approach, when complemented with human vaccination would provide the strongest framework for Q fever prevention. However, lack of empirical studies and the need for assessing preparedness of the Australian livestock industry for adopting a One Health approach esteemed to suggest a cross-sectional survey would be an efficient way of acquiring evidence. We aimed to assess livestock farmers' knowledge, attitudes and perceptions about Q fever and its prevention adopting a One Health approach to inform livestock industry's current Q fever prevention policies including farmers' vaccination in Australia.

2. Methods

2.1. Study design, site and population

An online cross-sectional study was targeted at all registered members of Livestock SA, a nonprofit organization that represents livestock producers in South Australia (SA). Cattle, sheep and goat farmers registered with Livestock SA in 2019 were invited to participate in the survey. Participants were recruited via the Livestock SA website, newsletters, stock journal, Facebook page and email during March 21–June 10, 2019 using SurveyMonkey platform (Supplement S4–S7). The questionnaire consisted of 23 questions (22 closed and 1 open) divided across six sections; (1) socio-demographic information, (2) knowledge and perceptions about Q fever, (3) self-reported exposure to specific animals and Q fever prevention practices, (4) vaccine awareness and recommendation for specific at-risk groups, (5) perceived challenges for vaccination, and (6) vaccination promotion strategies.

2.2. Pretesting, data collection and ethics approval

Experts external to the research group including Livestock SA representatives with knowledge of Q fever and expertise on conducting surveys pretested the legibility and coherence of the questionnaire. The questionnaire was initially made available via SurveyMonkey (www.surveymonkey.com) on Livestock SA website, Facebook page, newsletters and the stock journal (a weekly newspaper for the agricultural industry) in March-April 2019. A direct email was sent on two successive occasions two weeks apart in May 2019 to enhance recruitment. Participation in the survey was voluntary. Ethics approval was granted by the Low-Risk Human Research Ethics Review Group, The University of Adelaide (Approval No: H-2019-040).

2.3. Statistical analysis

Demographic characteristics were descriptively analyzed. The spatial distribution of livestock farmers' socio-economic positioning was examined using the Australian Bureau of Statistics (ABS) published data on Socio-Economic Indexes for Areas (SEIFA). Each SEIFA is constructed by combining specific weighted variables against postcode of usual residence ranging from one decile (lowest) to 10 deciles (highest) [14].

Livestock farmers were asked to indicate the size of their stock and categorized into small-medium and large producers: beef cattle, $\leq$200 animals = small-medium producer and > 200 animals = large producer; and sheep, $\leq$1000 animals = small-medium producer and > 1000 animals = large producer. Livestock SA confirmed the levels of classification that we used as they estimated that the average number of livestock in SA was 1600 sheep or 220 cattle per farm.

Fisher's exact tests were used where appropriate to assess whether livestock farmers' knowledge of Q fever was associated with their self-reported disease prevention practices, perceived modes of disease transmission, and suggested strategies for vaccine promotion. Although data on farmers' knowledge were collected using a four-level Likert scale i.e., a great deal, some, little and nil knowledge, responses were combined into a binary variable as "a great deal or some knowledge" and "little or nil knowledge". Likewise, responses to exposure to specific animals were collected using a five-level Likert scale that was eventually rescaled into a four-level: high exposure = exposed always/often, moderate exposure = exposed sometimes, low exposure = exposed rarely, and nil exposure = never exposed.

Univariate logistic regression was used to calculate effect estimates for Q fever prevention practices among livestock farmers by their self-reported knowledge, stock type stratified as single vs multiple, and vaccination status. Responses to Q fever prevention practices were collected using a five-level Likert scale i.e., always, often, sometimes, rarely and never, which were subsequently collapsed and recoded as yes = practice always/often/sometimes and no = practice rarely/never. After recoding, some observations were still not sufficiently large to produce an effect estimate and hence excluded from the model.

Multivariate logistic regressions were used to estimate livestock farmers' odds of being vaccinated for selected predictors including perceptions about Q fever vaccine, barriers for vaccination, and disease impacts. A five-level Likert scale was used to collect responses to these predictors of vaccination, which was re-stratified as (1) strongly agree/agree = agree, (2) neither agree nor disagree and (3) disagree/strongly disagree = disagree. The positive level of agreement i.e., agree was considered as the reference category. All models were adjusted for age, gender, level of education and years of farming. Coefficient plots were used to display selected point estimates and their confidence intervals computed from regression models.

All statistical analyses were performed using Stata version 15 [15]. Geographic mapping of livestock farmers' postcode of residence was carried out using ESRI's ArcGIS version 10.5.1 [16].

3. Results

3.1. Study population

A total of 3513 members of Livestock SA were targeted. Members who provided their email addresses received an email: the first invite was distributed to 2586 members: 1161 (44.9%) opened the email and 294 (11.4%) clicked on the survey link. A reminder invitation was distributed to 2582 members: 1010 (39.1%) opened the email and 276 (10.7%) clicked on the link. A total of 351 livestock farmers completed the survey.

3.2. Socio-demographic characteristics

Of 351 livestock farmers, 172 (49.0%) had one type of stock and 179 (51.0%) had multiple types of stock (Table 1). Most farmers (309/350, 88.3%) were between 40 and 79 years old and the majority (227/349, 65.0%) were males. About half of the farmers (172/349, 49.3%) had a

Table 1
Livestock farmers' characteristics, Q fever knowledge and vaccination status by stock type, 2019 ($N = 351$).

Characteristics	Single stock (n = 172)	Multiple stock (n = 179)
Age group (%)		
20–39 years	12 (7.0)	25 (14.0)
40–59 years	91 (53.2)	78 (43.6)
60–79 years	66 (38.6)	74 (41.3)
≥ 80 years	2 (1.2)	2 (1.1)
Sex (%)		
Female	55 (32.2)	67 (37.6)
Male	116 (67.8)	111 (62.4)
Level of education (%)		
Completed part secondary	34 (19.8)	29 (16.4)
Completed secondary	46 (26.7)	48 (27.1)
Trade / Apprenticeship	12 (7.0)	6 (3.4)
Certificate / Diploma	43 (25.0)	52 (29.4)
Bachelor degree or higher	37 (21.5)	42 (23.7)
Year of farming (%)		
1–10	10 (5.8)	14 (7.8)
11–20	25 (14.5)	21 (11.7)
>20	137 (79.7)	144 (80.4)
Beef and sheep stock status (%)		
Beef only	44 (25.6)	11 (6.1)
Sheep only	122 (70.9)	22 (12.3)
Both beef and sheep	0	145 (81.0)
Neither beef nor sheep[a]	6 (3.5)	1 (0.6)
Number of types of stock (%)		
1	172 (100.0)	0
2	0	138 (77.1)
3–5	0	41 (22.9)
Beef producer (%)		
Small-medium producer (≤200 animals)	32 (72.7)	100 (64.1)
Large producer (>200 animals)	12 (27.3)	56 (35.9)
Sheep producer (%)		
Small-medium producer (≤1000 animals)	41 (33.6)	68 (40.7)
Large producer (>1000 animals)	81 (66.4)	99 (59.3)
Socio-Economic Indexes for Areas – IRSAD (%)[b]		
Decile 1–5	123 (72.3)	115 (65.7)
Decile 6–10	47 (27.7)	60 (34.3)
Q fever knowledge (%)		
A great deal	17 (10.0)	20 (11.2)
Some	98 (57.6)	114 (63.7)
Little	48 (28.2)	41 (22.9)
Nil	7 (4.1)	4 (2.2)
Awareness of Q fever vaccine (%)		
Aware	150 (94.3)	168 (98.8)
Not aware	9 (5.7)	2 (1.2)
Vaccination status (%)		
Yes	82 (55.0)	102 (60.4)
No	67 (45.0)	67 (39.6)
Time elapsed since the vaccination (%)		
1 year	6 (7.2)	5 (4.9)
2–5 years	17 (20.5)	17 (16.7)
> 5 years	60 (72.3)	77 (75.5)
Do not know	0	3 (2.9)
Reason for vaccination (%)		
Self-perceived risk of getting Q fever	64 (77.1)	72 (70.6)
Employer perceived risk of getting Q fever	7 (8.4)	15 (14.7)
General practitioner perceived risk of getting Q fever	7 (8.4)	6 (5.9)
Other	5 (6.0)	9 (8.8)

Note: Percentages in parentheses are relative to the number of respondents for a specific characteristic, and where relevant may not add up to 100 due to rounding.
[a] Of seven farmers who had neither beef nor sheep six had single stock (two dairy cattle; one goats; and three other stock — one pigs, horses and poultry; one layer hens; and one horses) and one multiple stocks (goats and other stock — horses), except beef cattle, dairy cattle, goats, and sheep all other livestock were classified as "other".
[b] IRSAD — The Index of Relative Socio-Economic Advantage and Disadvantage.

certificate/diploma/higher level of education. Most farmers (281/351, 80.1%) had been farming for >20 years. Of 200 beef cattle producers, 132 (66.0%) were small-medium producers, and of 289 sheep producers, 180 (62.3%) were large producers. The majority of farmers (238/345, 69.0%) lived in an area having the IRSAD (The Index of Relative Socio-Economic Advantage and Disadvantage) decile one to five (Table 1 and Fig. 1A). Contrastingly, farmers lived in areas of mixed vegetation and land use i.e., native (predominantly woody/non-woody native and mangrove) and non-native such as dryland agriculture, but rarely areas with other vegetation including urban or built up area (Fig. 1B).

3.3. Knowledge and awareness of Q fever and its vaccine

Of 349 livestock farmers who reported knowledge on Q fever, 249 (71.3%) indicated a great deal or some knowledge (Table 1). Farmers' knowledge was not associated with their type of livestock (single vs multiple). Most farmers (318/329, 96.7%) were aware of a human vaccine for Q fever (Table 1). A greater proportion of farmers having had multiple stocks were aware of the vaccine compared to farmers who had single stock (Fisher's exact, $p = 0.024$).

3.4. Perception of Q fever transmission by the level of knowledge

Substantial variation was noted among the listed routes for Q fever transmission: from 19/265 (7.2%) farmers reporting sexual transmission between humans to 261/309 (84.5%) identifying aerosol transmission was likely (Supplementary Table S1). All listed transmission modes except transmission through culling infected animals were significantly associated with farmers' self-reported knowledge: consuming undercooked meat, consumption of unpasteurized dairy, aerosol transmission, laundering of clothes and sexual transmission.

3.5. Level of exposure to animals

High exposure to dogs and sheep was reported by 306/335 (91.3%) and 279/334 (83.5%), and 188/310 (60.6%) – 230/324 (71.0%) of farmers had moderate-high exposure to cats, kangaroos, poultry and beef cattle, and low-nil exposure was reported by the majority for other listed animals with camels being the least reported animal (Fig. 2A).

3.6. Q fever prevention practices

Most livestock farmers reported frequently wearing work boots (338/345, 98.0%) and a uniform (339/347, 97.7%) when having contact with animals (Fig. 2B). The majority of farmers reported frequent handwashing after contact (267/346, 77.2%) and changing into a uniform/work boots before contact (220/336, 65.5%). Conversely, 277/336 (82.4%) – 324/329 (98.5%) reported rare or no use of eye goggles, facemasks or N95 respirators (Fig. 2B).

When livestock farmers' Q fever prevention practices were related to their self-reported knowledge, only wearing work boots and showering after contact with animals were found to be associated. Other practices such as wearing a uniform, using a facemask, handwashing after contact, changing into uniform/work boots before animal contact, changing out of uniform/work boots after animal contact, using hand gloves, using eye goggles and using an N95 respirator were not associated (Supplementary Table S2).

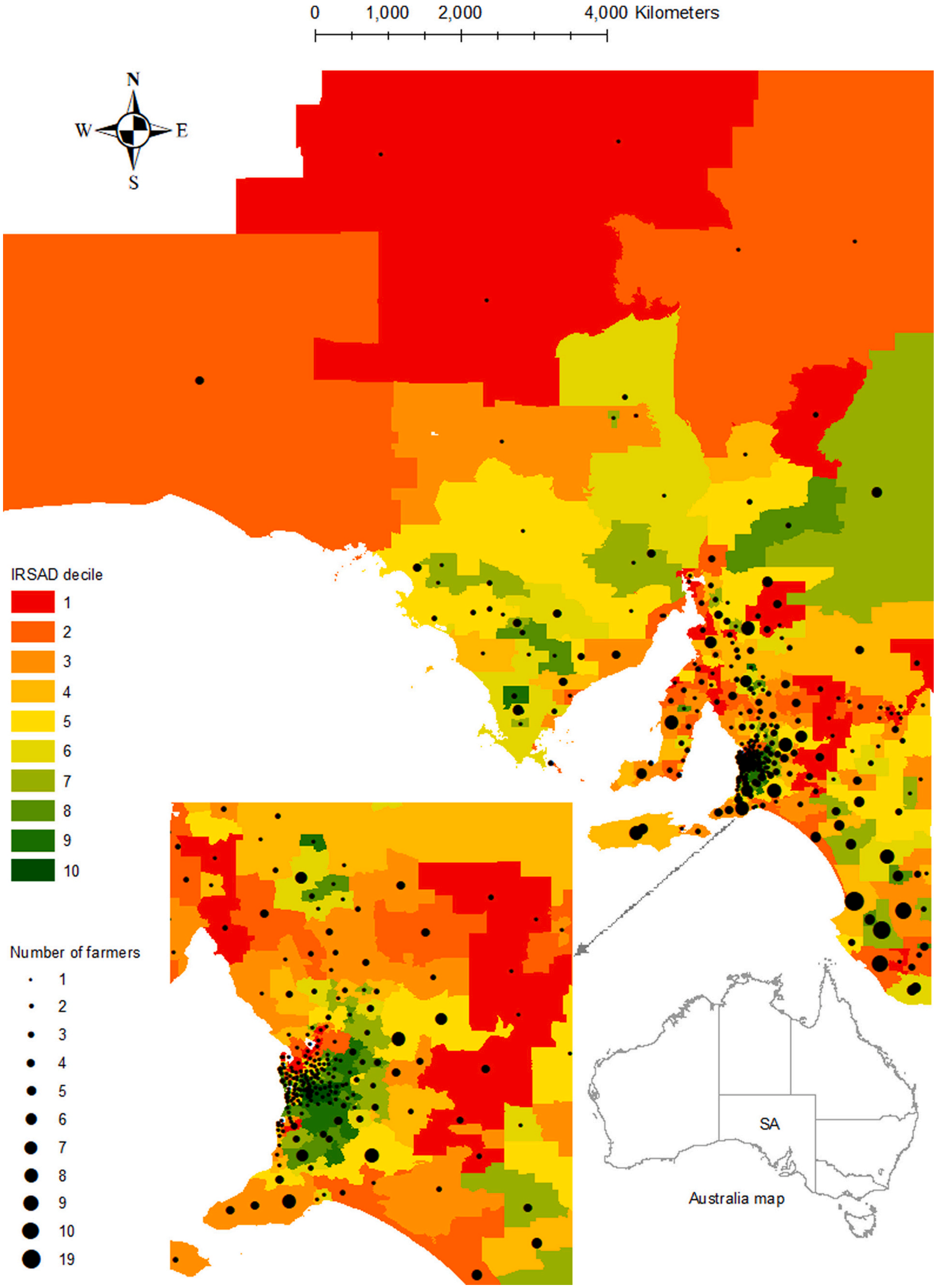
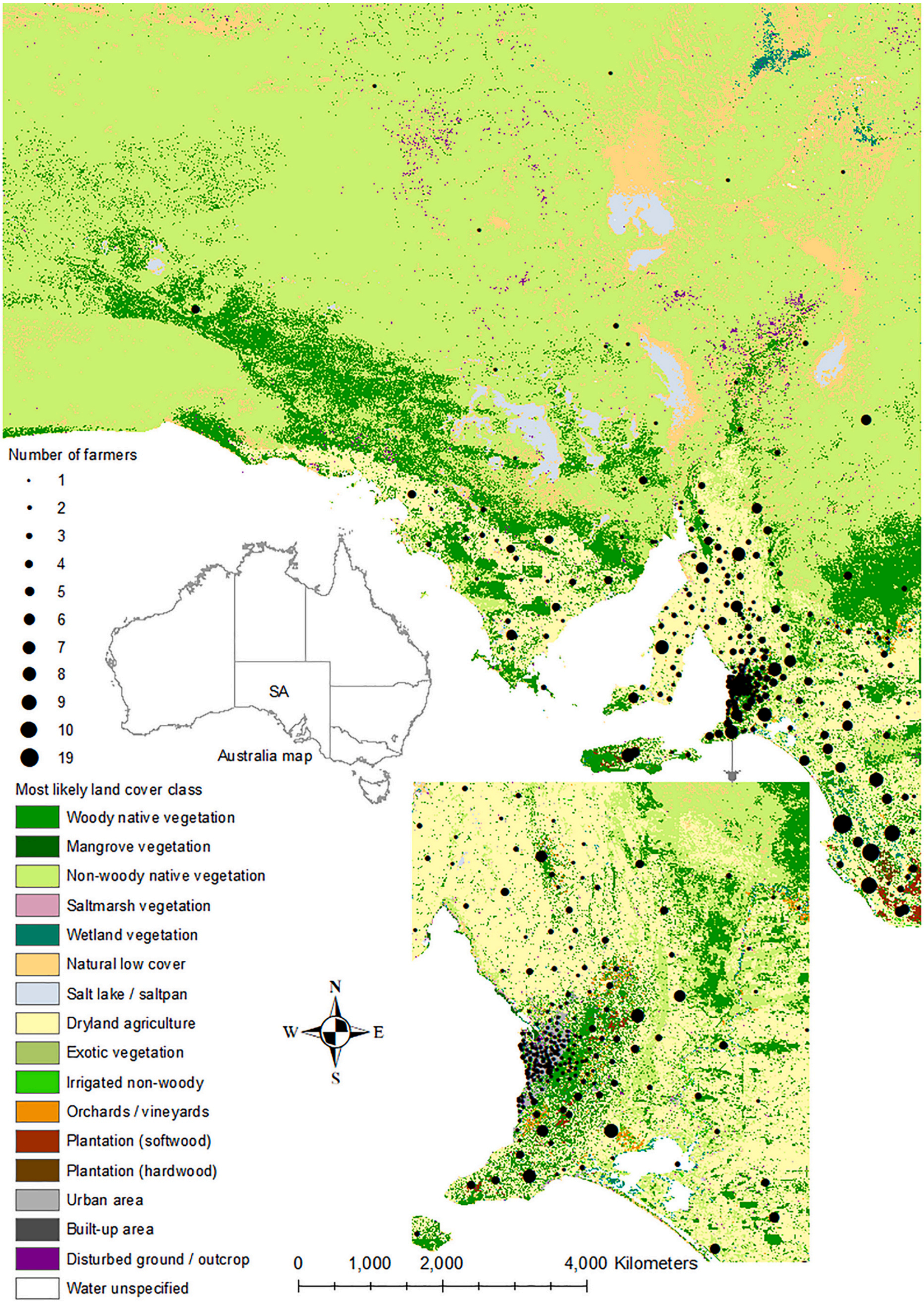


Fig. 1. Location of livestock farmers by postcode of the usual place of residence, and corresponding Index of Relative Socio-Economic Advantage and Disadvantage (IRSAD) decile (Panel A — source: Australian Bureau of Statistics), and land cover/vegetation class (Panel B — source: Department for Environment and Water), South Australia (SA), 2019. Appearance differs between Panel A and Panel B at the northwest region, as there was no postcode information for that region in Panel A.



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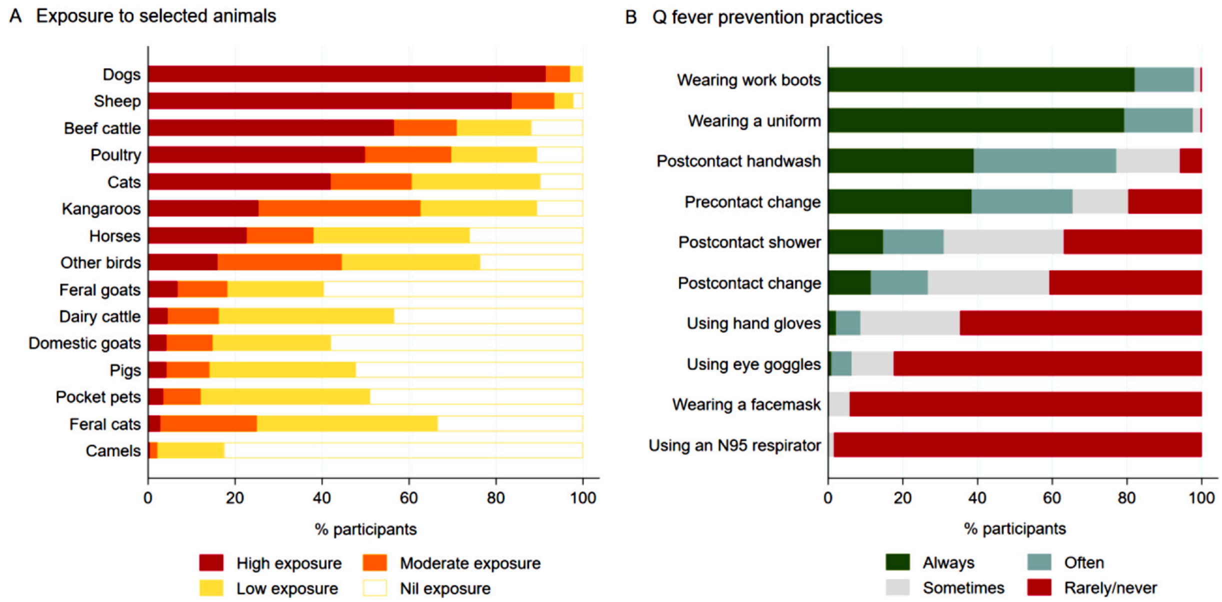

Fig. 2. Livestock farmers' self-reported exposure to specific animals (Panel A) and reported practices for Q fever prevention (Panel B), 2019.

3.7. Prevention practices by the level of knowledge

In univariate logistic regression, showering after contact with animals (OR 1.63; 95% CI, 1.01–2.65) was associated with livestock farmers' knowledge (Fig. 3A). Farmers who had a great deal or some knowledge were more likely (OR 1.7; 95% CI, 1.03–2.82) to shower after contact with animals compared with farmers who had little or nil knowledge (Fig. 3B). Likewise, farmers who completed a secondary level education were more than twice (OR 2.27; 95% CI, 1.15–4.51) as likely to shower after contact with animals compared with farmers who did not after adjusting for other covariates. However, farmers who had a bachelor or higher education were three times (OR 3.06; 95% CI, 1.42–6.62) more likely to change out of uniform/work boots after contact with animals compared with farmers with lower educational attainment (Fig. 3B).

3.8. Prevention practices by beef and sheep producer size

Large beef producers who had a bachelor's degree or higher education were six times (OR 5.99; 95% CI, 2.07–17.36) more likely to change out of uniform/work boots after contact with animals compared with small-medium producers (Fig. 4). In contrast, large sheep producers who had a trade or apprenticeship education were seven times (OR 7.0; 95% CI, 1.61–30.5) more likely to use hand gloves compared to small-

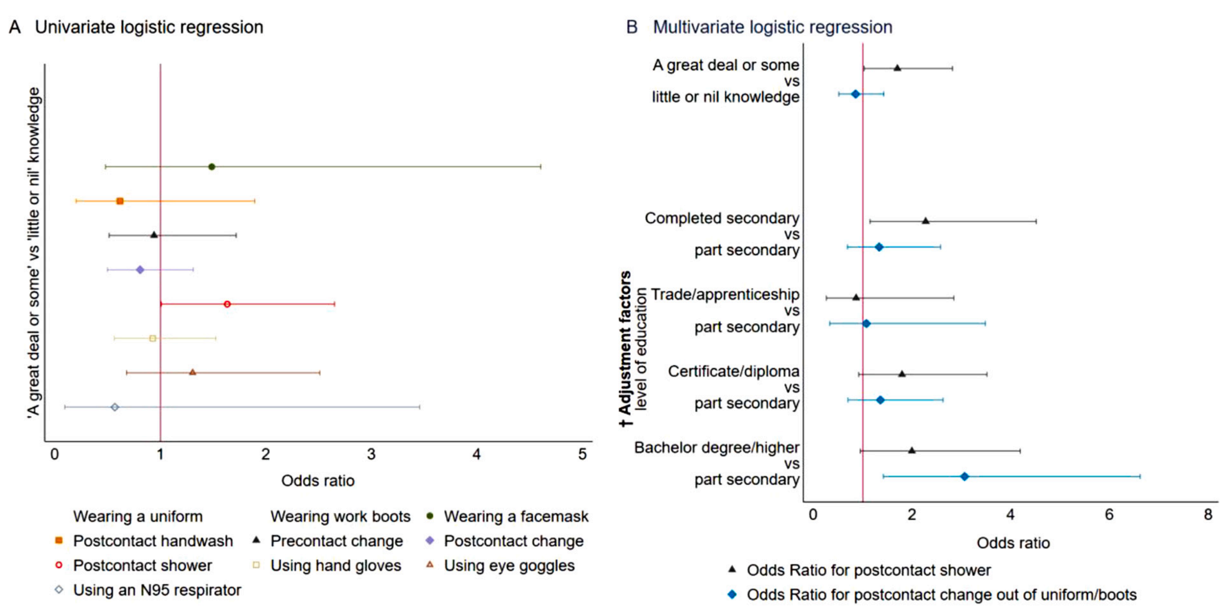

Fig. 3. Relationship between livestock farmers' self-reported knowledge and Q fever prevention practices, 2019.
Panel A. Unadjusted Odds Ratio for Q fever knowledge and prevention practices, wearing a uniform and wearing work boots omitted from models because of collinearity.
Panel B. Adjusted Odds Ratio for Q fever knowledge and selected prevention practices.
Ref. category – little or nil knowledge, part secondary. The vertical red line indicates Odds ratio = 1 i.e., no relationship. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

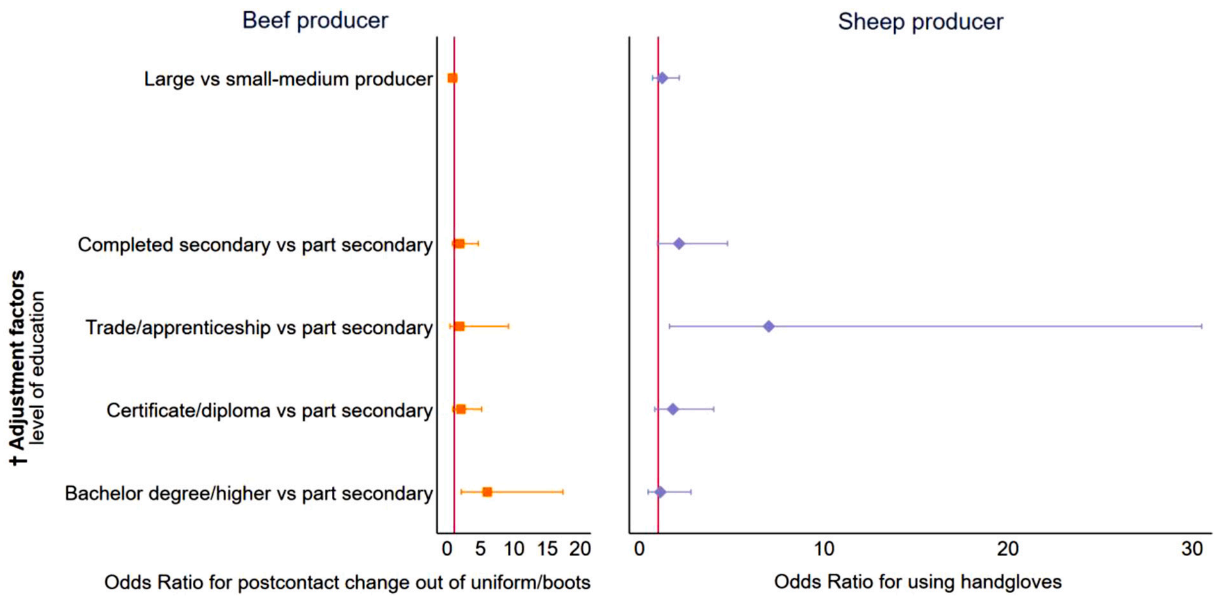

Fig. 4. Relationship between livestock farmers' stock type and size, and selected Q fever prevention practices, 2019.
† Models were adjusted for age, sex, level of education and years of farming (except education other adjustment factors' confidence intervals for odds ratios included 1, hence were not plotted). Ref. category – small-medium producer (beef ≤200 animals, sheep ≤1000 animals). The vertical red line indicates Odds ratio = 1 i.e., no relationship. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

medium producers (Fig. 4).

3.9. Perceptions of Q fever vaccine, attitudes towards vaccination and farmers' vaccination status

Livestock farmers with a great deal or some knowledge of Q fever were > 3 times (OR 3.29; 95% CI, 1.92–5.66) more likely to get vaccinated against Q fever compared to farmers with little or no knowledge after adjusting for covariates. Conversely, farmers who were neutral or disagreed with Q fever vaccine being effective were 82% (OR 0.18; 95% CI, 0.05–0.70) less likely to get vaccinated as opposed to those who agreed. Likewise, farmers who disagreed with people's belief of Q fever not being a serious illness and does not require vaccination were 53% (OR 0.47; 95% CI, 0.27–0.83) less likely to get vaccinated compared to those who agreed.

3.10. Perceived impacts of Q fever and barriers to vaccination

Most participants agreed that Q fever has health and economic impacts (≥311/322, ≥96.6%) and the human vaccine is effective (295/309, 95.5%), while 141/236 (59.8%) believing the vaccine is harmful to previously exposed individuals. More than half (167/301, 55.5%–201/301, 66.8%) of livestock farmers agreed with the listed barriers for vaccination such as people's belief of Q fever not being a serious illness, costs, time and access to an accredited vaccine provider.

3.11. Vaccination recommendations and promotion strategies

Most livestock farmers (≥274/306, ≥89.5%) recommended vaccination against Q fever for themselves, their spouses, farmhands, stockyard workers, shearers, roustabouts and veterinarians, except for others living on farms (256/304, 84.2%). Most farmers (≥278/307, ≥90.6%) suggested subsidized vaccination, improving access to a trained doctor

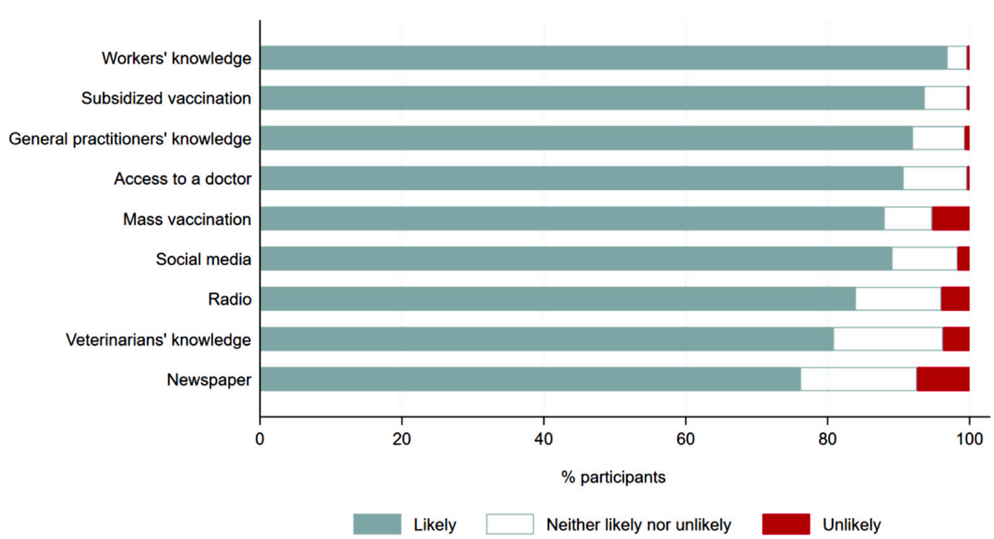

Fig. 5. Livestock farmers' suggested Q fever vaccination promotion strategies, 2019.

and improving general practitioners' and workers' knowledge of Q fever are likely to help increase vaccination uptake (Fig. 5). Other strategies were also considered effective by at least 239/296 (80.7%) of farmers except for print media (226/297, 76.1%) (Fig. 5). All strategies were associated with farmers' knowledge ($p \leq 0.001$) (Supplementary Table S3).

4. Discussion

This is the first study involving a large sample of Australian livestock farmers representing the whole of South Australia and investigating their knowledge, attitudes and perceptions of Q fever within a One Health framework. Open rates and click rates for this study were much higher than the Food and Agriculture industry survey average in 2019 [open rate — 23.3% and click rate — 2.9%] [17].

The male preponderance in our study conforms with other Australian [18], and international studies [19]. Demographic profiles including education and usual place of residence based on the IRSAD decile, indicate Australian livestock farmers' modest overall socioeconomic status and possibly highlights the cost of vaccination as a barrier [18]. Farms with mostly dryland vegetation may mean that farmers' susceptibility to Q fever remains high because contaminated dust is a major vehicle of transmission [20]. The majority of farmers in our study had sheep stock, with sheep previously found to be associated with elevated *Coxiella burnetii* seroprevalence in the Netherlands [21], and increased incidence of human Q fever in Minnesota, U.S. [22]. Large stock size (defined as ≥100 cattle) was found to be associated with higher *Coxiella burnetii* seropositivity [19], and in our study, 64% of cattle producers had >100 animals. In addition, the majority of farmers had been farming for a prolonged period of time and had a long exposure and duration of time since vaccination, adding further complexities to their disease risks as the duration of livestock exposure was previously shown to increase susceptibility to Q fever [23].

In our study, only 3% of all farmers indicated that they did not know anything about Q fever compared to 8% of Australian goat producers [24], reflecting an overall better knowledge among sheep and cattle producers. Given a good understanding of Q fever among livestock farmers and their relatively modest socioeconomic conditions, 'cost of vaccination' and 'access to accredited Q fever immunization providers' could be a major challenge for vaccination as opposed to 'lower than real risk perceptions', although both were highlighted as potential barriers in Australia [25]. Our findings substantiate previously highlighted barriers, yet are novel as these were drawn from the direct perspectives of Australian livestock farmers compared to the previously reported findings from epidemiological reviews. We recommend that government and industry partners consider livestock farmers' understanding and risk perceptions about Q fever as potential enablers of vaccination, and promote subsidized vaccination through enhanced rural and remote access to accredited vaccination providers, as well as promoting good infection control practices.

In this study, we found that livestock farmers had moderately high levels of exposure to animals that are considered to be high risk for Q fever in humans through exposure to their birth products, placenta, milk, urine and faeces. These animals include sheep and cattle [26], pets such as domestic cats [27], and kangaroos [28]. Thus, Australian livestock farmers may be at increased risk of Q fever. Almost all livestock farmers reportedly practice general biosecurity measures such as wearing protective clothing and work boots during contact with animals, which are recommended to reduce indirect transmission from animals to humans [29]. Nevertheless, these biosecurity measures if not accompanied by the use of respirators, which the majority of Australian livestock farmers did not practice, are likely to be inadequate to prevent airborne transmission [4,30]. Use of respirators in a farm setting may seem less feasible and as farmers have unavoidable contact with livestock and their environment, vaccination remains the most viable option for Q fever prevention [7]. Australian livestock farmers should be vaccinated to ensure adequate protection against Q fever, in addition to practicing biosecurity measures, as the duration of immunity conferred by the vaccine is unknown.

Our study had limitations. As recruitment was only from one state, generalizability of our findings nationally and internationally is limited. It is reasonable to consider that livestock farmers' remoteness and socioeconomic background potentially could have precluded many of them from getting vaccinated against Q fever. In turn, reporting bias might have been introduced i.e., livestock farmers' willingness to pay for vaccination could have influenced the responses. Although our sample size was moderate, the breadth of our target population, the higher click rates and open rates in the Agriculture industry support the scientific validity of our findings.

Overall, livestock farmers with greater knowledge of Q fever were more likely to practice certain prevention measures than farmers with less knowledge. Some prevention practices were commoner among farmers having higher education and larger herds. Besides, farmers with higher levels of knowledge and perceptions about Q fever were more likely to be vaccinated compared with their counterparts. While vaccinating at-risk groups arguably constitutes the best case scenario as shown during the nationally subsidized vaccination campaign in Australia [9], sustaining such programs is always challenging [31]. Countries without a human vaccine may need to rely on non-specific measures such as disease surveillance, on-farm veterinary measures, environmental decontamination, and use of personal protective equipment all working in coordination [4].

5. Conclusions

Supporting all suggested Q fever prevention strategies with strong policies in a coordinated approach is more likely to be effective. We recommend an inter-sectoral approach with revision of livestock farmers' vaccination policy and enforcing strict biosecurity measures at farm levels to protect the Australian livestock sector against Q fever. A One Health partnership is required among the Government, the livestock industry, and human and animal health departments to promote Q fever awareness and address low vaccination rates among livestock workers by funded vaccination programs.

Author contributions

MRR, HM, AM and PB conceptualized the study. MRR and DC collected data. MRR analyzed data and drafted the manuscript. The manuscript was contributed to by HM, AM, DC and PB.

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Declaration of Competing Interest

The authors declare no competing interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.onehlt.2021.100232.

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7

Chapter 7 ─ Q fever prevention: perspectives from university animal science and veterinary students and livestock farmers

7.1 Preface

This chapter presents the fifth article contributing to this thesis submitted to *The Australian Journal of Rural Health*. This article conceived a qualitative framework to examine the varying perceptions of animal and veterinary science students and livestock farmers on Q fever prevention obtained through an open-ended question seeking their suggestions at the time of the surveys presented in Chapters 5 and 6. Both students and farmers viewed Q fever vaccination as important, but barriers included excessive cost for students while farmers raised GPs' lack of knowledge of Q fever and access to an accredited immunization provider. Students suggested the need for more education and community awareness, whilst farmers emphasized the importance of increasing public awareness of Q fever.

Findings suggest that partnerships are required between the Government and industries to increase vaccination uptake among animal science and veterinary students and livestock farmers who are currently recommended Q fever vaccination in Australia. Additionally, findings underscore that without a sector-wide approach involving targeted community awareness programs, GPs' education and training, and subsidized vaccination, recommendations may not sufficiently reduce Q fever burden among at-risk groups.

7.2 Statement of authorship

Title of Paper	Q fever prevention: perspectives from university animal science and veterinary students and livestock farmers.
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Principal author

Name of Principal Author (Candidate)	Md Rezanur Rahaman		
Contribution to the Paper	Designed the study, collected and analysed the data, refined themes and subthemes, drafted the manuscript and incorporated feedback.		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	13 May 2021

Co-author contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Teresa Burgess		
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Q fever prevention: perspectives from university animal science and veterinary students and livestock farmers

Running head: University students, livestock farmers and Q fever prevention

Abstract

Objective: To explore animal science and veterinary students' and livestock farmers' perceptions concerning Q fever prevention.

Setting: Animal science and veterinary students enrolled at the University of Adelaide and members of Livestock SA representing cattle, sheep and goat farmers in South Australia.

Design: An online survey with an open-ended question seeking knowledge and perceptions about Q fever prevention was distributed among participants during March-September 2019. We applied thematic analysis to identify emerging themes.

Participants: A total of 55 animal science and veterinary students and 154 livestock farmers responded to the open-ended question.

Results: Two major themes arose in each group. Students and farmers viewed Q fever vaccination as important. However, excessive cost for students was a barrier and for farmers it was general practitioners' lack of knowledge of Q fever and access to an accredited immunisation provider. Similarly, both groups highlighted the need for education and increasing public and community awareness of Q fever.

Conclusion: Our findings underscore that a sector-wide approach involving community awareness programs, education and training for general practitioners, and subsidised vaccination as well as commitment from government and industry partners may contribute in reducing the burden of Q fever among at-risk populations.

KEYWORDS

Q fever; animal science; veterinary; livestock farmer; vaccination

25 **What is already known on this subject:**

- Australia bears a substantial burden of Q fever among certain occupational groups despite the availability of a human vaccine. Identified barriers for Q fever vaccination included time, cost and access to a vaccine provider.
- A multi-sectoral approach to Q fever prevention has been successfully piloted in Australia and internationally, but its large-scale transferability with opportunities for human vaccination has not been examined.

What this study adds:

- Animal science, veterinary students and livestock farmers emphasised the importance of Q fever vaccination. However, farmers identified poor access and general practitioners' suboptimal knowledge as barriers, whilst students highlighted that vaccination was accessible but not affordable.
- A sector-wide approach between government and industries involving public awareness programs, general practitioners' education and training and subsidised vaccination may reduce the burden of Q fever among at-risk occupational groups.

1 | INTRODUCTION

Reservoirs of *Coxiella burnetii* include cattle, sheep, goats, cats, dogs, kangaroos and wallabies.[1-3] Humans who are occupationally exposed to these animals are at risk of being infected, particularly when unvaccinated.[4] Q fever is a vaccine-preventable zoonosis, a disease resulting from animal to human transmission.[5-7] Despite an effective human vaccine for Q fever being registered in Australia since 1989,[8,9] disease burden persists, particularly among farmers, abattoir workers, veterinarians, veterinary students and wildlife workers.[10,11]

Recently in Australia, a considerable reduction in Q fever notification has occurred amongst abattoir workers likely due to high vaccination uptake during the National Q Fever Management Program (NQFMP), 2001–2006.[12,13] Although the NQFMP was also targeted at farmers, their vaccination uptake was very low.[12] Since then, an increasing number of Q fever cases have been notified among livestock farmers post-NQFMP compared to higher notifications amongst abattoir workers in the pre-NQFMP period.[14] Outside the NQFMP scope, Australian animal science and veterinary students are required by public universities to self-fund Q fever vaccination.[15] The prospective animal health workforce is at significant risk of Q fever both in Australia and internationally.[4,10]

An Australian study among veterinary workers identified several barriers for Q fever vaccination including time, cost and access to a vaccine provider.[15] Another study showed similar barriers to Q fever vaccination among Australian farmers.[16] Given the similarity of barriers to Q fever vaccination across different occupational groups, a multisectoral framework would offer an articulated Q fever prevention approach.[7] An inter-sectoral approach to Q fever prevention involves participation from the human, animal and environmental health sectors.[17,18] Such an approach including human Q fever vaccination has been piloted in Australia and internationally with discernible success.[19,20] However, a limited number of studies sought to examine the transferability of this approach with opportunities for Q fever vaccination. This study aimed to identify potential challenges and opportunities for a coordinated Q fever prevention approach drawing upon varying perceptions of prospective animal health practitioners and livestock farmers.

2 | METHODS

2.1 | Study design

An online survey with an open question (Box 1), seeking participants' knowledge and perceptions about Q fever prevention was undertaken among animal science and veterinary students enrolled at the University of Adelaide (UoA) and registered members of livestock SA, a nonprofit organisation representing cattle, sheep and goat producers in South Australia (SA). Animal science and veterinary students were recruited through their university course between 14 March and 6 September 2019, whilst livestock farmers were recruited using Livestock SA promotional materials such as website, newsletters and advertisements between 21 March and 10 June 2019.

BOX 1 Are there any comments you would like to make about Q fever prevention in South Australia?

2.2 | Study site and population

This study was conducted in the only School of Animal and Veterinary Sciences (SAVS) in SA at the UoA. Degree programs included were: 3-year Bachelor of Science (BSc Animal Science); 3-year BSc Veterinary Bioscience; and 3-year Doctor of Veterinary Medicine (DVM) with most students entering the DVM after successful completion of Veterinary Bioscience. Students enrolled in the three programs in 2019 across all years were invited to participate in the survey. All cattle, sheep and goat farmers who were registered with Livestock SA in 2019 were also invited to participate.

2.3 | Data collection and analysis

An email invitation was sent to all students enrolled in SAVS by course coordinators and lecturers across degree programs. A reminder email was sent two weeks following the initial invitation. Livestock farmers were initially recruited via the Livestock SA website, newsletters, stock journal and Facebook page during March and April 2019. A direct email was sent on two successive occasions two weeks apart in May 2019 to enhance recruitment. Participation in the survey was voluntary.

We sought to investigate: how university students and livestock farmers perceived Q fever, how disease perceptions influenced their attitudes related to vaccination, and what barriers and opportunities for Q fever prevention could inform policies? A step-by-step thematic analysis of the data was undertaken, following the Braun and Clarke framework.[21] Once data were collated and the participants' responses read and re-read to ensure familiarisation with the data (Step-1), the dataset was systematically deductively and inductively coded (Step-2). These initial codes were then reviewed and collated to identify potential themes and subthemes (Step-3). Themes and subthemes were then reviewed by rearranging and linking the codes and subthemes, which assisted in clarifying the key understandings arising from the two different groups' responses (Step-4). In this step, themes were refined to understand the viewpoint of each group regarding Q fever prevention and associated barriers and enablers (Step-5). The themes and subthemes were finalised and illustrated with quotes (Step-6).

All procedures performed in this study were in accordance with the ethical standards of the University of Adelaide Human Research Ethics Committee (Approval No: H-2019-040), and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

3 | RESULTS

Of the 209 participants who completed the survey, 24 (11%) responses including no comment, nil comment and no thanks were excluded; and 185 (89%) responses were analysed, 45 (24%) ─ animal science and veterinary students, and 140 (76%) ─ livestock farmers. Two major themes arose in each group, and whilst each group identified similar themes and subthemes (Figure 1), there was a differing emphasis on the importance of these.

3.1 | Animal science and veterinary students

Identified themes included the cost of vaccination with strategies to decrease the cost of vaccination as subtheme, and awareness with education and community awareness as subthemes.

3.1.1 | Cost of vaccination

Overall, students across all year levels and programs indicated that the cost of vaccination was very high, *Vaccine very expensive for students*. Cost of vaccination was highlighted, particularly by animal science students although they emphasised the importance of vaccination.

> *It's super expensive! Not required for me (yet) as I'm an animal science student, so I haven't had the vaccination, but I probably would have if it was cheaper.*

Although costs prevented some students from getting vaccinated, vaccination cost per se did not offset animal science students being concerned about their safety related to animal handling.

> *I find it interesting that… animal science and vets do a lot of the same animal handling practical and yet only vet students are recommended to get the vaccination.*

On the whole, students recognised Q fever vaccination to be important for everyone who works with animals.

> *I believe everyone should have this as my father has Q fever and I see the symptoms he has, he is unable to get the vaccine, unfortunately.*

3.1.1.1 | Subtheme: strategies to decrease the cost of vaccination

Many students proposed some strategies to abate vaccination-related costs such as subsidised vaccination, *...if students are expected to get the vaccination then the university should subsidise*. While others favoured an on-campus clinic with a group subsidy, particularly when a whole class needs vaccination, *Would be really good if there could be a vaccination clinic done on campus and maybe a group discount*.

3.1.2 | Awareness

A number of students highlighted the prevailing low levels of awareness about Q fever among themselves and in the community, *It's (more?) that people are unaware of the disease*. One student labeled low awareness of Q fever to be an underestimation of the actual risk, *A lot of stock workers underestimate it*. Some respondents also indicated how the farming industry suffered from a lack of awareness.

There is very little awareness of Q-fever as I grew up with animals (horses, cattle, goats, sheep etc.) and didn't know it existed until I was required to be vaccinated by the university.

3.1.2.1 | Subtheme 1: education

Several students suggested that providing themselves education on Q fever and its implications is integral to building awareness about the disease.

Would appreciate more awareness. There's still a lot that I don't know or understand about Q-fever, or the vaccine.

Additionally, many of them emphasised that more clinical information is required for greater student awareness.

More education on what is Q fever and what clinical sign would you get if you got Q fever. Let people know how slay [sic] that is.

Some students suggested that in order to improve awareness, the information should be provided from the beginning of their studies.

As first-year students, we don't know anything about it—so it's the uni's job to educate us.

Students urged the University intervening at the earliest possible time to ensure students' education and preparedness about Q fever prevention.

Educate students about the risks of getting Q-fever (e.g., symptoms) and how easy it is to catch the disease.

3.1.2.2 | Subtheme 2: community awareness

Students viewed greater public awareness as pivotal for an integrated approach to Q fever prevention.

Community involvement will be a great way to get the message across, as well as local council/government.

They emphasised raising community awareness as an instrument to increase vaccination uptake among at-risk populations.

Make sure all people at risk be vaccinated — raise more awareness.

Moreover, students urged the dissemination of Q fever information in the public sphere.

More information for the public. I didn't know about Q fever prior to studying veterinary science.

3.2 | Livestock farmers

Major themes included the importance of Q fever vaccination with barriers and enablers as subthemes, and increased public awareness with Q fever knowledge and Q fever awareness and promotion as subthemes.

3.2.1 | Importance of Q fever vaccination

Most livestock farmers recognised the importance of Q fever vaccination with responses such as, *Get vaccinated. Prevention is always better than a cure. The injection doesn't hurt — getting Q fever surely is a worse fate*. Some farmers sought vaccination not only for their families but also for their community and were enthusiastic about running a clinic.

I want to organise a clinic but have come up against roadblocks to do this, please if you can help us organise a clinic give us the contacts, resources to pull it together, I am a shearers wife and a shearers mother and I want to protect my family… My husband had Q fever in the '80s and he has said he has never fully recovered. I want to protect my family and myself.

Farmers raised concerns about their children under 15 years of age as the current recommendations exclude them from vaccination.

I am concerned that my 15-year-old grand-daughter and her younger siblings who are in regular contact with sheep and cattle on their farm are unable to be vaccinated.

Some farmers urged speedy approval of Q fever vaccination for children under 15 years of age.

> *Please hasten the trials/approval for those younger than 15 yrs. to be vaccinated, and advertise more re the vaccine and risk management, prevention etc.*

3.2.1.1 | Subtheme 1: barriers to vaccination

Although farmers acknowledged the importance of Q fever vaccination, they identified certain barriers such as excessive cost, *The cost of over $400 plus at least 3 to 4 doctor visits make it a cost in both time and expense that most farmers can afford*. Apart from cost, farmers noted strongly about their inability to access appropriate vaccination programs.

> *…costs several hundred dollars, don't have access to appropriately trained doctors locally, and takes several weeks to get an appointment. The high-risk group only has a small window in which to be vaccinated and work casually so may miss out on work due to other constraints.*

Livestock farmers indicated that there were few providers of Q fever vaccination in rural areas.

> *It is difficult to access, other members of my family have traveled to have the tests & subsequent vaccination, I am currently on a waiting list…*

Nevertheless, even if they had access, they were very concerned about the provider not knowing much about Q fever.

> *Asked the local doctor for the vaccine and I was placed on a list to get back to me, that was 2 years ago, seemed too hard and it wasn't that important to have it done, the doctor had very limited knowledge.*

3.2.1.2 | Subtheme 2: enablers of vaccination

Livestock farmers identified several enablers that could help increase vaccination uptake. Farmers supported a subsidised vaccination as key.

> *…Pre-vaccination blood and GP visits should be made eligible for Medicare rebates. The vaccine should be available free of charge to relevant farmers and their families.*

Mandatory vaccination was suggested as another key to success, *Make it compulsory for all those over 15 and on farms and involved with animals to be tested and vaccinated*. However, the issue of personal choice was not overlooked.

It may come down to individual preference, but as long as they are aware of symptoms, and the illness, so they make an informed choice.

Several support programs for rural and regional vaccination providers were also suggested. The education of general practitioners (GPs) was emphasised.

Education of GPs to vaccination availability ─ including city GPs because there are many 'hobby' farmers who live in the city.

Additionally, more vaccination providers were sought to be streamlined.

…We need all country GP practices involved in promoting and providing the service, or the health department traveling to rural areas to provide vaccination clinics for us.

Farmers also indicated that as an employer they were ready to arrange vaccination programs for staff working on their farms but emphasised the necessity for more providers.

…We also tried to get our workman vaccinated a few years ago and were told we had to wait until they had enough on the waiting list to run a clinic. I don't think they reached their numbers before his employment with us finished. If the vaccine is available and someone is willing to pay for it you should be able to book in for the tests and vaccinations at a time that suits you.

3.2.2 | Increased public awareness

Livestock farmers spoke about the importance of increased public awareness. Major concerns were raised about the prevailing low level of Q fever awareness in farming communities.

I don't believe people understand the real implications of a serious attack on a person. If people knew what the disease can do to you and what it can do to your organs and some of the main ways it is contracted, people may be more questioning of their doctor.

3.2.2.1 | Subtheme 1: Q fever knowledge

In general, farmers appeared to have a good understanding of Q fever including that positive serology is a contraindication for vaccination.

> *I have already been exposed to Q fever, otherwise, I would have the vaccine.*

Furthermore, they possessed a very good understanding of the impacts of Q fever on health and livelihood.

> *I understand this disease can have a catastrophic effect on the individual as well as their family and business they work for. I don't understand why more farmers are not being vaccinated. I believe they don't truly understand the severity of the disease and its likely effect on them. There is a perception that it is too expensive to be vaccinated and they don't see it as an issue for them.*

However, other farmers wanted to know more about Q fever.

> *Um. Hm. I guess I'd like to know roughly the probability/likelihood of getting it, how many have it etc., some more stats. We have enquired about it, but it is a bit of a process & costly. But hopefully worth it.*

Misinformation about Q fever was quite common amongst farmers highlighting the significance of increasing public awareness.

> *Q fever is a virus, not a disease. I was scratched positive in August 2018. I was sick for a week, no big deal. Would rather be sick for a week, than to have a costly vaccine with nasty chemicals injected into me.*

3.2.2.2 | Subtheme 2: Q fever awareness and promotion

Livestock farmers suggested that dissemination of Q fever information among the public through a variety of media would help sensitise the community about the disease.

> *More widespread stories and information needs to be put out in the public domain i.e., TV, radio, print media, social media with people who have been affected and medical people with knowledge of the disease.*

For such a community-wide approach they preferred the coverage of real-life stories.

Perhaps some case studies to put in the media. For example, a chap from… contracted Q fever and developed cardiomyopathy = died. This was a catalyst for a huge number of people in the… districts to be vaccinated and had a mass test & vaccination 2 days.

Farmers strongly supported a population-level approach and urged GPs to educate the community, *…health professionals promoting this could be of benefit*. Farmers suggested a coordinated approach to Q fever prevention.

It needs to be a multi-facet information program to all involved from farmworkers to employers and providers. I was vaccinated as part of a local promotion which is a great way to go, work across the community level all at once.

4 | DISCUSSION

This is the first Australian study comparing the varying perceptions about Q fever prevention between two different, yet high-risk groups for Q fever infection. While animal science and veterinary students focused more on financial barriers to vaccination and the need for greater education, livestock farmers emphasised the importance of Q fever vaccination. In this study, the cost of vaccination was highlighted by both groups similar to previous Australian studies.[15,22] Cost of vaccination per se did not preclude livestock farmers getting vaccinated for Q fever, which was also similar to previous studies involving Australian farmers.[16] Livestock farmers in this study raised two important issues about access to a vaccine provider: limited access to an accredited immunisation provider and GPs' suboptimal knowledge of Q fever. Despite our findings reflecting those of previous studies,[15,16,22] a key finding was that, for students, the cost of the vaccination was a major barrier ─ they could access vaccination ─ they just could not afford it.

Both groups identified subsidised vaccination as a key to success for supporting vaccine uptake. Students also suggested an on-campus clinic offering mass vaccination with a group subsidy which may encourage vaccine uptake. A group approach to vaccination was also supported by Australian farmers,[16] and this was efficient and effective during the NQFMP.[12,15] When discussing the cost of vaccination, students indicated that Q fever vaccination was mandated for some of them. Farmers considered mandated vaccination an enabler to increase uptake, as was the case for abattoir workers in other Australian states,[23] requiring employers to ensure workers' vaccination. The employer provision of vaccination was supported by livestock farmers in our study. Likewise, Australian beef industry workers also viewed Q fever vaccination to be an employer's responsibility.[24]

In order to increase vaccination uptake, particularly in rural farming communities, livestock farmers suggested that more trained providers for vaccination are required. They indicated several strategies including increasing GPs' education and training, the involvement of rural GP and clinics in providing Q fever vaccination, other healthcare workers involved in vaccination, and holding regular outreach clinics by the Health Department, as supported by other at-risk groups in Australia.[16,22,24]

'Awareness' was the second major theme common to both animal science and veterinary students and livestock farmers. However, students talked about the need for more education whereas livestock farmers focused on awareness of the general public and GPs. Students suggested that awareness needs to be built at two levels ─ improving their clinical knowledge about Q fever, and building public awareness about disease transmission and impacts. Livestock farmers also indicated that awareness should be promoted by GPs educating rural farming communities, and mass media awareness covering real-life case studies. Students indicated that the University has a role to play whilst farmers highlighted the role of GPs and the media as a catalyst for promoting vaccination. However, many livestock farmers were concerned about GPs' insufficient knowledge of Q fever and a lack of experience in providing such vaccinations. Evidence suggests that GPs and animal health providers are key in protecting humans against zoonoses including Q fever.[25,26]

We recommend that animal science and veterinary students are educated about Q fever from the first year of their studies. Livestock farmers including farmworkers and employers need to be aware of Q fever, its impacts and ways of prevention through community awareness programs and the media including social media. An inter-sectoral approach with sustainable funding is the key to improving public health policy, therefore, a sector-wide partnership involving at-risk groups, animal and human health providers, industries and the government is required for an integrated Q fever prevention approach.[18]

Study limitations included no opportunity for further discussion and investigation of insights into participants' consideration of Q fever prevention as responses were provided in writing. This also meant there was no opportunity to observe non-verbal communications. Nevertheless, we had a diverse range of respondents (e.g., socio-economic, rural-urban) with a variety of different experiences of Q fever vaccination. This helped to ensure our findings are transferable and reflect the perspectives of two important stakeholder groups. Besides, using an inductive approach, we were able to provide a rich description of the dataset and so identify a variety of themes which the respondents discussed.

5 | CONCLUSIONS

Animal science and veterinary students and livestock farmers acknowledged that Q fever vaccination is an efficient method of disease prevention. Strong enablers as identified by both groups were subsidised vaccination, community-wide education on Q fever and prevention, and improved access to vaccination. Our findings are a reminder that a coordinated approach involving relevant stakeholders for targeted and community awareness programs coupled with a subsidy could promote increased uptake of Q fever vaccination, particularly among at-risk occupational groups.

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399 **Figure legend**

400 **FIGURE 1** Major themes and subthemes identified by animal science and veterinary students and livestock farmers, 2019. *This level constitutes themes (unshaded). †This level constitutes subthemes (grey shaded).

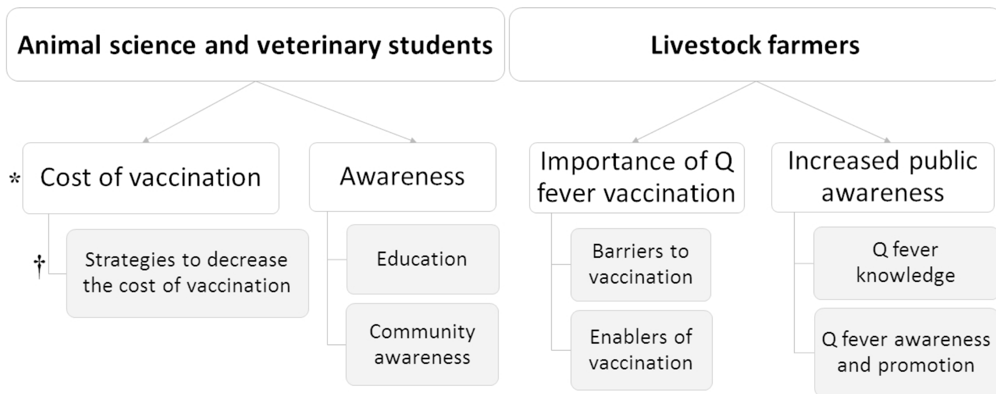

FIGURE 1 Major themes and subthemes identified by animal science and veterinary students and livestock farmers, 2019. *This level constitutes themes (unshaded). †This level constitutes subthemes (grey shaded).

108x60mm (300 x 300 DPI)

8

Chapter 8 – Q fever prevention in Australia: general practitioner and stakeholder perspectives on preparedness using a One Health approach

8.1 Preface

This chapter contains the final of a series of six articles contributing to this thesis. This article has been submitted to *The Medical Journal of Australia*, and examines multi-stakeholders' perspectives on the feasibility of adopting a One Health approach to Q fever prevention. During July-October 2020, semi-structured interviews were conducted across a range of stakeholders including GPs, veterinarians, government officials, researchers and representatives from the farming industry to investigate their perspectives on the preparedness of primary healthcare for Q fever prevention, using a One Health approach.

Q fever vaccination must be provided by an accredited GP, which is particularly challenging in rural areas due to GP shortages and the two stage vaccination process of pre-screening (serology and skin test), reading of the test results 7 days later, followed by vaccination if both tests are negative requiring two/three visits to a GP. GPs' and overall the Department of Health's (DoH's) preparedness for Q fever prevention is rarely discussed, and the perspectives of multi-disciplinary stakeholders have rarely been sought. Findings suggest that GPs play a vital role in Q fever diagnosis, notification, treatment and prevention including vaccination. However, they possess limited knowledge of Q fever. Additionally, DoH must lead a program of communication and inclusiveness across multiple disciplines. At a policy level, medical curricula need to be updated with regard to principles of management of Q fever zoonosis, and professional development programs, including vaccination training to all GPs. Subsidized vaccination programs would also be a key pillar of effective Q fever prevention, and should be provided through government-industry partnerships in a One Health coordination led by DoH.

8.2 Statement of authorship

Title of Paper	Q fever prevention in Australia: general practitioner and stakeholder perspectives on preparedness using a One Health approach.
Publication Status	☐ Published ☐ Accepted for Publication ☑ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	Rahaman MR, Hodgetts K, Milazzo A, Marshall H, Chaber A-L, Crabb D, Bi P. Q fever prevention in Australia: general practitioner and stakeholder perspectives on preparedness using a One Health approach. Submitted to *The Medical Journal of Australia* (ID – mja21.00558).

Principal author

Name of Principal Author (Candidate)	Md Rezanur Rahaman		
Contribution to the Paper	Designed the study, collected and analysed the data, refined themes and subthemes, drafted the manuscript and incorporated feedback.		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	13 May 2021

Co-author contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Katherine Hodgetts
Contribution to the Paper	Analysed the data, refined themes and subthemes and reviewed the manuscript.

Signature		Date	13 May 2021

Name of Co-Author	Adriana Milazzo		
Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	13 May 2021

Name of Co-Author	Helen Marshall		
Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	13 May 2021

Name of Co-Author	Anne-Lise Chaber		
Contribution to the Paper	Recruited participants and reviewed the manuscript.		
Signature		Date	13 May 2021

Name of Co-Author	Deane Crabb		
Contribution to the Paper	Recruited participants and reviewed the manuscript.		
Signature		Date	13 May 2021

Name of Co-Author	Peng Bi		
Contribution to the Paper	Designed the study, supervised the development of work and reviewed the manuscript.		
Signature		Date	13 May 2021

8.3 Publication

Rahaman MR, Hodgetts K, Milazzo A, Marshall H, Chaber A-L, Crabb D, Bi P. Q fever prevention in Australia: general practitioner and stakeholder perspectives on preparedness using a One Health approach. Submitted to *The Medical Journal of Australia* (ID – mja21.00558).

Q fever prevention in Australia: general practitioner and stakeholder perspectives on preparedness using a One Health approach

Journal:	*Medical Journal of Australia*
Manuscript ID	Draft
Manuscript Type:	Research (original)
Keywords:	Q fever < Infectious diseases, General practice < General medicine, Vaccination < Infectious diseases, Qualitative research < Statistics, epidemiology and research design, Zoonoses < Infectious diseases

Medical Journal of Australia Manuscript submission template

Type of article	**Original research**
Title	Q fever prevention in Australia: general practitioner and stakeholder perspectives on preparedness using a One Health approach

Abstract	
Abstract word count	**248**

Objectives:

To investigate primary health care and broader health system preparedness for Q fever prevention. To examine stakeholder perspectives on the constituents of an effective systemic approach to Q fever, and the potential benefits of a One Health framework.

Design, setting and participants:

Semi-structured interviews were conducted between July and October 2020 with 16 participants including general practitioners (GPs) and veterinarians, government officials, researchers, and representatives from the farming industry. Interview transcripts were subject to thematic analysis.

Results:

Six major themes were identified as key factors underpinning an effective approach to Q fever: understanding Q fever burden, effective surveillance, the role of general practitioners and other stakeholders, barriers and enablers of vaccination, an integrated approach, and increased Q fever awareness. Most participants indicated that GPs play a central role in disease detection, notification, treatment and prevention through health promotion and vaccination. However, we found that GPs' knowledge and awareness of Q fever are currently limited, and that leadership is required from the Department of Health (DoH) to foster communication, collaboration, and the inclusion of GP networks within an inter-sectoral approach.

Conclusions:

A One Health approach holds opportunities for zoonoses prevention. Given GPs' limited knowledge and awareness of Q fever, we recommend that medical curricula and professional development be enhanced. Furthermore, DoH could strengthen zoonosis working group networks and encourage the participation and inclusion of all stakeholders within an integrated program. Finally, government-industry partnerships should be strengthened for coordinated efforts including data sharing for Q fever preventative service delivery.

Box	
Box word count	**100**

The known

Despite availability of a vaccine, Q fever burden in Australia remains high. Vaccination is provided by accredited general practitioners (GP), which is challenging in rural areas with GP shortages. GPs' preparedness for Q fever prevention is rarely discussed with little insight from multi-stakeholders.

The new

GPs play a role in Q fever diagnosis, notification, treatment and prevention. However, they have limited knowledge of Q fever. Leadership from health departments to foster communication and inter-sectoral collaboration is required.

The implications

Updating medical curricula, GP professional development programs, and inter-sectoral collaboration led by health departments may reduce Q fever burden.

Text	
Text word count	**2500**

Introduction

Q fever caused by *Coxiella burnetii* is present in Australian livestock, wildlife and ticks,[1,2] and is a persistent problem for high-risk occupations in Australia.[3] Although clinical presentation varies from flu-like symptoms to endocarditis, chronic sequelae including chronic fatigue may contribute to workforce turnover incurring high compensation claims in livestock and meat industries.[4,5]

The only licensed human Q fever vaccine is manufactured in Australia.[4] Vaccination involves pre-screening and must be provided by an accredited general practitioner (GP).[3,6] Q fever is of concern in regional and remote communities,[7] with GP shortages in rural Australia compounding disease burden. Identified barriers to vaccination include costs;[6,8] to overcome this the National Q Fever Management Program was a successful, but short-term, subsidised vaccination campaign.[9] Evidence suggests that this type of vaccination campaign should be accompanied by sustainable system change.[10] To facilitate such change, a multi-sectoral approach known as a One Health framework is advocated as a means of connecting human, animal and environmental domains in a Q fever prevention program.[11]

A thorough understanding of Q fever burden and potential solutions from the perspective of stakeholders including GPs, health officials and policymakers has not been sought. Bringing together cross-disciplinary stakeholders allows for examination of practical, on-the-ground concerns by those with an understanding of the pragmatics of policymaking and health system functionality. Further, it allows factors identified by stakeholders as essential to Q fever prevention, and to an effective One Health approach, to inform policy responses. This study assesses the preparedness of GPs and the Department of Health (DoH) to prevent Q fever, and provides policy recommendations for improved clinical practice and preventative service delivery including vaccination.

Methods

Between July-October 2020, interviews were undertaken with four stakeholder groups responsible for Q fever detection, treatment and notification; developing and implementing Q fever policy; generating evidence to inform clinical practice; and providing tailored advice to the farming industry.

Recruitment

Participants were identified using networks of the Environment and Health Research Group, Adelaide University, and were invited purposively to have representation across practitioners, policymakers, researchers and the farming industry. Additionally, GPs were recruited through newsletter of the Australian College of Rural and Remote Medicine, The Royal Australian College of General Practitioners, and the Primary Health Networks and Rural Clinical School. Participant roles and positions are outlined in Box 1.

Data collection

A semi-structured interview schedule (Appendix 1) was used, informed written consent obtained (Appendix 2), and interviews recorded with permission. Participants reflected on their understanding of Q fever, their perspectives on current approaches to surveillance and vaccination, and the potential application of a One Health approach to Q fever prevention. Additionally, GPs were asked about a standard consultation for a suspected case of Q fever, while veterinarians were asked about potential for animal vaccination.

Data analysis

Participant interviews were audio-recorded and transcribed verbatim, with identifying information removed. Thematic analysis was undertaken following the framework outlined by Braun and Clarke.[12] Data coding involved five phases to identify pervasive subthemes and themes. Two researchers (MRR and KH) read the transcripts to ensure familiarisation with the data (Phase Ⅰ). Phase Ⅱ involved a more thorough reading of the transcripts and theoretical coding of relevant concepts, ideas and arguments. Subthemes and themes were identified via an iterative process in which transcripts were re-read and codes incrementally refined (Phase Ⅲ). Phases Ⅱ and Ⅲ were repeated to revisit codes, subthemes and themes and were refined to develop an initial thematic map (Appendix 3) (Phase Ⅳ).[13] In Phase Ⅴ, themes and subthemes were finalised, illustrated with quotes and presented in a thematic map (Box 2).

The study was approved by the SA Department for Health and Wellbeing Human Research Ethics Committee (HREC/20/SAH/8).

Results

Six major themes were identified: understanding Q fever burden; effective surveillance; role of general practitioners and other stakeholders; barriers and enablers of vaccination; an integrated approach; and increased Q fever awareness (Boxes 2–3). Each theme had three to six subthemes. In the sections that follow, each theme is discussed, and interconnections between themes are considered (see Box 2). Illustrative quotes are presented in Box 3.

Understanding Q fever burden

Participants agreed that the clinical presentation of Q fever is variable, yet strongly acknowledged its seriousness, particularly in terms of chronic sequelae. A few participants highlighted the mental health consequences including depression associated with the chronic stage. Participants indicated that Q fever has a significant impact on the workforce, particularly for casual workers in livestock and meat industries whose compensation claims can be substantial. The majority of participants indicated that the enduring burden of Q fever is related to the organism's existence in different hosts including livestock, wildlife and ticks. However, GPs self-identified their knowledge about Q fever transmission to be suboptimal, which may cause underestimation of the true burden (Box 3, Quote ─ Q1–4).

Effective surveillance

A number of stakeholders reported that human surveillance is as good as it could be, yet some policymakers and GPs suggested that underreporting remains a major issue. Participants attributed underreporting to diagnostic complexities, for example, in many instances GPs are not vigilant about zoonotic potential for humans and do not consider Q fever among differentials during a standard consultation. Some participants suggested that, unless severely ill, people may not necessarily seek medical care with mild-moderate degree of symptoms due to ignorance or apathy (Box 3, Q5).

Participants questioned the usefulness of animal surveillance given the wide range of reservoirs in which *Coxiella burnetii* prevails. Likewise, although integrated human-animal surveillance appeared to have little support, some participants suggested that event-based integrated surveillance could act as an early warning system. However, these participants argued that such integration is only useful when humans present with Q fever and an investigation is warranted for source tracing in a related animal population, or vice versa (Box 3, Q6–10).

Role of general practitioners and other stakeholders

Almost all participants indicated GPs are integral in disease detection, notification, treatment and prevention through health promotion and vaccination. Nevertheless, participants indicated that it is common for GPs to seek testing for Q fever only when all other possibilities are exhausted. Lack of vigilance was attributed to GPs' "limited awareness" and "limited knowledge", and acknowledged by GPs themselves. Despite these limitations, GPs, particularly in rural clinics, were considered to be well placed to promote vaccination against a background context of promotion that usually follows a "top-down" approach via DoH (Box 3, Q11–15).

The need for strong leadership was also emphasised when identifying key partners required to facilitate a One Health approach. Most participants nominated GPs and relevant medical colleges, DoH, Department of Agriculture, Water and the Environment including biosecurity, Safe Work Australia, veterinarians and the Australian Veterinary Association, and livestock producers and meat processors in their list of key stakeholders (Box 3, Q16).

Barriers and enablers of vaccination

Given the number of GPs trained in Q fever screening and vaccination is limited, particularly in rural Australia, access to a provider was widely identified as a barrier. Complexities around screening tests including the need for two GP visits, the limited number of test centres and time constraints further compounded the issue of vaccination access. The risk of adverse effects following vaccination represented another barrier to broader provision. Furthermore, the cost of vaccination including “screening cost”, “vaccine cost” and “salary loss” from loss of working hours was raised as another barrier (Box 3, Q17–22).

A number of participants supported subsidies as an enabler of vaccination. While some indicated that the government should subsidise vaccination campaigns, others advocated a need for contributions from relevant industries/employers. Some participants suggested that mandating vaccination may have dual benefits, in that it both enables vaccination and promotes broader community awareness. Although subsidised and mandatory vaccination were considered as enablers, some reservations were noted around the funding, responsibilities and target populations of such programs. However, health education as an enabler was emphasised by the majority for informed decision-making (Box 3, Q22–25).

An integrated approach

Participants unanimously agreed that open communication among stakeholders is an essential component of zoonosis prevention within One Health. While participants agreed this can be difficult, many suggested that lessons learned from the public health response to COVID-19 can be usefully adopted. Despite this agreement, some government officials reported that they had never been invited into discussions around a Q fever response, had received only limited statistical outputs, and felt insufficiently empowered to engage in the decision-making process. Other stakeholders, including farming industry representatives and veterinarians reported experiencing significant power disparities and limited inclusiveness in decision-making. A "bottom-up" approach was advocated by participants to promote cross-sectoral collaboration on the issue rather than creating a completely new unit tasked with driving change (Box 3, Q26–28).

The majority of participants indicated that having a clear definition of roles and responsibilities would be an important enabler of an inter-sectoral approach to Q fever. However, concerns were identified around funding as participants indicated that sectors may not be inclined to collaborate when their funding models and priorities do not overlap. To overcome this challenge, a novel model was suggested where infectious diseases, non-communicable diseases, nutrition and climate change could be addressed in a One Health approach. This model could be built on an existing structure such as one applied for avian influenza, bat lyssavirus or rabies (Box 3, Q28–30).

Increased Q fever awareness

Most participants reported that awareness about Q fever and other zoonotic diseases is extremely low at the community level and among clinical and industry stakeholders. The majority advocated widespread awareness raising, although targeted interventions were thought to be more efficient. Targeted interventions included industry-led awareness campaigns, serological surveys among at-risk workers, zoonotic screening for GPs and veterinarians, a One Health summit, or a novel ecological intervention such as combating zoonotic diseases through the sustainable use of green space and boosting human immunity. Raising occupational awareness was strongly advocated as a means of countering misinformation reported to prevail among certain occupational groups with relatively low education levels, such as abattoir workers, and even in the wider community due to anti-vaxxers' influence on social media. Many participants also underscored the importance of promoting education about Q fever by GPs, as well as through media coverage of real-life accounts of the disease (Box 3, Q31–33).

Discussion

This is the first Australian study to investigate the suitability of One Health for zoonoses prevention through qualitative analysis of stakeholders' perspectives on current and potential approaches to Q fever. Of the themes identified, the "role of general practitioners and other stakeholders" was most central to participants' accounts of the elements underpinning an effective approach to the disease. A majority of participants concurred that GPs and DoH represent key players while other stakeholders form the rest of the interwoven fabric in the One Health framework for Q fever prevention. However, participants suggested that GPs' current "limited awareness" of Q fever and underreporting of the disease,[14] along with "limited leadership" from DoH, represent constraints on effective Q fever prevention.

Many participants reported that GPs do not possess adequate knowledge and awareness of zoonoses, particularly when they see patients with occupational risk factors for such disease. Significantly, GPs themselves highlighted their limitations, linking them to inadequacies in medical curricula concerning zoonoses. This finding resonates with Australian studies conducted among at-risk occupational groups.[6,8,15,16] Although there is no quick fix, one option is to incorporate major zoonotic diseases in medical curricula in a manner similar to that recommended to Australian veterinary and animal sciences students,[6] as well as in professional development programs for GPs.

Several participants believed DoH's leadership in Q fever prevention is limited. They argued that DoH must take the lead by promoting awareness of Q fever among at-risk workers and GPs, and exchanging information with relevant stakeholders to ensure an integrated response. Although participants from DoH indicated that a Q fever strategy or zoonosis working group has been recently formulated, it seems its influence is not yet established. However, it is obvious that COVID-19 has prompted some collaboration among sectors. Strengthening such collaboration may merit adoption of the suggested model including a range of diseases/conditions that may prove practically and economically efficient, and promote inclusiveness.

In line with existing literature,[3] most participants argued that the substantial health and economic burden of Q fever among Australian at-risk populations is inextricably linked to the large domestic and wildlife reservoir of *Coxiella burnetii*. This highlights the natural limitations of animal vaccination in Australia, and sets the benchmark for human vaccination as the mainstay of prevention.[17] However, barriers to human vaccination may include costs and access to appropriately trained GPs. Prohibitive vaccination costs have been identified in other studies,[6,8] and formed the basis of many participants' view that a subsidised program[15] would be the most efficient means of preventing Q fever-related direct healthcare costs.[18]

Nevertheless, funding and priorities were highlighted by stakeholders, particularly when sectors are considered solo and unintegrated. Although most participants favoured the government-subsidised vaccination programs, some indicated that industry must also contribute to an effective Q fever response. Given other competing priorities, our research suggests that a practical model may involve government-industry joint-ventured Q fever preventative services.[8] Provision of such services may require system change and include at-risk community education, GPs' awareness and training, targeted vaccinations for all at-risk workers ─ not just abattoir workers for whom it is an occupational requirement,[19] and event-based integrated surveillance. Community education could potentially support workers to challenge misinformation, and GPs' awareness and training may enhance their vigilance and promote vaccination.[20]

Despite our efforts, this study was limited by an inability to recruit a practicing rural GP (although we interviewed a policy stakeholder with significant experience in rural general practice), a representative from the meat industry, or a staff member from SA Pathology (owing to workload constraints in light of COVID-19). Additionally, our sample (16) may seem to be small, and does not include rural Australian outside of the farming industry who are also at increased risk of Q fever.[21] Despite these limitations, interviewing a range of stakeholders with significant expertise on Q fever surveillance, treatment, zoonosis prevention, a One Health approach and most importantly policy perspectives enhanced the richness of our data and increased the transferability of findings. Our study provided novel opportunities to find solutions, in addition to identifying potential barriers of an integrated approach.

Our results highlight that although the perceived barriers to a One Health approach are substantial, the opportunities are significant. In order to deal with the most concerning themes, we recommend updating medical curricula with dedicated inclusions on infectious diseases including major zoonosis. We also recommend that DoH provides proactive leadership, and that the zoonosis working group and Q fever strategy be streamlined to empower stakeholders and ensure inclusiveness with clear definitions of roles. The zoonosis working group could include multiple zoonotic diseases. We suggest government agencies exchange information and intelligence including data sharing,[22] and institute targeted interventions including awareness-raising and human vaccination. Although Q fever is a predominant concern for human health, technical and financial support from all stakeholders will be required to establish effective, sustainable government and industry partnerships.

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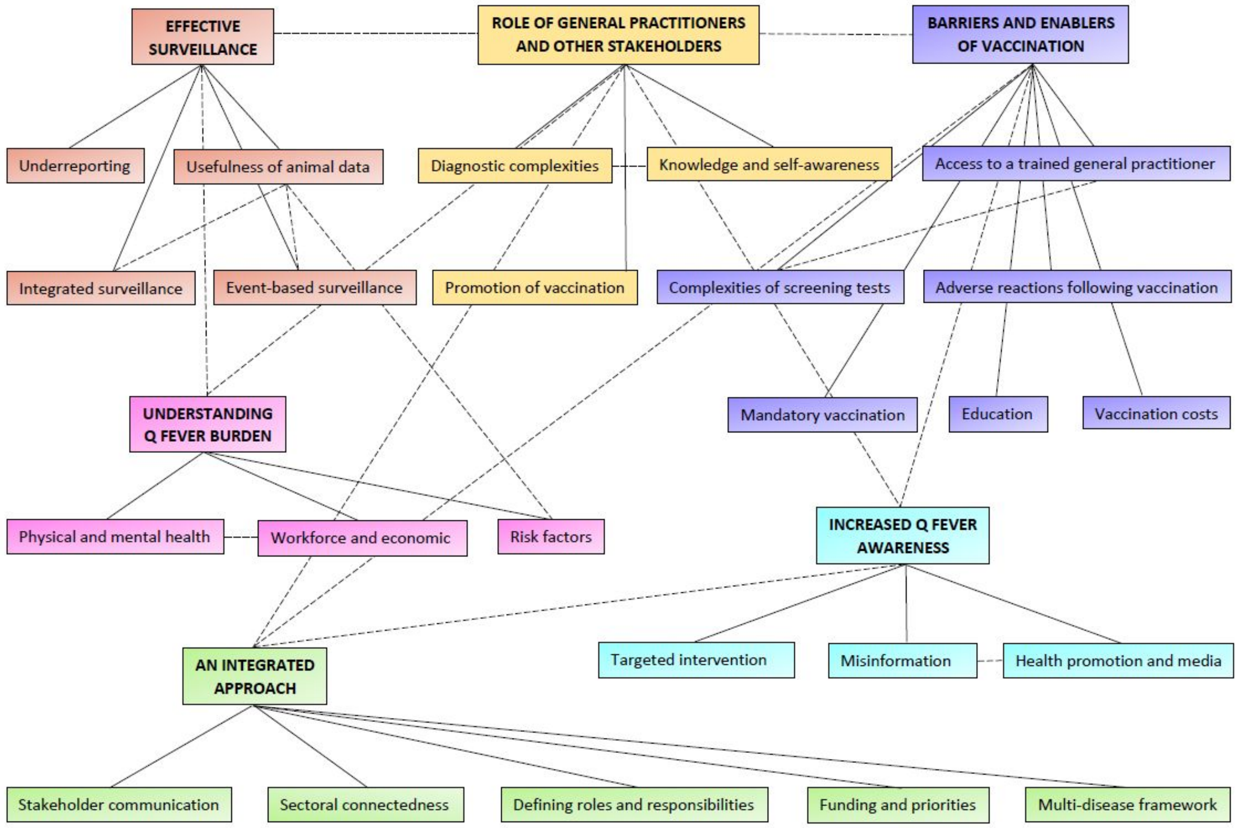
Tables and Boxes

1 Participant roles and positions

Participant	Stakeholder role	Position
1	Researcher	Public health researcher
		One Health researcher
2	Practitioner	Veterinarian
3	Representative from farming industry	Livestock and wool producer
4	Practitioner	Veterinarian
5	Practitioner	General practitioner
6	Practitioner	Veterinarian
7	Researcher	Veterinary public health researcher
8	Policymaker	Government official
9	Researcher	Veterinary pathologist
10	Representative from farming industry	Livestock and wool producer
11	Representative from farming industry	Policy advisor
12	Researcher	Ecosystem health researcher
		Public health physician
13	Policymaker	Government official
14	Policymaker	Government official
	Practitioner	General practitioner
15	Policymaker	Government official
16	Practitioner	General practitioner

2 Thematic map of major themes (bold upper case) and subthemes (sentence case). Solid lines indicate connections between themes and their corresponding subthemes (colour coded). Dashed lines indicate how themes and subthemes are interconnected



308 **3** Selected quotes (numbered 1–33) from interviewed stakeholders that illustrate the major themes and subthemes

Themes	Subthemes	Selected quotes
Understanding Q fever burden	Physical and mental health burden (P11)	[1] [T]here's acute and chronic […] people can get out of breath really easily. They can get the Q fever fatigue syndrome, endocarditis, hepatitis all those significant health impacts. Also, mood impacts, so mental health can be impacted. I know that [senior office holder] has had depression brought on from his Q fever experience.
	Workforce and economic burden (P1)	[2] I think the compensation claims that I've seen … relate to abattoir workers, they tend to have much more vulnerable contracts. So I think impact on casual workforce in agriculture would be quite dramatic because it's potentially a number of weeks, and for people who are casually employed that's a substantial amount of salary loss.
	Risk factors (P15)	[3] [Q] fever bacteria is excreted in large numbers in birthing products of animals. But also in feces and urine of those animals that it can, apart from coming in direct contact with the feces, birthing products and urine. That these can also be aerosolized.
	(P5)	[4] I don't actually know the details of exactly how it's transmitted from the animal to the human. I don't know whether it has to being injured by an animal or whether just contact with the infected meat, for example, of a slaughtered cow.
Effective surveillance	Underreporting (P15)	[5] I think that there's a huge underestimation of [how] many people might be affected by Q fever in a year.
	Usefulness of animal data (P9)	[6] I think I would have some doubts about the effectiveness of animal surveillance.
	(P13)	[7] [S]etting up a surveillance system in animals just to get to find out what's happening in humans. I don't think it's warranted because we already have a surveillance system in humans that works quite well.
	(P4)	[8] If you're looking for early warning signs of an increase in environmental contamination, or incidences of Q fever in unusual animals, maybe that would be quite useful for example.
	Integrated surveillance (P4)	[9] [Y]ou'll never get rid of it because there's too many different intermediate hosts. And I would want to know what ... to what purpose would such dual surveillance be put or how could you make use of that surveillance?
	Event-based surveillance (P7)	[10] [I]f you had an outbreak, in a farm, you could then start looking into that area in the human population. On the other side, if you had a couple of people coming in with Q fever, then you could start doing something in that area and in the animal population to find out where did this Q fever actually originate from.
Role of general practitioners and other stakeholders	Diagnostic complexities (P1)	[11] The disease itself is difficult. I've had conversations with the clinical pathologists, microbiologists, and they will tell you that they often diagnose Q fever because they've ruled out other causes of illness.
	(P12)	[12] [T]here'd be very few GPs that would be capable of making the correct diagnosis. So no doubt, we will be missing a few cases of Q fever … .
	Knowledge and self-awareness (P5)	[13] I think that many people in the medical profession's awareness of Q fever would be very low […] I wasn't taught specifically about most zoonoses at all, like infectious diseases played a very small part in the curriculum.
	(P16)	[14] So I think awareness is probably one thing is that a lot of GPs maybe just don't know about it or don't think about it.

	Promotion of vaccination (P3)	[15] [I]f you promoted it via Livestock SA and SA Health, they had little posters up in doctor's surgeries in the country. I think your healthcare providers being the doctor surgeries and so on, that's where we said about they should have posters promoting the fact that you should get checked and vaccinated.
	Key partners (P14)	[16] [T]he key partner would be SA Health, health protection, Biosecurity SA, and then the big groups where you're more likely to get workers who are going to get Q fever. So Livestock SA, and probably the meat-processing corporation, sheep producers […] unfortunately, the college of general practitioners and the college of rural and remote medicine are sort of in competition. So you probably need to involve both of those. I was going to add, SafeWork SA would be another of those high profile partners.
Barriers and enablers of vaccination	Access to a trained general practitioner (P14)	[17] [T]he other potential barrier is access. So there are a limited number of rural GPs, and we know there's rural GP shortage and therefore there's turnover. So there's the GPs with experience in you know, screening and vaccinating for Q fever is constantly changing.
	Complexities of screening tests (P10)	[18] I think one of the big problems is that … you've got to have a test. You don't know whether you've had it, or you could get it. And it takes some time for that test to come back. People in regional areas live a long way from doctors in a lot of cases. So there's that time-lapse between the test and getting the result back. And then if you're positive, and if you've had it, you don't have to have the vaccination. But if you come out where you should be vaccinated, then there's another time-lapse … .
	Adverse reactions following vaccination (P9)	[19] I read about the reactions to the vaccines. I've thought about it. And I'm still undecided as to whether or not I'll ever finally get vaccinated.
	P (1)	[20] I've also heard anecdotally that many GPs are not happy providing the vaccination because of the potential for the local adverse reactions that tends to put them off.
	Vaccination costs (P11)	[21] [C]ost is a main one. So people having to pay over $500 to get vaccinated. The perception of cost is another one, people thinking that they have to pay over $500.
	(P10)	[22] [T]he problem as I see it is that a lot of those people are casual workers. [O]f course, if people can't work, they're on social security benefits and that's a cost of the government. I believe, if there was a subsidy program that would help to eliminate those costs to the government.
	Mandatory vaccination (P2)	[23] I think people in the meat working industry for example, and perhaps veterinary students, for example, they would actually have an awareness, because it's been required as a pre requisite to have a vaccine to do your work.
	(P8)	[24] So our general guidance as a safety regulator is you try and prevent disease, so we would expect people moving stock and handling animals to all be Q fever vaccinated.
	Education (P6)	[25] If [farmers] were educated, I believe that they would take [the vaccine] up. And with education then people at least can make an educated decision on it.
An integrated approach	Stakeholder communication (P13)	[26] [W]e do have … meetings, regular meetings with primary industries and department of environment. So at a government level … there is that interaction across the departments to make sure that we are aware of what's happening.

	Sectoral connectedness (P3)	[27] Look, the potential is there to be able to bridge gaps between various organisations and link stuff together, whether you actually have to form a completely separate organisation if you like to deliver, or would you simply need to provide links between all those concerns.
	Defining roles and responsibilities (P8)	[28] [W]e only see the workplace reports or the human reports and mostly related to workplace, so I don't even know if my reports are filtered by SA health … but we have not had any meetings to discuss what our different roles are.
	Funding and priorities (P16)	[29] I think along with that probably comes things like funding and resourcing problems. So funding for health or funding for agriculture and they don't necessarily overlap. So that would be other ... and sort of different sectors having different priorities … .
	Multi-disease framework (P2)	[30] [O]bviously, there's more conditions to be focused on rather than just Q fever alone. [S]o perhaps if you've got three, four or five diseases, that we say okay, we want to take a collective approach to creating an awareness and control prevention strategies for these in the human population, you've got more strings to your bow so to speak – perhaps a multipronged approach … .
Increased Q fever awareness	Targeted intervention (P7)	[31] [Y]ou would need to have a campaign basically to make people aware of that […] so that would have to be targeted towards producers, towards doctors and probably also actually people in the risk areas. So in rural areas, you would have to target everyone there.
	Misinformation (P12)	[32] You now have idiots … who run the anti-vax campaigns on social media. And unfortunately many of the less educated people who work in abattoirs, for example are prone to pick up those misinformation misleading and inaccurate statements on social media and won't get the vaccinations accordingly.
	Health promotion and media (P2)	[33] There was some press last week about children of a farming family … contracted Q fever and the ongoing problem several years down the tracks, so it's only through that sort of media attention and publicity that there's going to be increased awareness of the risk.

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Study 4: What are the barriers and enablers of a One Health approach to Q fever prevention in South Australia (SA)?

INTERVIEW SCHEDULE

Introduction

Thank you for participating in today's interview. As you may know, Q fever is a zoonotic infection, transmitted from animals to humans, and despite the availability of a vaccine for humans, incidence in Australia remains high, particularly amongst certain occupational groups. More recently, a One Health approach for the prevention and control of zoonotic diseases has been recognised as an important approach because of its interdisciplinary nature linking human, animal and ecological sectors together. **Our key interest is to look at issues relating to a One Health approach to Q fever prevention in SA.**

What we want to examine in more detail is how feasible it is to adopt a One Health approach to Q fever prevention and control in SA. We really want to draw on your understanding about Q fever and its transmission, a One Health approach, Q fever surveillance, Q fever vaccination, and the barriers and enablers of a One Health approach to Q fever prevention. If you are happy with this I would like to proceed.

I would also like to confirm that you are still happy for me to record this interview? If you wish me to, I can turn off the recorder at any time throughout the interview, so please ask me if you would like me to turn it off.

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<u>Q 1-3 – Introductory Questions</u>

1. Do you think Q fever is a growing problem in SA? Why/Why not?

2. Can you tell me about your understanding of how people catch Q fever?

3. Do you think there are particular groups of people that may be at more risk of contracting Q fever than others? Why/Why not? Who are they?

<u>Q 4 – Specifically for GPs</u>

If you get a patient who works with animals and is at risk of getting Q fever

4. What are the things you do during the consultation including (if any) giving them Q fever prevention advice?

5. Could you please tell me a little bit about the impact Q fever has on a person's:

- own health

- family

- employment or business?

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<u>Brief intro: For many infectious diseases, Australia uses surveillance systems to track the occurrence of the disease in human and animal populations, and there are human surveillance and animal surveillance systems currently in place for Q fever.</u>

6. Do you think these current systems are effective in controlling Q fever? Why/Why not?

<u>Brief intro: For infectious disease prevention more generally, vaccination is clearly effective, and it is also effective for Q fever, however there is a low uptake of the human Q fever vaccination.</u>

7. What do you think could be some of the reasons for the low uptake of human Q fever vaccination?

Prompt (if required):

- *Two stage screening (GPs only)*
- *Cost of screening and the vaccine*
- *Time associated with vaccination completion*
- *Access to a vaccine provider*

<u>Specifically for veterinarians</u>

<u>Brief intro: There is also an animal vaccine available, which in Australia has never been used.</u>

8. Why do you think that might be the case?

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Brief intro: Now I would like to talk about a One Health approach. This has recently been proposed as a strong framework to deal with zoonotic infections such as Q fever.

9. Could you please tell me a little bit about your understanding of a One Health approach?

Brief intro: An integral strategy in a One Health approach is to combine human and animal surveillance systems.

10. How would you see this integration occurring in regards to Q fever prevention?

11. What do you see as some of the potential challenges of adopting a One Health approach to Q fever prevention in SA?

If listed any

12. What do you think some of the strategies that might help overcome these challenges?

13. What would you see as the potential enablers of a One Health approach?

13a. Can you tell me how you think this might work as an enabler?

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14. It's been suggested that an integrated surveillance system should be a core component of a One Health approach. Do you think this would be an enabler for a One Health approach? Why/Why not?

Brief intro: We've talked about Q fever surveillance systems, Q fever vaccination, and a One Health approach to Q fever prevention.

15. If SA was to introduce a One Health approach to Q fever, who do you think would be the most important partners to involve in the planning and implementation of such a process?

15a. Can you tell me a little bit about why you think these particular partners are important?

16. Do you think there are other issues that we should be considering about Q fever or do you have anything else you would like to add?

Thank you for your time. If you would like to contribute further at a later time please feel free to contact us on

[redacted]

[redacted]

Medical Journal of Australia

The One Health approach to Q fever prevention and control in South Australia

PARTICIPANT INFORMATION SHEET/CONSENT FORM

Title	The One Health approach to Q fever prevention and control in South Australia (SA)
Protocol Number	**HREC/20/SAH/8**
Project Sponsor	The University of Adelaide
Coordinating Principal Investigator/ Principal Investigator	[redacted]
Associate Investigator(s)	[redacted]
Location	Adelaide, SA

Dear Participant,

You are invited to participate in a research project on the topic of a One Health approach to Q fever prevention and control in SA.

Please note the following definitions for scientific terms that pertain to this information sheet:

- Q fever: A zoonotic bacterial disease transmissible from animals to humans.
- Zoonosis: A disease that is transmitted from animals to humans.
- One Health: An approach that integrates human, animal and the environmental health sectors to control and prevent zoonotic diseases.
- Surveillance: A system that tracks the occurrence of specific diseases in human and animal populations.

What is the research about?

Q fever is an infection transmitted from animals to humans, and despite the availability of a vaccine for humans, incidence in Australia remains high amongst certain occupational groups. More recently, a One Health approach for the prevention and control of zoonotic diseases has been recognised as an important approach because of its interdisciplinary nature

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linking human, animal and ecological sectors. In this study, we are investigating the feasibility of adopting a One Health approach to Q fever prevention and control in SA.

Who is undertaking this research?

A number of experienced researchers from the University of Adelaide are working together to undertake this research: [redacted] (Adelaide Medical School), [redacted]

Why am I being invited to participate?

You are invited to participate in this project because of your expertise and/or responsibilities in the area of policy and practice around Q fever and its prevention and control. We are inviting participation of relevant stakeholders from government and non-government organizations, general practitioners, veterinarians and researchers.

What will I be asked to do?

If you agree to participate, we will invite you for an interview. The interview will be audio-recorded, and organized at a time that is most convenient for you. The interview can be conducted in person or by phone, whichever you prefer. As part of the interview, we will be asking you about your knowledge and perceptions of Q fever and its prevention, a One Health approach to Q fever control and prevention and its associated opportunities and challenges, Q fever surveillance systems: barriers and enablers, and Q fever vaccination and related policies and guidelines.

If you wish, you can receive a draft of the paper/chapter for review once it is ready with the opportunity to suggest any quotations relating to your interview that you are uncomfortable with them being included.

How much time will participation take?

The interview will take approximately 30 to 45 minutes. Reviewing and returning the draft of the paper/chapter may take another 20-25 minutes.

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Are there any risks associated with participating in this research?

Information discussed in these interviews is confidential and the only people with access to the information from the interviews will be the project team. Although the questions are straightforward, and we do not anticipate that they would cause you any distress, if any issues are raised for you that are distressing during or after the interview, please contact one of the researchers or the Executive Officer of the SA Health Human Research Ethics Committee whose details are below.

Although we will remove identifying information, it is still possible that someone might be able to identify a study participant given the small number of people in similar roles to yourself in South Australia.

What are the benefits?

Your participation in this project will help us to identify the feasibility of a One Health approach to Q fever prevention and control in SA, and how Q fever surveillance systems might be improved so as to reduce Q fever disease burden through our ongoing advocacy for Q fever vaccination, especially in industries. Policy recommendations and formulating suggested guidelines are the expected outcomes.

Can I withdraw from the research?

Participation in this research is completely voluntary. If you agree to participate, you do not have to answer any interview questions that you do not wish to. It will also be possible to remove your information, should you wish to have that removed before the analysis.

What will happen to my information?

All data collected will be confidentially stored in a password-protected file for as long as necessary for research purposes. Audio recording of interviews will be transcribed verbatim and the transcripts will be stored in a lockable filing cabinet in the School of Public Health, the University of Adelaide (AHMS building) – this area can only be accessed with authorised security swipe cards. Your information will be managed with strict privacy and confidentiality at all stages. Only the research team will have access to your information.

As highlighted above although findings will be anonymized it is possible that you could be identified given the small number of people working in similar roles in South Australia.

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The One Health approach to Q fever prevention and control in South Australia

However, we will minimise such possibilities through the below steps but acknowledge that this will not necessarily guarantee that identifiability is not a possibility.

Steps include:

- Removing identifying information (e.g. name, position title and organisation)
- Using broad stakeholder's categories (e.g. public sector staff, GP, vet, researcher and other) and removing specific work roles of the participants
- A separate document with participant names and unique participant numbers will be kept in a separate location to the transcripts and only accessed by the PhD student
- At the end of the interview, we will ask if you would like to receive a draft of the paper for publication/chapter for review. If you say yes, we will send you a draft of the paper/chapter once it is ready. If you would like to withdraw any quotations related to your interview in the paper/chapter, please highlight those and return the draft to us within 2 weeks. We will remove any highlighted sections relating to your interview before continuing with publications.
  If you are happy with the draft of the paper as is, you do not need to do anything. If we do not hear from you within 2 weeks, we will continue with publications with the provided draft of the paper.

All data and documents will be destroyed 5 years after the project has been completed (in accordance with the University policy).

Complaints and compensation

No compensation for participation in the interviews is available.

Should you have any complaints about any aspect of this research please contact one of the researchers listed below or the Executive Officer of the SA Health Human Research Ethics Committee whose details are also below.

Reviewing HREC name	SA Department for Health and Ageing Human Research Ethics Committee
HREC Executive Officer	[redacted]
Telephone	(08) 8226 7235
Email	healthhumanresearchethicscommittee@sa.gov.au

The One Health approach to Q fever prevention and control in South Australia

Further information and who to contact

For further information concerning this project or if you have any issues you wish to raise about this research, please contact either:

[redacted]

Who is organising and funding the research?

This research project is being conducted as part of the PhD research being undertaken by [redacted] It is part of a larger research project being undertaken by a research team led by Chief Investigator [redacted]pervisor and is supported by the University of Adelaide. Therefore, no additional funding arrangement is applicable. None of the research team member will receive a financial benefit from your part in this research project (other than their ordinary wages).

Who has reviewed the research project?

All research in Australia involving people is reviewed by an independent group called a Human Research Ethics Committee (HREC). The ethical aspects of this research project have been approved by the HREC of the SA Department for Health and Wellbeing [Approval no. **HREC/20/SAH/8**]. This project will be carried out according to the *National Statement on Ethical Conduct in Human Research (2007)*. This National Statement has been developed to protect the interests of people who agree to participate in human research studies.

The One Health approach to Q fever prevention and control in South Australia

CONSENT FORM

Title	The One Health approach to Q fever prevention and control in South Australia (SA)
Protocol Number	**HREC/20/SAH/8**
Project Sponsor	Institution, The University of Adelaide
Coordinating Principal Investigator/ Principal Investigator	[redacted]
Location	Adelaide, SA

Declaration by Participant

- I have read the Participant Information Sheet or the interviewer has read it to me in clear and understandable English.
- I understand the purposes, procedures, and risks of the research described in the project. I am sufficiently assured that my information will be handled with strict privacy and confidentiality, will be de-identified immediately after the interview and no identifying information will be published. In addition, only the research team will have access to my information.
- I agree that the interview will be audio taped.
- I have had an opportunity to ask questions and I am satisfied with the answers I have received.
- I freely agree to participate in this research project as described and understand that I am free to withdraw at any time during the project without affecting my future relationships with my employer or the University of Adelaide.
- I understand that I will be given a signed copy of this document to keep.

Name of Participant (please print)____

Signature____________________________ Date_________________________

The One Health approach to Q fever prevention and control in South Australia

Declaration by Researcher†

I have given a verbal explanation of the research project, its procedures, and risks. I believe that the participant has understood that explanation.

Name of Researcher† (please print)____
Signature____________________________ Date___________________________

†An appropriately qualified member of the research team must provide the explanation of, and information concerning, the research project.

Note: All parties signing the consent section must date their own signature.

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The One Health approach to Q fever prevention and control in South Australia

WITHDRAWAL OF PARTICIPATION FORM

Title	The One Health approach to Q fever prevention and control in South Australia (SA)
Protocol Number	**HREC/20/SAH/8**
Project Sponsor	Institution, The University of Adelaide
Coordinating Principal Investigator/ Principal Investigator	[redacted]
Location	Adelaide, SA

Declaration by Participant

I wish to withdraw from participation in the above research project and understand that such withdrawal will not affect my relationships with the researchers or the University of Adelaide. I further understand that any contribution to date (recorded in interview transcripts) will be removed from the research project.

Name of Participant (please print)____

Signature____________________________ Date_________________________

In the event that the participant's decision to withdraw is communicated verbally, the Senior Researcher must provide a description of the circumstances below.

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Declaration by Researcher†

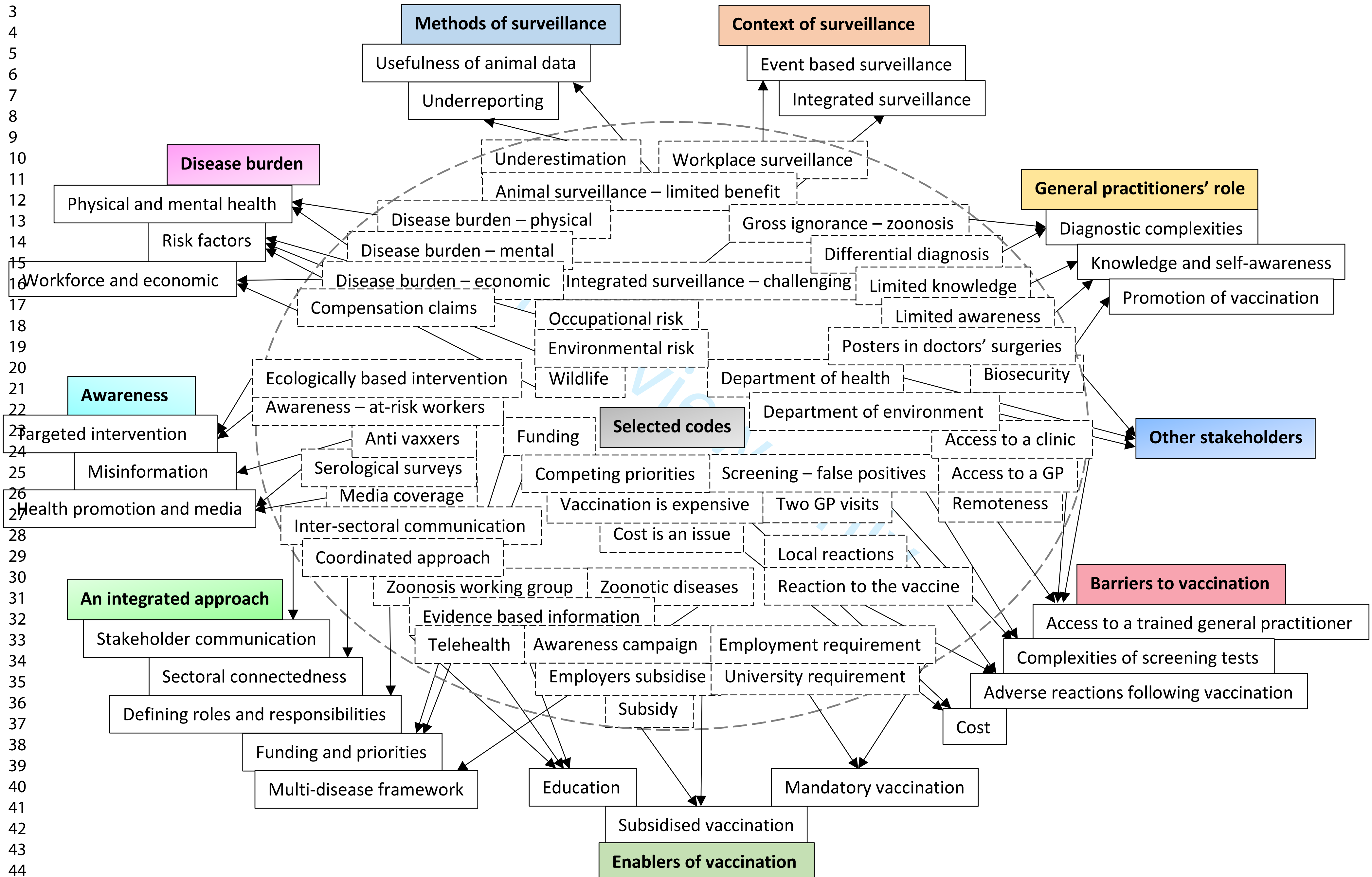
I have given a verbal explanation of the implications of withdrawal from the research project and I believe that the participant has understood that explanation.

Name of Researcher† (please print)____

Signature__________________________ Date_________________________

†An appropriately qualified member of the research team must provide information concerning withdrawal from the research project.

Note: All parties signing the consent section must date their own signature.


Methods of surveillance
Usefulness of animal data
Underreporting
Context of surveillance
Event based surveillance
Integrated surveillance
Disease burden
Physical and mental health
Risk factors
Workforce and economic
General practitioners' role
Diagnostic complexities
Knowledge and self-awareness
Promotion of vaccination
Underestimation
Workplace surveillance
Animal surveillance – limited benefit
Disease burden – physical
Gross ignorance – zoonosis
Disease burden – mental
Differential diagnosis
Disease burden – economic
Integrated surveillance – challenging
Limited knowledge
Compensation claims
Occupational risk
Limited awareness
Environmental risk
Posters in doctors' surgeries
Awareness
Ecologically based intervention
Wildlife
Department of health
Biosecurity
Awareness – at-risk workers
Department of environment
Targeted intervention
Funding
Selected codes
Access to a clinic
Other stakeholders
Anti vaxxers
Misinformation
Serological surveys
Competing priorities
Screening – false positives
Access to a GP
Health promotion and media
Media coverage
Vaccination is expensive
Two GP visits
Remoteness
Inter-sectoral communication
Cost is an issue
Coordinated approach
Local reactions
Zoonosis working group
Zoonotic diseases
Reaction to the vaccine
Barriers to vaccination
An integrated approach
Evidence based information
Access to a trained general practitioner
Stakeholder communication
Telehealth
Awareness campaign
Employment requirement
Complexities of screening tests
Sectoral connectedness
Employers subsidise
University requirement
Adverse reactions following vaccination
Defining roles and responsibilities
Subsidy
Cost
Funding and priorities
Multi-disease framework
Education
Mandatory vaccination
Subsidised vaccination
Enablers of vaccination

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Chapter 9 ─ Discussion

9.1 Preface

This chapter brings together the evidence generated in this PhD beginning with an overview of the research background, and the objectives of the study (section 9.2). Section 9.3 outlines the key findings to each corresponding study, and provides an overview of the key discussion points in sub-sections 9.3.1–9.3.6. Section 9.4 provides a synthesis of evidence, while section 9.5 outlines limitations of this research. The chapter concludes with a discussion of the challenges experienced during the conduct of this research in section 9.6.

9.2 Overview of the research

This mixed-method PhD research has reviewed Q fever epidemiology in SA, KAP about Q fever and its prevention among certain at-risk populations, and multi-stakeholders' perspectives on the barriers and enablers of a One Health approach to Q fever prevention and control with six primary objectives listed in Table 9.1. Overall, the aim of the research was to examine Q fever control and prevention approaches in SA and to explore the enablers and barriers of adopting a One Health approach to provide policy recommendations and guidelines. As study 1 was a literature review, and Chapters 1–3 are respectively the introduction, literature review, and study design and methodology, these are not listed in Table 9.1.

Table 9.1 Research objectives and corresponding studies (by chapters).

Study	Research objectives	Chapter
2	1. To analyze Q fever notification data in order to define at risk groups based on occupation and possible exposure in SA.	4
2	2. To examine the association between notified Q fever cases and spatial and temporal distribution of cattle, sheep and goats in SA.	4
3	3. To assess the KAP about Q fever and its prevention among university animal and veterinary science students in SA.	5
4	4. To investigate the KAP about Q fever and its prevention among SA livestock farmers.	6
5	5. To compare and contrast the perceptions of Q fever and its prevention between university animal and veterinary science students and livestock farmers in SA.	7
6	6. To explore multi-stakeholders' perspectives for identifying barriers and enablers of a One Health approach to Q fever prevention and control in SA.	8

The first two objectives (1 and 2) were scoped around further understanding of Q fever epidemiology with particular focus on occupational, and spatial and temporal livestock exposures. The third, fourth and fifth objectives were aimed at assessing the KAP about Q fever and its prevention among university animal and veterinary science students, and livestock farmers, and to compare and contrast their varying perceptions using a qualitative framework. Finally, the sixth objective aimed to interview relevant stakeholders including GPs and veterinarians, policymakers, researchers and industry partners concerning Q fever prevention and to synthesize the evidence for a stronger disease prevention and control framework using a One Health approach.

Three types of data sources were used ─ quantitative secondary data including human Q fever notifications and cattle, sheep and goat counts across 11 years in SA; quantitative primary data obtained from cross-sectional surveys with university animal and veterinary science students and livestock farmers; and qualitative data elicited from the cross-sectional surveys with students and farmers as above and interviews with multiple stakeholders. The diversity and richness of data from this research has provided flexibility in synthesizing evidence from multiple data sources across human, animal and environmental domains. This path-dependency has allowed investigating the research questions from a variety of angles, and such triangulation has increased the strength and effectiveness of the generated evidence in terms of its applications for Q fever prevention and control across the three domains.

9.3 Key findings

The key findings from this PhD study are listed in Table 9.2, further discussed under sub-sections 9.3.1–9.3.6, and synthesized into evidence under section 'Significance of this research'.

Table 9.2 Summary of key findings and their corresponding studies, data sources and chapters.

Study	Key findings	Data source	Chapter
1	***Literature review***		
	1. Sixteen studies had practiced or recommended a One Health approach. One Health themes identified from the studies were human risk assessment, serology, integrated surveillance, human vaccination, environmental measures, multi-sectoral collaboration, and education and training.	Published studies, including reviews	2
2	***Analysis of Q fever notifications in SA***		
	2. Among the 167 reported Q fever cases in SA, higher rates were observed among males aged 20–40 years, with the highest notifications recorded from a suburb containing an abattoir.	Notifiable disease reporting, CDCB, SA Health. Livestock densities, PIRSA	4
	3. Most common reported occupations were livestock farmers, abattoir workers and individuals with no known occupational risks.*		
	4. Goats, cattle and sheep annual counts were highly correlated with each other, but none of them, or the total number of livestock were associated with Q fever notifications.		
3	***Animal and veterinary science students' KAP***		
	5. Animal and veterinary science students' knowledge on Q fever was suboptimal.	Online survey	5
	6. The majority of animal science students were unvaccinated for Q fever.		
4	***Livestock farmers' KAP***		

	7. SA livestock farmers had a good understanding of Q fever.	Online survey	6
	8. Knowledge of farm-level biosecurity measures among farmers was suboptimal.		
	9. A high proportion of livestock farmers were unvaccinated for Q fever.		
5	***Students' and farmers' varying perceptions***		
	10. Animal and veterinary science students and livestock farmers emphasized the importance of Q fever vaccination.	Open-ended questions from the online surveys	7
	11. While students highlighted prohibitive costs, farmers underscored time, access to a trained vaccine provider, and GPs' suboptimal knowledge about Q fever as barriers to vaccination.		
	12. Both groups suggested subsidies, improving healthcare access, targeted awareness programs and GP education as enablers of vaccination.		
	13. Both groups identified themselves, relevant industries and the government as the key partners for Q fever prevention.		
6	***Stakeholders' perspectives on One Health***		
	14. Six major themes were identified including understanding Q fever burden, effective surveillance, the role of general practitioners and other stakeholders, barriers and enablers of vaccination, an integrated approach, and increased Q fever awareness.	Semi-structured interviews	8
	15. GPs' role was highlighted as instrumental in disease detection, notification, treatment and prevention through health promotion and vaccination; however, participants reported that GPs' knowledge and awareness of Q fever was limited.		

16. Participants asserted that leadership is required from DoH fostering communication, collaboration, and inclusion of wider stakeholder groups across human, animal and environmental domains within an inter-sectoral approach.

Note. *The occupation per se is not known to be a risk factor for Q fever and obtained dataset did not have specific detail on exposures.

9.3.1 One Health practice and/or recommendation for Q fever prevention

Evidence of a One Health approach to prevent and control Q fever was consolidated through a review of the literature. The review identified sixteen studies internationally[1-15] and in Australia[16] that had practiced or recommended a One Health approach (Table 9.2). Despite many variations in the application of a One Health approach in previous studies, most unanimously proposed multi-sectoral collaboration as an integral component.[17] Reflecting on such collaboration, it is important to recognize that a practical model of a One Health framework should satisfy the necessary principles of having broader representation from human, animal and environmental domains. Although a theoretical model may favor a proportional balance of the three domains, in reality it may not be achievable for the desired outputs given differences in responsibilities within the framework.

Of the 16 studies, only one was conducted in Australia as a pilot,[16] highlighting a contextual application gap in One Health practice. Findings from this PhD study merits consideration to fill identified gaps in knowledge through the application of certain One Health principles in line with internationally successful methods that were used in cross-sectional surveys and ecological correlations.[3,6,7,9] Amongst identified themes, except human-animal serology, others were examined in this PhD study in an integrated fashion, which started with assessing the human risks.

9.3.2 Occupational, spatial and temporal epidemiology of Q fever

One of the key findings from the epidemiological review of Q fever cases in SA was the higher notification rates among males in their twenties and thirties, which is consistent with the profile of abattoir workers.[18] Historically, abattoir workers are an at-risk population for acquiring Q fever, because of the transient nature of their work and casual employment contributing to lower vaccination coverage (employers are reluctant to vaccinate short-term employee) and higher susceptibility to workplace exposure.[18,19] This study also found that abattoir workers were the second most commonly reported occupation with the highest notifications of Q fever in SA occurring in a suburb containing an abattoir. These findings underscore the enduring vulnerabilities of this workforce. Among the notified Q fever cases in SA, livestock farmer was the most frequently reported occupation. Greater notifications among livestock farmers is consistent with other epidemiological reviews, particularly since the completion of the NQFMP in 2006.[20]

Other epidemiological studies in Australia highlighted a trend of increasing Q fever notifications among livestock farmers versus abattoir workers during post-NQFMP period compared to higher reporting among abattoir workers versus livestock farmers pre-NQFMP period.[21-23] Reduction in incidence among abattoir workers was thought to be the direct effect of the NQFMP program with high coverage among the primary target group.[20] In contrast, poor vaccination uptake among livestock farmers may have been responsible for higher Q fever notifications in this workforce. Changing epidemiology,[22,24] low vaccination coverage among livestock farmers,[20] and the reported occupation classified as ‘no known occupational risk’, which is consistent with a nationally conducted epidemiological review,[25] altogether have increased the epidemiological complexities of Q fever.

The second research objective was thus conceived to examine the epidemiological complexity by assessing the relationship between human notifications and livestock density as a recent study in the U.S. found associations between livestock densities and spatial clustering of Q fever cases.[26] This PhD study found that individual counts for cattle, sheep and goats and combined total number of livestock were not associated with spatial clustering of Q fever cases. Lack of an association between livestock and Q fever may highlight the role of the environment and wildlife in Q fever transmission as in an endemic area in Queensland, seasonal rainfall and wildlife have been implicated as substantial sources of infection.[27] The role of environment in Q fever transmission is argued to be substantive and complex due to the nature of *C. burnetii* with its shedding and survival in the environment for long periods of time, especially in dry weather and land conditions causing aerosolization of the bacteria.[28,29] Although ideally researching the environmental domain would have been the best case scenario, we predominantly focused on human and animal aspects of the disease recognizing the importance of the environment but falling outside the scope of this PhD. Hypothetically, despite our efforts in understanding the role of the environment in Q fever transmission, and in an ideal situation, efforts to minimize farm level aerosol generation, animal birthing in wildlife is difficult to monitor and control, limiting our capacity to control Q fever. Further environmental studies are required to assess novel and workable solutions.

9.3.3 Animal and veterinary science students' perspectives on Q fever

The third research objective pertaining to study 3 was to assess university animal and veterinary science students' KAP of Q fever and its prevention. With the exception of students in DVM program, knowledge of Q fever among animal science and veterinary bioscience students was suboptimal. However, students across the three degree programs reported moderate-high level of exposure to high-risk animals such as cattle, sheep and goats.[30] Students' limited knowledge, which may lead to poorer compliance to disease prevention measures,[31] coupled with students' reported high-risk exposure to animals may place animal science students at higher than generally perceived risk of Q fever, as the majority remained unvaccinated.

Despite Q fever vaccination being a course requirement for veterinary degrees in Australia,[32] several veterinary bioscience, and most animal science students' unvaccinated status is concerning given their reported level of exposure to high-risk animals. However, quantification of these potential risk exposures was not possible. Q fever vaccination is not a university requirement for animal science students in SA,[33] although they are currently recommended to seek vaccination. Therefore, it is important to understand the factors that may preclude students from receiving Q fever vaccination. Students identified certain barriers to vaccination including costs of Q fever vaccine, time associated with the vaccination process,[34] and access to an accredited medical doctor, which is in line with other Australian studies.[35,36] Additionally, in keeping with published studies, they suggested certain strategies for increasing vaccine uptake such as improving healthcare access,[19] and subsidized and mass vaccination.[36]

9.3.4 Livestock farmers' perspectives on Q fever

The fourth research objective pertaining to study 4 involved a cross-sectional survey of livestock farmers' perspectives about Q fever prevention and preparedness as currently they are at high risk of infection in Australia,[21,22,24] as well as internationally.[37-39] Unlike other Australian[40] and international studies,[8] livestock farmers in this study were found to have a good understanding about Q fever. However, their knowledge about farm-level biosecurity measures was suboptimal, which is often believed to place individuals at increased risk of zoonosis.[41] Most farmers in this study had been farming for ≥ 20 years, which is likely to increase their susceptibility of infection given the fact of a dose-response relationship of a person's exposure to a high-risk environment and the likelihood of contracting Q fever as was observed among veterinary students, another at-risk group.[42]

Given the inherent susceptibility of livestock farmers to Q fever infection and their poorer adherence to biosecurity measures such as using masks to prevent airborne transmission of zoonosis, human vaccination remains the mainstay of disease prevention.[41,43] However, 42% of the farmers in this study were not vaccinated for Q fever, which is a cause for concern. This may indicate some roadblocks associated with livestock farmers seeking Q fever vaccination. Identified barriers to vaccination included poor access to a trained doctor, and time and cost related to vaccination in line with other published studies.[36] As a way forward, livestock farmers supported a coordinated approach to building awareness and funding vaccination programs.

9.3.5 Varying perceptions of Q fever between animal and veterinary science students and livestock farmers

The relative importance placed by university animal and veterinary science students and livestock farmers in their open response was difficult to separate from the cross-sectional study design. Thematic analysis was thus conceived in anticipation of gaining rich data from the surveys (studies 3 and 4), and constituted research objective 5 (study 5).

In line with published studies suggesting high efficacy of Q-Vax®,[20,43-45] animal and veterinary science students and livestock farmers emphasized the importance of Q fever vaccination and its effectiveness. Despite that unanimity, students highlighted that vaccination was accessible but not affordable, while farmers mentioned that access to a GP vaccine provider due to geographical remoteness is an issue, which is consistent with other

Australian studies among different at-risk populations.[32,35] However, if farmers managed to access a provider, they were concerned about the providers having limited knowledge about Q fever. Livestock farmers implicated GPs' limited knowledge with their suboptimal capacity and lack of confidence to vaccinate, as shown in multi-staged social cognition behavioral models.[36,46,47] A multi-staged behavioral model assumes that behavior change occurs with a variety of stimuli related to knowledge and training influencing individuals' confidence that drives a new action.[46]

Similar to other studies, both students and farmers suggested strategies for improving the uptake of Q fever vaccination including subsidized vaccination,[29] targeted awareness programs,[48] and GP professional development.[49] On top of these, common suggestion by both groups was the need for a coordinated effort from all relevant stakeholders, including at-risk populations, the university, livestock industry, and government agencies resonating conceptually with the One Health approach. Despite subsidized vaccination programs such as the NQFMP that was efficacious in reducing Q fever incidence in the short-term, public health interventions without system change is less sustainable,[24] thereby adding further support to the students' and farmers' suggestion of a coordinated approach. Linking suggested strategies, a holistic model may start with industry-led awareness helping individuals make an informed decision, utilize GP expertise and vigilance to promote vaccination, as well as subsidizing vaccination programs by government-industry partnerships.

9.3.6 Key stakeholders' perspectives on Q fever prevention and control in a One Health approach

The sixth objective of this research was to explore the suitability of a One Health approach to Q fever prevention through interviews with multi-stakeholders. Amongst the six major themes that emerged from participants' responses "the role of general practitioners and other stakeholders" was central to Q fever prevention and control and deeply connected to all other themes. These other themes included understanding Q fever burden, effective surveillance, barriers and enablers of vaccination, an integrated approach, and increased Q fever awareness.

In a recent survey among Australian GPs and veterinarians, GPs' knowledge and vigilance about Q fever was identified as key to zoonosis prevention.[49] Despite GPs' instrumental roles in disease detection, notification, treatment and prevention through health promotion and vaccination, participants reported that GPs' knowledge and awareness of Q fever was limited. Outstandingly, GPs themselves labelled their knowledge and understanding to be suboptimal and implicated that to inadequacies in the medical curricula on zoonotic diseases. Not surprisingly, these limitations highlighted by GPs could potentially modify their patterns of care provision, meaning that, they could potentially discourage vaccination instead, as argued in an Australian study.[32] Along with the epidemiological complexities of Q fever including wide reservoir of *C. burnetii*,[50] GPs' lack of vigilance may contribute to the persistent burden of Q fever in Australia. Q fever has been notifiable in Australia since 1977,[51] but if GPs are not adequately vigilant, they may not consider Q fever in differentials resulting in underestimation of the true number. This is particularly important in rural farming communities where Q fever burden is relatively high, yet mostly undetected. In line with study 5 and other Australian studies,[32,35,36] together with costs and time associated with vaccination, two important barriers to vaccination included access to a trained GP, and their limited knowledge and awareness of Q fever.

The solution to this is complex; at the very minimum, it involves an integrated approach to Q fever prevention involving a novel approach that could include multiple zoonotic diseases in one framework; or holistically integrate infectious diseases, non-communicable diseases, nutrition, land use and vegetation, and climate change in another approach. A few participants suggested this novel approach, which resonates well with the overall research aim and satisfies many practical realities related to funding, human resources and priorities. Despite recent efforts, a zoonotic screening (serology for several zoonotic diseases) of practitioners including GPs and veterinarians in a One Health conference, or a One Health theme in public health conferences, may promote understanding about multiple zoonoses at the one time and increase vigilance to major notifiable zoonosis such as Q fever, anthrax and leptospirosis. This approach is feasible in the sense that it does not require establishment of a whole new framework, rather it could be built on an existing structure such as the one applied for avian influenza, Australian bat lyssavirus or rabies.

This framework may entail strengthening the existing zoonosis working group with DoH taking the lead as reaffirmed by several participants. DoH's leadership is deemed appropriate for fostering communication, collaboration and the inclusion of GP networks and veterinarians within a multi-sectoral framework. Such leadership was also considered of paramount importance to channel political wills and funds as was argued for another novel approach to create awareness as part of the zoonosis working group's portfolio. It was suggested that ecologically based health interventions may be of political interest demonstrating financial saving. It was reasonably argued that demanding more sustainable use of the environment and hence better ecosystem service availability might target politicians. Public health experts should be proactively communicating to policymakers including DoH, DEW and PIRSA, the value of the environment such as green spaces in boosting human immunity to zoonotic diseases,[52] acknowledging that caution needs to be exercised while interpreting environmental benefits from observational studies.

The other nuanced benefit of this would be empowering the environmental health domain, one of the three realms of One Health, but is often less appreciated when zoonosis is concerned. Participation and inclusion of this domain would help understand the dynamics of Q fever transmission, identify environmental drivers of disease, and design environmentally appropriate interventions, given that humans, animals and the environment are inseparable. The reason for this postulation is heavy environmental contamination ensues following the shedding of *C. burnetii* which can remain in soil for >1 year and serve as source for human infection.[53] As a starting point, structural adjustment of the existing zoonosis working group in the form of including human, animal and environmental domains may constitute a practical reality of the One Health approach.

9.4 Significance of this research

Q fever is an important zoonotic disease with significant health and economic implications that has the potential for outbreaks. Studies have confirmed that the epidemiology of Q fever is complex, primarily due to the extensive involvement of *C. burnetii* in a range of species including livestock, wildlife and ticks,[50] all of which are widely present in Australia. Despite ad hoc applications of a One Health approach to Q fever prevention and control showed promising results, synthesizing evidence has rarely been attempted. To our knowledge, this is the first comprehensive research conducted consolidating evidence around a One Health application to control and prevent Q fever despite our limitations of a greater emphasis on the animal and human domains and not on environmental component. However, we recognize that the environmental domain is a key part of the One Health framework. This omission is related to the scope of the research and does not affect the generalizability of findings within a broader One Health context given the large variations identified in applied components of the framework. For example, despite that animal vaccination was enforced during the Netherlands community Q fever epidemic,[54] this was prohibited in an Australian goat farm outbreak because of biosecurity reasons.[16] This study reinforces contextual priorities when executing One Health principles to Q fever prevention and control and may inform policymakers that evidence generated elsewhere may not be readily generalizable to the Australian context.

Building on that, this research provides contrasting evidence to the spatial relationship of sheep flocks with the clustering of human Q fever cases found in the U.S.[26] This is the first Australian study demonstrating that livestock may not be spatially related to human clustering of Q fever cases, at least in SA. Additionally, we were able to quantify the occupational risks of Q fever, which highlighted greater than generally perceived risks for certain at-risk groups such as veterinary students and park rangers. This has led to the first ever assessment of the KAP about Q fever and its prevention among university animal and veterinary science students and livestock farmers. Uniquely, we have identified inadequacies in the university veterinary curricula concerning zoonotic education, and the majority of animal science students remained unvaccinated despite their moderate-high exposure to high-risk animals. The results will provide solid evidence to protect university students working with animals through possible subsidized vaccination for Q fever.

This research is significant because Australian livestock farmers from a large geographical area had reflected on their perceptions around Q fever and its prevention. We have identified that livestock farmers possessed good understanding about Q fever, practiced general biosecurity measures modestly, but that two-fifths of them remained unvaccinated. This finding highlights that a reasonably aware workforce have experienced barriers to Q fever vaccination. The fifth study, the first of its kind, provided the avenue to confirm this postulation, with the findings from farmers and students emphasizing the importance of Q fever vaccination while identifying access to vaccine providers and affordability as the roadblocks. Access to a trained GP may compound vaccination barriers as the entire process requires several visits to a GP involving pre-vaccination screening including serology and skin test, having the test results read in a week and scheduling an appointment for vaccination if the person is not immune to Q fever — altogether a matter of access and affordability. Findings from this research will inform immunization policymakers accommodating possible subsidies for Q fever vaccination among at-risk populations.

Another highlight of this thesis is exploring participants' perspectives on Q fever epidemiology, disease surveillance, and its prevention including vaccination using a One Health framework drawn from a range of disciplines. To our knowledge, the final study is the first to investigate the barriers and opportunities of adopting a One Health approach including human vaccination for Q fever using a qualitative framework. We have identified limitations in the medical curricula, lack of leadership, and inadequate participation from stakeholders in decision making due to power disparity. The results will provide evidence for relevant stakeholders including practitioners, policymakers, researchers and lobby groups to pursue their own agenda within a collective framework such as the zoonosis working group while ensuring inclusiveness.

Overall, by using a mixed method approach, this study has contributed greatly to the understanding of Q fever epidemiology and its prevention. Quantitative approach coupled with the inclusion of qualitative methodologies and the opportunity to investigate insiders' perspectives has made this research unique for Q fever prevention and control. Overall, results from studies 1 and 2 have provided a synthesized review concerning Q fever epidemiology and application of a One Health approach, studies 3 through 5 have consolidated our conception around at-risk groups' readiness for disease prevention, and study 6 has highlighted stakeholders' preparedness for applying a One Health approach to Q fever.

9.5 Limitations

The limitations of each study have been discussed in the relevant chapters, and will not be repeated here, rather the overarching limitations of this PhD research and any underpinning key limitations from individual studies will be discussed. In terms of the scope of this research, despite human animal serology emerging as a key theme from the literature review, we were unable to design a serological study to measure Q fever prevalence given the ethical and logistical roadblocks associated with invasive procedures preventing its suitability for a PhD. However, a combination of epidemiological reviews, cross-sectional surveys and qualitative studies has enabled the formulation of a strong evidence-base and possibly offset that limitation in part while creating opportunities for future research.

In terms of the key limitations in specific studies, a small number of reported Q fever notifications was a limitation in study 2. This has particularly affected the statistical precision for estimates, such as the small number of veterinary students and park rangers as a group that had a relatively large IRR.[55] However, given the relatively small denominator for this group the estimates merit consideration. Additionally, examining the associations between reported Q fever cases and spatial livestock densities has added unique value to this research while opening up future research opportunity within Australia and internationally by using similar data to check the external validity of findings.

In the cross-sectional surveys presented in Chapters 5, 6 and 7, a limitation was that survey participants were from SA, thereby restricting our ability to account for inter-university and interstate variations if there was one. However, the demographic profile of animal and veterinary science students,[31,56] and livestock farmers,[57] was consistent with other Australian and state level studies, hence, our findings merit consideration. Another limitation of study 4 is the potential reporting bias as willingness to pay for vaccination may have influenced participants' responses, meaning that livestock farmers who were less likely to pay for their vaccination, were more likely to participate. Findings suggest that remoteness and socioeconomic status may have precluded some farmers from receiving vaccination. However, poor vaccination uptake is a longstanding issue for Australian livestock farmers, and this was reported during the subsidized NQFMP. Study 5 was limited by written responses to one open question seeking participants' suggestions for Q fever prevention, and participants did not have opportunities to expand and reflect on their suggested strategies, as there was no follow up question. However, the breadth of responses and the scope of comparing two very different, yet at-risk groups' perceptions has made this research unique and opened further qualitative research opportunities for the interviews in study 6.

Finally, we were unable to recruit stakeholders from rural GPs, laboratory staff, and a representative from the Australian Meat Industry Council (AMIC). This study was conducted at the beginning of the COVID-19 pandemic and rural GPs and laboratory staff were difficult to recruit. In contrast, AMIC declined our invitation to participate in this PhD research in 2018 with the proposal of surveying and interviewing abattoir workers. Although participation from AMIC was highly desirable, inclusion of other increasingly important at-risk groups such as livestock farmers following the post-NQFMP period,[21] and animal and veterinary science students has enhanced the depth and breadth of the generated evidence.

9.6 Methodological challenges faced while conducting this research

As highlighted in section 9.5, a One Health framework for Q fever prevention and control may warrant participation from the meat industry such as AMIC, given that historically abattoir workers were, and continue to be a high-risk occupational group in Australia.[43] When the research team contacted AMIC in March 2018, they were initially supportive of the project. Further, the research team was asked to provide information on the scope of the project, expected outcomes, benefit to AMIC, and type of support required from AMIC. We provided the requested information in May 2018, but were informed of their inability to proceed with the project in August 2018.

There was a lack of Australian studies that utilized a One Health approach to Q fever prevention and control, which limited our abilities to synthesize contextual evidence for potentially more appropriate and/or feasible study designs.[17] Another important methodological challenge was the lack of an animal surveillance for Q fever in Australia. Despite that, an ideal One Health model promotes to have an integrated human-animal surveillance,[58] or at least an animal surveillance;[59] this research was limited in evaluating such a practical One Health integration.

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10

Chapter 10 ─ Recommendations and conclusions

10.1 Preface

This chapter provides an outline of specific recommendations drawing upon the key findings generated in each of the six studies, important policy implications, and future research directions.

10.2 Specific recommendations

- Within a One Health framework, the primary onus belongs to DoH in taking a leadership role, while other stakeholders including DEW and PIRSA should be facilitating the execution of action items pursued through a task force such as the zoonosis working group.
- Identification and quantification of non-occupational risks of Q fever in Australia is required.
    - That we found no association between livestock and notified Q fever cases in SA should stimulate similar investigations interstate and warrant inclusion of wildlife, pets and ticks, given the extensive presence of *C. burnetii* in a range of species.
    - Ecological studies may merit research into climate effects, vegetation and land use and associated risk of Q fever infections, as well as atmospheric dispersion modeling to examine airborne transmission of *C. burnetii*.
- Abattoir workers are a priority group for Q fever vaccination: vaccination programs should be extended to cover workers with vulnerable contracts such as casual workers.

- Q fever vaccination should be better promoted in the farming industry as livestock farmers are at greater risk than other occupational groups due to their remoteness and limited access to an accredited GP, and the nature of their work exposing them to animal contact and high risk practices.
- Farmers would benefit practicing biosecurity measures such as wearing face masks while working in dusty environments to protect from dust and aerosol transmission of zoonotic diseases.
- Animal and veterinary science students should practice biosecurity measures, as they are at greater than commonly perceived risks of Q fever.
- Given animal science students' reported level of exposure to high-risk animals, we recommend that they receive Q-Vax® as veterinary students do, as part of their course requirement with possible subsidies from the university.
- Medical and veterinary curricula need to be updated with specific content on zoonosis to better educate prospective practitioners before entering the workforce with access to information and required training.
- Relevant colleges for GPs and veterinarians are recommended to organize periodic professional development activities with particular emphasis on zoonotic diseases.
- Expansion of rural GP services is required, necessitating the government, DoH and RACGP and ACRRM to have discussions about rural GP workforce retention, potentially through remuneration and other benefits as well as arranging continued professional development sessions to enhance GPs' expertise.
- Government-industry partnership is required. Ideally, an inter-sectoral taskforce should be formed with relevant industry partners having a common One Health

agenda — an overall agenda could be integrated with partners having their own industry-specific agenda and be liaising with the government agencies to secure funding for subsidized vaccination programs for their workers.

- Legislation needs to be formulated in terms of industry commitment to securing their employees' health and safety through providing information about Q fever and training on practicing personal protective equipment where relevant and funded vaccination programs for staff at all tiers of the supply chain.
- Research into Australian meat processing industry involving KAP and serological surveys, and qualitative studies may help quantify the true burden of Q fever among abattoir workers, and vaccination coverage and challenges, and identify the barriers and enablers of adopting a One Health approach.
- Evaluation and strengthening of human Q fever surveillance system should be coupled with establishing an animal surveillance (on an ad hoc or pilot basis) as an early warning system for human diseases.
- Research into potential waning immunity or issues related to vaccine efficacy would be instrumental in providing solid evidence of the duration of immunity conferred by Q-Vax®, which is reported to be at least five years.
- Research into the safety and efficacy of Q-Vax® for children is important to ensure adequate protection of children who live on farms.

10.3 Concluding remarks

Findings from this research will contribute further knowledge about the principles of a One Health framework and its adaptability based on the context of application, and Q fever epidemiology in Australia in relation to livestock species and occupational groups. This research is the first to have explored disease epidemiology, the KAP about Q fever and its prevention among at risk occupational groups and multi-stakeholders' perspectives about the barriers and opportunities of Q fever prevention using a mixed method study design. This is important as it provides quantitative accounts of the occupational risks, level of at-risk populations' preparedness and "insider perspective" into the problems and opportunities for Q fever prevention.

Evidence from this thesis confirms that a One Health framework has the underlying principles of controlling Q fever efficiently. Despite the fact that One Health program components may vary based on contextual priorities, representation from human, animal and environmental domains is crucial for its optimal functionality. DoH must take on the leadership role for an integrated approach to Q fever in Australia while ensuring participation and inclusiveness. An ideal One Health model for Q fever prevention and control in Australia could be constituted with veterinary measures, environmental control techniques and human vaccination.

Appendix A ─ Questionnaire and interview schedule

Studies 3–5

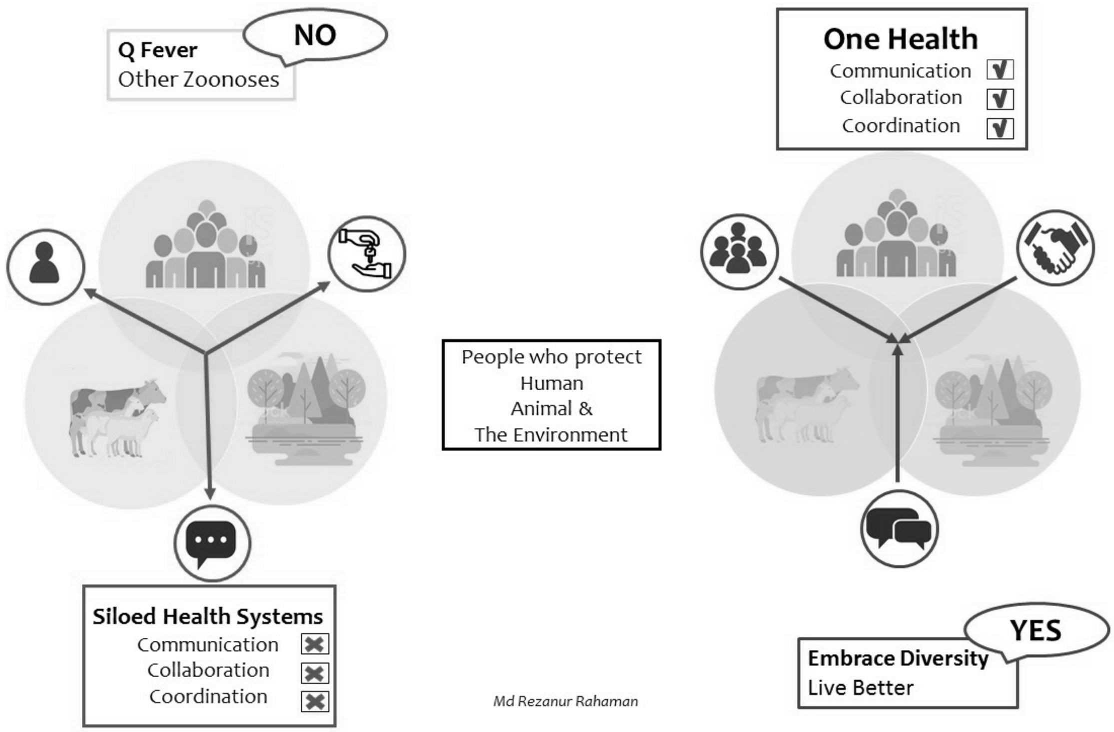
- Survey questionnaire for animal and veterinary science students
- Survey questionnaire for livestock farmers

Study 6

- Semi-structured interview schedule for stakeholders ─ Chapter 8 (supplementary materials for peer review in *The Medical Journal of Australia*)

The One Health approach to Q fever prevention and control in South Australia

Please read the participant information sheet in the following page before proceeding with the survey. Thank you for participating in our survey. Your feedback is important.



Dear Participant,

You are invited to participate in the research project described below.

What is the project about?
This research project is about Q fever which is an infection transmitted from animals to humans and despite the availability of a vaccine for humans, incidence in Australia remains high amongst certain occupational groups. In this study, we are investigating the level of knowledge, attitudes, and preventive practices of Q fever among South Australian veterinary and animal sciences students.

Who is undertaking the project?
This project is being conducted by Prof Peng Bi (School of Public Health), Prof Helen Marshall (School of Medicine), Dr Adriana Milazzo (School of Public Health) and Md Rezanur Rahaman (School of Public Health) of the University of Adelaide. The researchers are quite separate to participating students' program supervisors and teachers.

Why am I being invited to participate?
You are being invited as your line of study places you in contact with animals that are potentially associated with Q fever.

What am I being invited to do?
You are invited to complete an online survey about your understanding of Q fever, and your perspectives and practices concerning Q fever prevention and control. The survey may take approximately 15 minutes to complete.

Are there any risks associated with participating in this project?
This is an online survey on your knowledge, perspectives and practices related to Q fever and its prevention and control. There are some basic sociodemographic questions as well. All information obtained is anonymous. Therefore, there is no foreseeable risks/discomfort participating in this survey. In addition, participation, non-participation or withdrawal will not impact your study and this survey is not a test of your knowledge about the subject.

What are the potential benefits of the research project?
Determining the levels of Q fever knowledge among at-risk population groups may help identify the target populations' needs, whereby the level of their practice may help define gaps in disease control and prevention approaches and help formulate industry level policies and guidelines. Also, the results may provide valid evidence for incorporating specific curriculum updates for veterinary and animal science students. However, participating in this research will not have any direct/immediate benefit.

Can I withdraw from the project?
Participation in this project is completely voluntary. If you agree to participate, you can withdraw any time up until submission of the survey. If you decide to withdraw this will not affect your study at the University, now or in the future.

What will happen to my information?
The findings from the survey will be published in peer reviewed journals and made accessible to the wider, public health research community as well as the general population. The results will also be presented in conferences and finally incorporated into the thesis, required to submit to the University for the Research Candidature. As only non-identifiable responses will be sought and analysed, privacy and confidentiality will not be compromised.

Security of data storage:
Data in electronic format will be stored in the research student's (Md Rezanur Rahaman) computer which is password protected. The records and materials will be retained by the university for five (5) years after publications of the results. The data will not be used in future research nor shared in an online repository such as Figshare. Your information will only be used as described in this participant information sheet and it will only be disclosed according to the consent provided, except as required by law.

Who do I contact if I have questions about the project?
The person you may need to contact will depend on what you want to know. If you want any further information concerning this project or if you have any problems about you and this research, you can contact:

Prof Peng Bi (PI)
Phone: (08) 8313 3583
Email: peng.bi@adelaide.edu.au

Md Rezanur Rahaman
Email: mdrezanur.rahaman@adelaide.edu.au

What if I have a complaint or any concerns?
The study has been approved by the Human Research Ethics Committee at the University of Adelaide (approval number H-2019-040). This research project will be conducted according to the NHMRC National Statement on Ethical Conduct in Human Research 2007 (updated 2018). If you have questions or problems associated with the practical aspects of your participation in the project, or wish to raise a concern or complaint about the project, then you should consult the Principal Investigator (PI). If you wish to speak with an independent person regarding concerns or a complaint, the University's policy on research involving human participants, or your rights as a participant, please contact the Human Research Ethics Committee's Secretariat on:
Phone: +61 8 8313 6028
Email: hrec@adelaide.edu.au
Post: Level 4, Rundle Mall Plaza, 50 Rundle Mall, ADELAIDE SA 5000

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

Yours sincerely,

Prof Peng Bi	Principal Investigator/supervisor
Prof Helen Marshall	Co-investigator/supervisor
Dr Adriana Milazzo	Co-investigator/supervisor
Md Rezanur Rahaman	Co-investigator/Research student

* 1. Based on the study information presented above, do you consent to participate in this survey?

- ◯ Yes, I do
- ◯ No, I don't

2. Which of the following describes your age group?

- < 20 years
- 20-24 years
- 25-29 years
- 30-34 years
- 35-39 years
- ≥ 40 years

3. What is your gender?

- Male
- Female
- Other
- Prefer not to disclose

4. What is your postcode of residence?

5. Which program are you currently enrolled in?

- BSc Animal science
- Animal Behavior course
- Doctor of Veterinary Medicine (DVM)

6. What year level are you in?

- Year 1
- Year 2
- Year 3
- Year 4
- Year 5
- Year 6
- Other (please specify)

7. How frequently do you come into contact with the following animals through your veterinary/animal science study? (Select all that apply)

Use the scale to select one response for each animal listed.

	Always	Often	Sometimes	Rarely	Never	Don't know
Beef cattle	◯	◯	◯	◯	◯	◯
Dairy cattle	◯	◯	◯	◯	◯	◯
Sheep	◯	◯	◯	◯	◯	◯
Domestic goats	◯	◯	◯	◯	◯	◯
Feral goats	◯	◯	◯	◯	◯	◯
Dogs	◯	◯	◯	◯	◯	◯
Cats	◯	◯	◯	◯	◯	◯
Horses	◯	◯	◯	◯	◯	◯
Pigs	◯	◯	◯	◯	◯	◯
Poultry	◯	◯	◯	◯	◯	◯
Other birds	◯	◯	◯	◯	◯	◯
Pocket pets (guinea pigs, rabbits, ferrets etc.)	◯	◯	◯	◯	◯	◯
Kangaroos	◯	◯	◯	◯	◯	◯
Feral cats	◯	◯	◯	◯	◯	◯
Camels	◯	◯	◯	◯	◯	◯

Other (please specify)

8. How frequently do you engage in the following activities when having contact with animals?

Use the scale to select one response for each activity listed.

	Always	Often	Sometimes	Rarely	Never	Don't know
Wearing a uniform	◯	◯	◯	◯	◯	◯
Wearing work boots	◯	◯	◯	◯	◯	◯
Wearing a face mask	◯	◯	◯	◯	◯	◯
Hand washing after contact	◯	◯	◯	◯	◯	◯
Before contact change into uniform/boots	◯	◯	◯	◯	◯	◯
After contact change out of uniform/boots	◯	◯	◯	◯	◯	◯
Having a shower after contact	◯	◯	◯	◯	◯	◯
Use of hand gloves	◯	◯	◯	◯	◯	◯
Use of eye goggles	◯	◯	◯	◯	◯	◯
Use of an N95 respirator	◯	◯	◯	◯	◯	◯

Other (please specify)

* 9. How much do you know about Q fever?

◯ Nil ◯ Little ◯ Some ◯ A great deal ◯ Don't know

10. In your opinion how is Q fever likely to be transmitted to humans through the following?

Use the scale to select one response for each transmission method listed.

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Eating undercooked meat	◯	◯	◯	◯	◯	◯
Consumption of unpasteurised dairy products	◯	◯	◯	◯	◯	◯
Inhalation of aerosols or dusts in the environment occupied by animals	◯	◯	◯	◯	◯	◯
Laundering the clothes of a person who has had contact with animals	◯	◯	◯	◯	◯	◯
Sexual intercourse with a person who has had contact with animals	◯	◯	◯	◯	◯	◯
Culling of infected animals	◯	◯	◯	◯	◯	◯

11. In your opinion how effective are the following in preventing the transmission of Q fever from infected animals to humans?

Use the scale to select one response for each item listed.

	Very effective	Effective	Neither effective nor ineffective	Ineffective	Not at all effective	Don't know
Hand gloves	◯	◯	◯	◯	◯	◯
Uniform	◯	◯	◯	◯	◯	◯
Work boots	◯	◯	◯	◯	◯	◯
Face mask	◯	◯	◯	◯	◯	◯
Shower after contact	◯	◯	◯	◯	◯	◯

Other (please specify)

12. To what extent do you agree or disagree that Q fever illness has impacts on the following?

Use the scale to select one response for each level listed.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Don't know
People's health	◯	◯	◯	◯	◯	◯
Family	◯	◯	◯	◯	◯	◯
Business	◯	◯	◯	◯	◯	◯

13. Are you aware that there is a vaccine for Q fever?

◯ Yes ◯ No ◯ Don’t know

14. Have you been vaccinated for Q fever?

- Yes
- No
- Don't know

15. If you have been vaccinated for Q fever, when was it given?

- ◯ 1 year ◯ 2-5 years ◯ > 5 years ◯ Don't know

16. Were you vaccinated because, (Select one)?

- ◯ you perceived that you are at risk of getting Q fever
- ◯ the University perceived that you are at risk of getting Q fever
- ◯ your general practitioner perceived that you are at risk of getting Q fever
- ◯ Other (please specify)

17. To what extent do you agree or disagree that Q fever vaccine is?

Use the scale to select one response for each option.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Don't know
effective in preventing the disease	○	○	○	○	○	○
harmful for the individual who has previously been exposed to Q fever	○	○	○	○	○	○

18. Would you recommend the groups listed below be vaccinated for Q fever?

Use the scale to select one response for each group listed.

	Strongly recommend vaccination	Recommend vaccination	No recommendation either way	Recommend against vaccination	Strongly recommend against vaccination	Don't know
Animal science and veterinary students	○	○	○	○	○	○
Veterinarians	○	○	○	○	○	○
Veterinary nurses	○	○	○	○	○	○
Animal attendants and other animal handlers	○	○	○	○	○	○
Administrative staff working in veterinary practices with no direct animal handling	○	○	○	○	○	○

19. To what extent do you agree or disagree that the following are barriers for being vaccinated for Q fever?

Use the scale to select one response for each barrier listed.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Don't know
Cost of the vaccination	◯	◯	◯	◯	◯	◯
Time associated with completing vaccination (blood and skin test, results interpreted in one week, and vaccination if both tests are negative)	◯	◯	◯	◯	◯	◯
Access to a doctor who is trained to give the Q fever vaccine	◯	◯	◯	◯	◯	◯
People's belief that "Q fever is not a serious illness"	◯	◯	◯	◯	◯	◯
People's belief that "vaccine may have severe side effects"	◯	◯	◯	◯	◯	◯
People's belief that "vaccine does not protect them against Q fever"	◯	◯	◯	◯	◯	◯

20. In your opinion what strategy is likely to be effective in promoting Q fever vaccination among occupational groups that have contact with animals? *Use the scale to select one response for each strategy listed.*

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Radio	○	○	○	○	○	○
Newspaper	○	○	○	○	○	○
Social media	○	○	○	○	○	○
Subsidised vaccination	○	○	○	○	○	○
Mass vaccination at specific events e.g. farmers get vaccinated at farming events such as Royal Adelaide Show	○	○	○	○	○	○
Improving access to doctors who are trained to give Q fever vaccination	○	○	○	○	○	○
Improving general practitioners' knowledge	○	○	○	○	○	○
Improving veterinary practitioners' knowledge	○	○	○	○	○	○
Improving knowledge of the occupational groups who have contact with animals	○	○	○	○	○	○

Other (please specify)

21. Who do you think is responsible for Q fever prevention while studying at University? (Select one)

- The University
- Student
- Health department
- Don't know

Other (please specify)

22. Are there any comments you would like to make about Q fever prevention in South Australia?

Thank you very much for taking the time to complete our survey.
Your contribution to this research is much appreciated.

If you have any queries or further interest in this research, please contact:

Md Rezanur Rahaman
School of Public Health, the University of Adelaide.
Email:

END OF SURVEY

The One Health approach to Q fever prevention and control in South Australia

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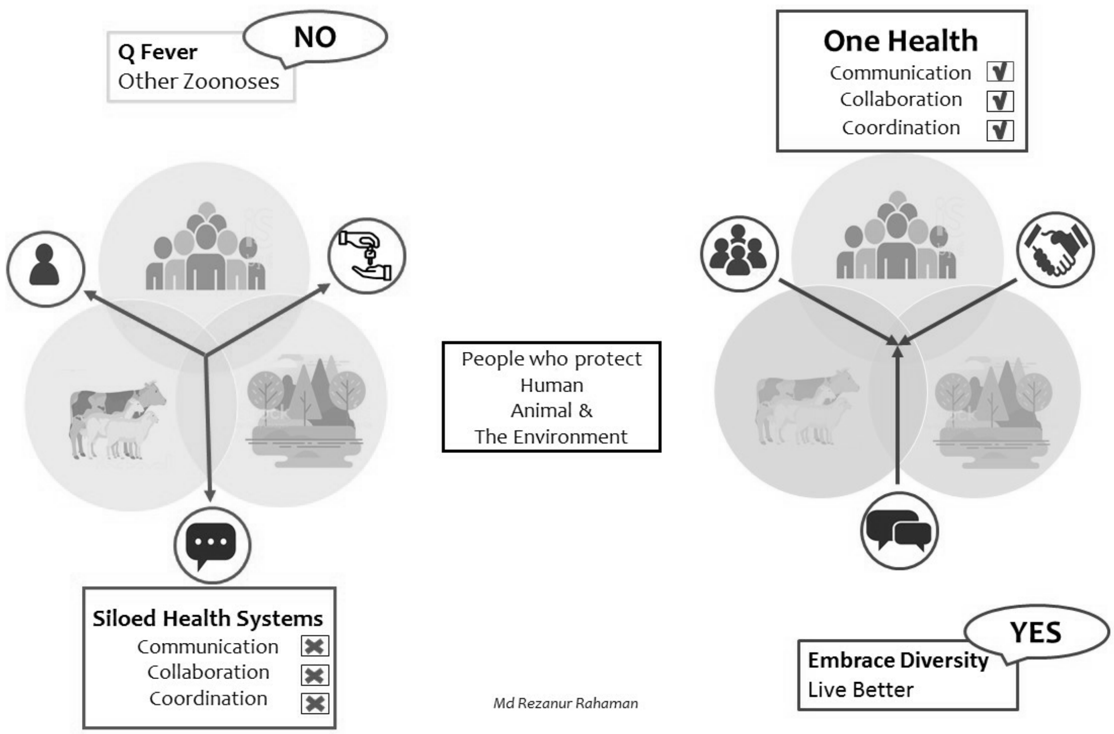

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Who is undertaking the project?
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Why am I being invited to participate?
You are being invited as your occupation places you in contact with animals that are potentially associated with Q fever.

What am I being invited to do?
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Are there any risks associated with participating in this project?
This is an online survey on your knowledge, perspectives and practices related to Q fever and its prevention and control. There are some basic sociodemographic questions as well. All information obtained is anonymous. Therefore, there is no foreseeable risks/discomfort participating in this survey.

What are the potential benefits of the research project?
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Prof Peng Bi (PI)	Md Rezanur Rahaman
Phone: (08) 8313 3583	Email: mdrezanur.rahaman@adelaide.edu.au
Email: peng.bi@adelaide.edu.au	

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Email: hrec@adelaide.edu.au
Post: Level 4, Rundle Mall Plaza, 50 Rundle Mall, ADELAIDE SA 5000

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

Yours sincerely,

Prof Peng Bi	Principal Investigator/supervisor
Prof Helen Marshall	Co-investigator/supervisor
Dr Adriana Milazzo	Co-investigator/supervisor
Md Rezanur Rahaman	Co-investigator/Research student

* 1. Based on the study information presented above, do you consent to participate in this survey?

- ○ Yes, I do
- ○ No, I don't

2. Which of the following describes your age group?

- ○ ≤ 19 years
- ○ 20-39 years
- ○ 40-59 years
- ○ 60-79 years
- ○ ≥ 80 years

3. What is your gender?

- ○ Male
- ○ Female
- ○ Other
- ○ Prefer not to disclose

4. What is your postcode of residence?

5. What is your highest level of education?

- ○ Primary
- ○ Completed secondary
- ○ Certificate / Diploma
- ○ Part secondary
- ○ Trade / Apprenticeship
- ○ Bachelor degree or higher
- ○ Other (please specify)

* 6. What livestock do you have?

Use the scale to select an estimated stock size for each type of livestock that you have.

	1-50	51-100	101-200	201-500	501-1000	>1000
Beef cattle	○	○	○	○	○	○
Dairy cattle	○	○	○	○	○	○
Sheep	○	○	○	○	○	○
Goats	○	○	○	○	○	○
Other	○	○	○	○	○	○

If selected "Other" - please name the type of livestock you have

* 7. How many years in total have you been working with the livestock that you indicated in Q6?

- ○ Less than 1
- ○ 1-10
- ○ 11-20
- ○ >20

8. How frequently do you come into contact with the following animals? (Select all that apply)

Use the scale to select one response for each animal listed.

	Always	Often	Sometimes	Rarely	Never	Don't know
Beef cattle	◯	◯	◯	◯	◯	◯
Dairy cattle	◯	◯	◯	◯	◯	◯
Sheep	◯	◯	◯	◯	◯	◯
Domestic goats	◯	◯	◯	◯	◯	◯
Feral goats	◯	◯	◯	◯	◯	◯
Dogs	◯	◯	◯	◯	◯	◯
Cats	◯	◯	◯	◯	◯	◯
Horses	◯	◯	◯	◯	◯	◯
Pigs	◯	◯	◯	◯	◯	◯
Poultry	◯	◯	◯	◯	◯	◯
Other birds	◯	◯	◯	◯	◯	◯
Pocket pets (guinea pigs, rabbits, ferrets etc.)	◯	◯	◯	◯	◯	◯
Kangaroos	◯	◯	◯	◯	◯	◯
Feral cats	◯	◯	◯	◯	◯	◯
Camels	◯	◯	◯	◯	◯	◯

Other (please specify)

9. How frequently do you engage in the following activities when having contact with animals?

Use the scale to select one response for each activity listed.

	Always	Often	Sometimes	Rarely	Never	Don't know
Wearing work clothes	◯	◯	◯	◯	◯	◯
Wearing work boots	◯	◯	◯	◯	◯	◯
Wearing a face mask	◯	◯	◯	◯	◯	◯
Hand washing after contact	◯	◯	◯	◯	◯	◯
Before contact change into work clothes/boots	◯	◯	◯	◯	◯	◯
After contact change out of work clothes/boots	◯	◯	◯	◯	◯	◯
Having a shower after contact	◯	◯	◯	◯	◯	◯
Use of hand gloves	◯	◯	◯	◯	◯	◯
Use of eye goggles	◯	◯	◯	◯	◯	◯
Use of an N95 respirator	◯	◯	◯	◯	◯	◯

Other (please specify)

* 10. How much do you know about Q fever?

◯ Nil ◯ Little ◯ Some ◯ A great deal ◯ Don't know

11. In your opinion how is Q fever likely to be transmitted to humans through the following?

Use the scale to select one response for each transmission method listed.

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Eating undercooked meat	○	○	○	○	○	○
Consumption of unpasteurised dairy products	○	○	○	○	○	○
Inhalation of aerosols or dusts in the environment occupied by animals	○	○	○	○	○	○
Laundering the clothes of a person who has had contact with animals	○	○	○	○	○	○
Sexual intercourse with a person who has had contact with animals	○	○	○	○	○	○
Culling of infected animals	○	○	○	○	○	○

12. In your opinion how effective are the following in preventing the transmission of Q fever from infected animals to humans?

Use the scale to select one response for each item listed.

	Very effective	Effective	Neither effective nor ineffective	Ineffective	Not at all effective	Don't know
Hand gloves	○	○	○	○	○	○
Work clothes	○	○	○	○	○	○
Work boots	○	○	○	○	○	○
Face mask	○	○	○	○	○	○
Shower after contact	○	○	○	○	○	○

Other (please specify)

13. To what extent do you agree or disagree that Q fever illness has impacts on the following?

Use the scale to select one response for each level listed.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Don't know
People's health	○	○	○	○	○	○
Family	○	○	○	○	○	○
Business	○	○	○	○	○	○

14. Are you aware that there is a vaccine for Q fever?

◯ Yes ◯ No ◯ Don’t know

15. Have you been vaccinated for Q fever?

◯ Yes ◯ No ◯ Don't know

16. If you have been vaccinated for Q fever, when was it given?

- ○ 1 year
- ○ 2-5 years
- ○ > 5 years
- ○ Don't know

17. Were you vaccinated because, (Select one)?

- ○ you perceived that you are at risk of getting Q fever
- ○ your employer perceived that you are at risk of getting Q fever
- ○ your general practitioner perceived that you are at risk of getting Q fever
- ○ Other (please specify)

18. To what extent do you agree or disagree that Q fever vaccine is?

Use the scale to select one response for each option.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Don't know
effective in preventing the disease	◯	◯	◯	◯	◯	◯
harmful for the individual who has previously been exposed to Q fever	◯	◯	◯	◯	◯	◯

19. Would you recommend the groups listed below be vaccinated for Q fever?

Use the scale to select one response for each occupation listed.

	Strongly recommend vaccination	Recommend vaccination	No recommendation either way	Recommend against vaccination	Strongly recommend against vaccination	Don't know
Farmers	◯	◯	◯	◯	◯	◯
Farmers' spouses	◯	◯	◯	◯	◯	◯
Other persons living on farms	◯	◯	◯	◯	◯	◯
Farm hands	◯	◯	◯	◯	◯	◯
Stockyard workers	◯	◯	◯	◯	◯	◯
Shearers	◯	◯	◯	◯	◯	◯
Roustabouts	◯	◯	◯	◯	◯	◯
Veterinarians	◯	◯	◯	◯	◯	◯

20. To what extent do you agree or disagree that the following are barriers for being vaccinated for Q fever?

Use the scale to select one response for each barrier listed.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Don't know
Cost of the vaccination	○	○	○	○	○	○
Time associated with completing vaccination (blood and skin test, results interpreted in one week, and vaccination if both tests are negative)	○	○	○	○	○	○
Access to a doctor who is trained to give the Q fever vaccine	○	○	○	○	○	○
People's belief that "Q fever is not a serious illness"	○	○	○	○	○	○
People's belief that "vaccine may have severe side effects"	○	○	○	○	○	○
People's belief that "vaccine does not protect them against Q fever"	○	○	○	○	○	○

21. In your opinion what strategy is likely to be effective in promoting Q fever vaccination among occupational groups that have contact with animals? *Use the scale to select one response for each strategy listed.*

	Very likely	Likely	Neither likely nor unlikely	Unlikely	Not at all likely	Don't know
Radio	○	○	○	○	○	○
Newspaper	○	○	○	○	○	○
Social media	○	○	○	○	○	○
Subsidised vaccination	○	○	○	○	○	○
Mass vaccination at farming events e.g. South East Field Days, Royal Adelaide Show etc.	○	○	○	○	○	○
Improving access to doctors who are trained to give Q fever vaccination	○	○	○	○	○	○
Improving general practitioners' knowledge	○	○	○	○	○	○
Improving veterinary practitioners' knowledge	○	○	○	○	○	○
Improving knowledge of the occupational groups who have contact with animals	○	○	○	○	○	○

Other (please specify)

22. Who do you think is responsible for Q fever prevention at the workplace? (Select one)

- ◯ Farmer
- ◯ Farm worker
- ◯ Health department
- ◯ Don't know
- ◯ Other (please specify)

23. Are there any comments you would like to make about Q fever prevention in South Australia?

Thank you very much for taking the time to complete our survey.
Your contribution to this research is much appreciated.

If you have any queries or further interest in this research, please contact:

Md Rezanur Rahaman
School of Public Health, the University of Adelaide.
Email: mdrezanur.rahaman@adelaide.edu.au

END OF SURVEY

Appendix B ─ Invitation flyer and email, participant information sheet and consent form

Studies 3–5

- Invitation flyer for animal and veterinary science students
- Invitation flyer for livestock farmers
- Participant information sheet for animal and veterinary science students
- Participant information sheet for livestock farmers
- Consent form for animal and veterinary science students and livestock farmers

Study 6

- Invitation email for stakeholders
- Participant information sheet and consent form for stakeholders ─ Chapter 8 (supplementary materials for peer review in *The Medical Journal of Australia*)

SCHOOL OF PUBLIC HEALTH | THE UNIVERSITY of ADELAIDE

Invitation flyer to complete an online survey for students of Animal Behaviour course, BSc Animal Science and DVM, the University of Adelaide

You are invited to participate in an online survey on the topic of "The One Health approach to Q fever prevention and control in SA".

This study examines the feasibility of adopting a One Health approach to Q fever prevention in South Australia. As Q fever is transmitted from animals to humans, a One Health approach has recently been recognised to be efficient in disease prevention because of its interdisciplinary nature linking human, animal and ecological sectors together. The aim of the survey is to get your opinions and perspectives concerning Q fever prevention and control.

We would like to invite students of Animal Behaviour course, BSc Animal Science and Doctor of Veterinary Medicine (DVM) of the School of Animal and Veterinary Sciences, the University of Adelaide to participate in a survey that may take approximately 15 minutes to complete. The online survey seeks information on your knowledge, views, and practices about Q fever and its prevention.

Participation in this survey is entirely voluntary, and that you may withdraw prior to the submission of your response. In addition, participation, non-participation, or withdrawal will have no impact on your ongoing study or assessment at Adelaide University. Your responses will be anonymous and there is no foreseeable risks of participating in this survey.

[Will be inserted subject to ethics approval]
This research has been approved by ethics and is part of a research project with the School of Public Health in the University of Adelaide.

If you have any concern you may contact the research team members, Professor Peng Bi **8313 3583** or peng.bi@adelaide.edu.au or Md Rezanur Rahaman on mdrezanur.rahaman@adelaide.edu.au

SCHOOL OF PUBLIC HEALTH | THE UNIVERSITY of ADELAIDE

Invitation flyer to complete an online survey for South Australian livestock farmers

You are invited to participate in an online survey on the topic of "The One Health approach to Q fever prevention and control in SA".

This study examines the feasibility of adopting a One Health approach to Q fever prevention in South Australia. As Q fever is transmitted from animals to humans, a One Health approach has recently been recognised to be efficient in disease prevention because of its interdisciplinary nature linking human, animal and ecological sectors together. The aim of the survey is to get your opinions and perspectives concerning Q fever prevention and control.

We would like to invite South Australian livestock farmers to participate in a survey that may take approximately 15 minutes to complete. The online survey seeks information on your understanding, views, and practices about Q fever and its prevention.

Participation in this survey is entirely voluntary, and that you may withdraw prior to the submission of your response. Your responses will be anonymous and there is no foreseeable risks of participating in this survey.

[Will be inserted subject to ethics approval]
This research has been approved by ethics and is part of a research project with the School of Public Health in the University of Adelaide.

If you have any concern you may contact the research team members, Professor Peng Bi **8313 3583** or peng.bi@adelaide.edu.au or Md Rezanur Rahaman on mdrezanur.rahaman@adelaide.edu.au

Participant Information Sheet for Veterinary and Animal Sciences Students, UoA
Project title: The One Health approach to Q fever prevention and control in South Australia
Human Research Ethics Committee approval number: H-2018-
Principal investigator: Prof Peng Bi
Student researcher: Md Rezanur Rahaman
Student's degree: PhD

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?
This research project is about Q fever which is an infection transmitted from animals to humans and despite the availability of a vaccine for humans, incidence in Australia remains high amongst certain occupational groups. More recently, a One Health approach for the prevention and control of zoonotic diseases (diseases transmitted from animals to humans) has been recognised as an important approach because of its interdisciplinary nature linking human, animal and ecological sectors together. In this study, we are investigating how feasible it is to adopt a One Health approach to Q fever prevention and control in South Australia (SA).
Overall aims:
Examine Q fever control and prevention approaches in SA and explore the enablers and barriers of adopting a One Health approach in order to provide policy recommendations and guidelines.
Research question pertains to this survey:
What is the level of knowledge, attitude and preventive practices of Q fever among South Australian veterinary and animal sciences students?

Who is undertaking the project?
This project is being conducted by **Prof Peng Bi** (School of Public Health), **Prof Helen Marshall** (School of Medicine), **Dr Adriana Milazzo** (School of Public Health) and **Md Rezanur Rahaman** (School of Public Health) of the University of Adelaide. The researchers are quite separate to participating students' program supervisors and teachers. This research will form the basis for Rezanur Rahaman's Master of Philosophy in Public Health degree at the University of Adelaide under the supervision of Prof Peng Bi, Prof Helen Marshall and Dr Adriana Milazzo.

Why am I being invited to participate?
You are being invited as your line of study places you in contact with animals that are potentially associated with Q fever.

What am I being invited to do?
You are invited to complete an online survey about your understanding of Q fever, and your perspectives and practices concerning Q fever prevention and control. The survey may take approximately 15 minutes to complete.

How much time will my involvement in the project take?
The survey may take approximately 15 minutes to complete.

Are there any risks associated with participating in this project?
This is an online survey on your knowledge, perspectives and practices related to Q fever and its prevention and control. There are some basic sociodemographic questions as well. All information obtained is anonymous. Therefore, there is no foreseeable risks/discomfort in participating this survey. In addition, participation, non-participation or withdrawal will not impact your study and this survey is not a test of your knowledge about the subject.

What are the potential benefits of the research project?

Determining the levels of Q fever knowledge among at-risk population groups may help identify the target populations' needs, whereby the level of their practice may help define gaps in disease control and prevention approaches, which can potentially be addressed through a One Health approach. The results may help formulate industry level policies and guidelines and provide valid evidence for incorporating specific curriculum updates for veterinary and animal science students. However, participating in this research will not have any direct/immediate benefit.

Can I withdraw from the project?
Participation in this project is completely voluntary. If you agree to participate, you can withdraw any time up until submission of the survey. If you decide to withdraw this will not affect your study at the University, now or in the future.

What will happen to my information?
The findings from the survey will be published in peer reviewed journals and made accessible to the wider, public health research community as well as the general population. The results will also be presented in conferences and finally incorporated into the thesis, required to submit to the University for the Research Candidature.

As only non-identifiable responses will be sought and analysed, privacy and confidentiality will not be compromised.

Security of data storage: Data in electronic format/hard copy will be stored in the research student's (Md Rezanur Rahaman) computer which is password protected and in locked filing cabinet in the office area for authorized school staff only.

Location of stored data: All data will be stored in a locked filing cabinet in the staff office area at level 9, AHMS building, North Terrace. The only person with access to the locked filing cabinet will be the research student.

Format of stored data: Electronic and hard copies.

The records and materials will be retained by the university for five (5) years after publications of the results. The data will not be used in future research nor shared in an online repository such as Figshare.

Your information will only be used as described in this participant information sheet and it will only be disclosed according to the consent provided, except as required by law.

Who do I contact if I have questions about the project?
The person you may need to contact will depend on what you want to know. If you want any further information concerning this project or if you have any problems about you and this research, you can contact:

Prof Peng Bi (PI)	Md Rezanur Rahaman
Phone: (08) 8313 3583	
peng.bi@adelaide.edu.au	mdrezanur.rahaman@adelaide.edu.au

If you have any complaints about any aspect of the project, how it is going, or any questions about taking part in research in general, then you may contact as below

What if I have a complaint or any concerns?
The study has been approved by the Human Research Ethics Committee at the University of Adelaide (approval number H-2018-). This research project will be conducted according to the NHMRC National Statement on Ethical Conduct in Human Research 2007 (updated 2018). If you have questions or problems associated with the practical aspects of your participation in the project, or wish to raise a concern or complaint about the project, then you should consult the Principal Investigator (PI). If you wish to speak with an independent person regarding concerns or a complaint, the University's policy on research involving human participants, or your rights as a participant, please contact the Human Research Ethics Committee's Secretariat on:

Phone: +61 8 8313 6028

Email: hrec@adelaide.edu.au

Post: Level 4, Rundle Mall Plaza, 50 Rundle Mall, ADELAIDE SA 5000

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

If I want to participate, what do I do?
Follow the survey link, complete and submit. Please remember to read carefully the survey preamble which covers the content of a participant information sheet and outline that completion and submission of the survey indicates consent to being involved in the research project.

Yours sincerely,

Prof Peng Bi	Principal Investigator/supervisor
Prof Helen Marshall	Co-investigator/supervisor
Dr Adriana Milazzo	Co-investigator/supervisor
Md Rezanur Rahaman	Co-investigator/Research student

Participant Information Sheet for South Australian Livestock Farmers
Project title: The One Health approach to Q fever prevention and control in South Australia
Human Research Ethics Committee approval number: H-2018-
Principal investigator: Prof Peng Bi
Student researcher: Md Rezanur Rahaman
Student's degree: PhD

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?
This research project is about Q fever which is an infection transmitted from animals to humans and despite the availability of a vaccine for humans, incidence in Australia remains high amongst certain occupational groups. More recently, a One Health approach for the prevention and control of zoonotic diseases (diseases transmitted from animals to humans) has been recognised as an important approach because of its interdisciplinary nature linking human, animal and ecological sectors together. In this study, we are investigating how feasible it is to adopt a One Health approach to Q fever prevention and control in South Australia (SA).
Overall aims:
Examine Q fever control and prevention approaches in SA and explore the enablers and barriers of adopting a One Health approach in order to provide policy recommendations and guidelines.
Research question pertains to this survey:
What is the level of knowledge, attitude and preventive practices of Q fever among South Australian livestock farmers?

Who is undertaking the project?
This project is being conducted by **Prof Peng Bi** (School of Public Health), **Prof Helen Marshall** (School of Medicine), **Dr Adriana Milazzo** (School of Public Health) and **Md Rezanur Rahaman** (School of Public Health) of the University of Adelaide. This research will form the basis for Rezanur Rahaman's Master of Philosophy in Public Health degree at the University of Adelaide under the supervision of Prof Peng Bi, Prof Helen Marshall and Dr Adriana Milazzo.

Why am I being invited to participate?
You are being invited as your occupation places you in contact with animals that are potentially associated with Q fever.

What am I being invited to do?
You are invited to complete an online survey about your understanding of Q fever, and your perspectives and practices concerning Q fever prevention and control. The survey may take approximately 25 minutes to complete.

How much time will my involvement in the project take?
The survey may take approximately 25 minutes to complete.

Are there any risks associated with participating in this project?
This is an online survey on your knowledge, perspectives and practices related to Q fever and its prevention and control. There are some basic sociodemographic questions as well. All information obtained is anonymous. Therefore, there is no foreseeable risks/discomfort in participating this survey.

What are the potential benefits of the research project?

Determining the levels of Q fever knowledge among at-risk population groups may help identify the target populations' needs, whereby the level of their practice may help define gaps in disease control and prevention approaches, which can potentially be addressed through a One Health approach. The results may help formulate industry level policies and guidelines concerning Q fever prevention. However, participating in this research will not have any direct/immediate benefit.

Can I withdraw from the project?
Participation in this project is completely voluntary. If you agree to participate, you can withdraw any time up until submission of the survey.

What will happen to my information?
The findings from the survey will be published in peer reviewed journals and made accessible to the wider, public health research community as well as the general population. The results will also be presented in conferences and finally incorporated into the thesis, required to submit to the University for the Research Candidature.

As only non-identifiable responses will be sought and analysed, privacy and confidentiality will not be compromised.

Security of data storage: Data in electronic format/hard copy will be stored in the research student's (Md Rezanur Rahaman) computer which is password protected and in locked filing cabinet in the office area for authorized school staff only.

Location of stored data: All data will be stored in a locked filing cabinet in the staff office area at level 9, AHMS building, North Terrace. The only person with access to the locked filing cabinet will be the research student.

Format of stored data: Electronic and hard copies.

The records and materials will be retained by the university for five (5) years after publications of the results. The data will not be used in future research nor shared in an online repository such as Figshare.

Your information will only be used as described in this participant information sheet and it will only be disclosed according to the consent provided, except as required by law.

Who do I contact if I have questions about the project?
The person you may need to contact will depend on what you want to know. If you want any further information concerning this project or if you have any problems about you and this research, you can contact:

Prof Peng Bi (PI)	Md Rezanur Rahaman
Phone: (08) 8313 3583	
peng.bi@adelaide.edu.au	mdrezanur.rahaman@adelaide.edu.au

If you have any complaints about any aspect of the project, how it is going, or any questions about taking part in research in general, then you may contact as below

What if I have a complaint or any concerns?
The study has been approved by the Human Research Ethics Committee at the University of Adelaide (approval number H-2018-). This research project will be conducted according to the NHMRC National Statement on Ethical Conduct in Human Research 2007 (updated 2018). If you have questions or problems associated with the practical aspects of your participation in the project, or wish to raise a concern or complaint about the project, then you should consult the Principal Investigator (PI). If you wish to speak with an independent person regarding concerns or a complaint, the University's policy on research involving human participants, or your rights as a participant, please contact the Human Research Ethics Committee's Secretariat on:

Phone: +61 8 8313 6028
Email: hrec@adelaide.edu.au
Post: Level 4, Rundle Mall Plaza, 50 Rundle Mall, ADELAIDE SA 5000

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

If I want to participate, what do I do?
Follow the survey link, complete and submit. Please remember to read carefully the survey preamble which covers the content of a participant information sheet and outline that completion and submission of the survey indicates consent to being involved in the research project.

Yours sincerely,

Prof Peng Bi — Principal Investigator/supervisor
Prof Helen Marshall — Co-investigator/supervisor
Dr Adriana Milazzo — Co-investigator/supervisor
Md Rezanur Rahaman — Co-investigator/Research student

Human Research Ethics Committee (HREC)

CONSENT FORM

1. I have read the attached Information Sheet and agree to take part in the following research project:

Title:	The One Health approach to Q fever prevention and control in South Australia
Ethics Approval Number:	

2. I have had the project, so far as it affects me, and the potential risks and burdens fully explained to my satisfaction by the research worker. I have had the opportunity to ask any questions I may have about the project and my participation. My consent is given freely.

3. Although I understand the purpose of the research project is to improve the quality of health / medical care, it has also been explained that my involvement may not be of any benefit to me.

4. I agree to participate in the activities as outlined in the participant information sheet.

5. I understand that as my participation is anonymous, I can withdraw any time up until submission of the survey. I am aware that if I decide to withdraw this will not affect (my study at the University) / (medical advice in the management of my health), now or in the future.

6. I have been informed that the information gained in the project may be published in a book/journal article/thesis/conference presentations etc.

7. I have been informed that in the published materials I will not be identified and my personal results will not be divulged.

8. My information will only be used for the purpose of this research project and it will only be disclosed according to the consent provided, except where disclosure is required by law.

SCHOOL OF PUBLIC HEALTH | THE UNIVERSITY of ADELAIDE

The One Health approach to Q fever prevention and control in South Australia

YOU ARE INVITED TO PARTICIPATE IN AN INTERVIEW ON THE TOPIC OF A ONE HEALTH APPROACH TO Q FEVER PREVENTION AND CONTROL IN SOUTH AUSTRALIA (SA).

Dear [insert name of the invitee],

My name is Md Rezanur Rahaman, and I am conducting research on "A One Health approach to Q fever prevention and control in SA". I am a PhD student in the School of Public Health, the University of Adelaide, and am supervised by Prof Peng Bi (School of Public Health), Prof Helen Marshall (School of Medicine) and Dr Adriana Milazzo (School of Public Health) of the University of Adelaide.

Q fever is a zoonotic disease transmitted from animals to humans, and is a significant public health problem in Australia. A One Health approach that engages collaboration among human, animal and environmental sectors may be an appropriate framework for Q fever prevention and control because of its coordinated approach. It is now possible to combine human and animal surveillance systems together, which is proposed to be integral to a One Health approach. You may know that a surveillance system tracks the occurrence of a disease in human and animal populations, and there are already human surveillance and animal surveillance systems in place for Q fever. Although in SA there is only human surveillance practiced for Q fever.

The aim of this study is to assess the feasibility of adopting a One Health approach to Q fever prevention and control in SA.

We are inviting stakeholders from different organisations and disciplines who work in the human, animal and environmental domains that are related to the occurrence of Q fever to participate in an interview. The purpose of the interview is to discuss the specific issues related to knowledge, attitudes and perceptions about Q fever; human-animal integrated Q fever surveillance; Q fever vaccination; and a One Health approach to Q fever control and prevention. We believe that your expertise/professional experience will provide useful information.

The interviews are expected to be carried out in July-October 2020 and they will be at a time that suits you best and can be completed in person, by phone or via zoom. No compensation for participation in the interviews is available.

This research has been approved by the Human Research Ethics Committee, SA Department for Health and Wellbeing (Approval number: HREC/20/SAH/8) having CDCB site-specific assessment – project authorisation number: SSA/20/SAH/63.

Please find the participant information sheet and consent form attached for your convenience. If you are interested in participating in an interview, please contact:

Professor Peng Bi 8313 3583 or peng.bi@adelaide.edu.au or
Md Rezanur Rahaman mdrezanur.rahaman@adelaide.edu.au
to discuss any further information including the time and location of the interview.

Kind regards,
Md Rezanur Rahaman

Appendix C ─ Ethics approval

Study 2

- HREC SA Health ethics approval letter
- SA Health project authorization letter
- CDCB data custodian support letter
- HREC SA Health annual review report approval letter
- HREC SA Health publication approval letter

Studies 3–5

- HREC UoA ethics approval letter

Study 6

- HREC SA Health ethics approval letter
- SA Health project authorization letter
- HREC SA Health ethics application request for further information
- HREC SA Health ethics application request for further information
- HREC SA Health ethics project amendment application rejection letter

Collaborative project ─ climatic determinants of childhood diarrhoea in Bangladesh

- HREC UoA ethics exemption letter

Government of South Australia
SA Health

SA Department for Health and Wellbeing
Human Research Ethics Committee

Citi Centre Building
Level 5, 11 Hindmarsh Square
Adelaide SA 5000

PO Box 287, Rundle Mall
Adelaide SA 5000
DX 243

Tel 08 8226 7702

21 June 2018

Prof Peng Bi
School of Public Health
Level 9
Adelaide Health and Medical Sciences Building
The University of Adelaide

Dear Prof Bi

HREC reference number: HREC/18/SAH/47
Project title: *The One Health approach to Q fever prevention and control in South Australia*

RE: HREC/18/SAH/47 - Ethics Application Approval

Thank you for submitting the above project for ethical and scientific review. This project was considered by the SA Department for Health and Wellbeing Human Research Ethics Committee (HREC) on 14 June 2018

I am pleased to advise that your submission has been granted full ethics approval and meets the requirements of the NHMRC *National Statement on Ethical Conduct in Human Research* and the *Australian Code for the Responsible Conduct of Research*. The documents reviewed and approved include:

Document	*Version*	*Date*
Covering Letter	-	13 April 2018
LNR Assessment Checklist	-	-
Application: HREA (signed)	173785	13 April 2018
Protocol	2.0	13 April 2018
Data Custodian Support: Dr Louise Flood, Acting Director, Communicable Disease Control Branch, SA Department for Health and Wellbeing	-	13 April 2018
University of Adelaide: Student Recommendation	-	*undated*

Period of Approval: 21 June 2018 to 21 June 2021

Sites covered by this approval:
- SA Department for Health and Wellbeing

Please note the following conditions of approval:
- The research must be conducted in accordance with the NHMRC *National Statement on Ethical Conduct in Human Research.*
- Confidentiality of the research subjects shall be maintained at all times as required by law.
- A progress report, at least annually, must be provided to the HREC.
- A report and a copy of any published material should be forwarded to the HREC at the completion of the project.
- Researchers are required to immediately report to the HREC anything which might warrant review of ethical approval of the protocol, including:
  a. protocol deviations;
  b. proposed changes to the investigators;
  c. proposed changes to the study protocol;
  d. proposed changes to any approved study documentation;
  e. new study documentation; and
  f. unforeseen events that might affect continued ethical acceptability of the project

- Any proposed changes to the original proposal must be submitted to and approved by the HREC before they are implemented.
- If the project is discontinued before its completion, the HREC must be advised immediately and provided with reasons for discontinuing the project.

Site Specific Assessment (SSA)/Governance Approval:
This letter constitutes ethical approval only.
You are reminded that in accordance with the SA Health Research Governance Policy, **you must_not commence this research project with a SA Health site until separate governance approval from that site has been obtained** via the completion of a Site Specific Assessment (SSA) form.
For assistance with the SSA process, please contact relevant site Research Governance Officer(s) pertaining to the study sites listed above.

University Personnel:
If university personnel are involved in this project, the relevant university should be notified before commencing their research to ensure compliance with university requirements including any insurance and indemnification requirements.

Should you have any queries about the HREC's consideration of your project please contact the Executive Officer of the HREC, on phone (08) 82267702 or email Health.HumanResearchEthicsCommittee@sa.gov.au

The HREC wishes you every success in your research.

Yours sincerely

Professor Annette Braunack-Mayer
Chair, Human Research Ethics Committee
SA Department for Health and Wellbeing
ABM:mk

cc David van der Hoek, Research Governance Officer, SA Department for Health and Wellbeing

Government of South Australia
SA Health

Office for Research
Level 5, Citi-Centre Building
11 Hindmarsh Square
ADELAIDE SA 5000
Telephone: (08) 8226 7461

Prof Peng Bi
School of Public Health
The University of Adelaide
Level 9, AHMS Building
North Terrace
ADELAIDE SA 5005

Dear Prof Bi

RE: SITE SPECIFIC ASSESSMENT – PROJECT AUTHORISATION

Project title:	The One Health approach to Q fever prevention and control in South Australia
SSA reference:	SSA/18/SAH/71
Site Name:	Department for Health and Wellbeing

Thank you for submitting the Site Specific Assessment form and associated documentation for the above named project.

Following a review of the submission, and noting the protocol was ethically approved by the SA Department for Health and Wellbeing HREC, I am pleased to advise your project has received research governance approval.

Period of approval: 09/08/18 to 21/06/21*
** This coincides with current DHW HREC approval expiry.*

Aside from the documentation approved by the HREC, this approval specifically encompasses the following:

- Data Access Request form, SSA/18/SAH/71
- C.V., Prof. P. Bi (undated)
- C.V., Dr. H. Marshall, dated 20 June 2018
- C.V., A. Milazzo, dated June 2018
- C.V., Dr. R. Rahaman (undated)
- HREC approval letter, DHW HREC (HREC/18/SAH/47), dated 21 June 2018
- Study protocol, version 2.0, dated 13 April 2018
- Certificate of currency (Public, Products, NFC and Liability for Clinical Trials), The University of Adelaide, valid until 31 December 2018.

Please note the following conditions of authorisation:

- Authorisation is limited to the named site and specific activities described in the application provided. Any changes to the project that affect the site should be submitted as a research governance amendment, separate to the requirements of the reviewing HREC.
- Any requirements of the data custodian/s, including signing of a Deed of Confidentiality for use of the data provided, must be followed. A copy of the signed Deed of Confidentiality should be provided to the Research Governance Officer as soon as possible.
- You should advise the Research Governance Officer of any changes to the status of the project within a timely manner, including discontinuation of the study at the site, or changes to the scope of the project including the participants, research staff, data required, site resources or other research governance matters affecting the conduct of the study at the site.
- If undertaking the project as a staff member of a university, you should notify your institution's Insurance Office prior to commencing this study.
- Any updated certificates of insurance associated with the SSA should be sent to the Research Governance Officer upon expiry of the current certificates.
- The study must be conducted in accordance with the conditions of ethical approval provided by the lead HREC, and in conjunction with the standards outlined in the *National Statement on Ethical Conduct in Human Research* (2007, incorporating all updates as at May 2015) and the *Australian Code for the Responsible Conduct of Research* (2018).
- You are required to provide annual progress reports and/or a final report for the project. A copy of the reporting template may be requested from the Research Governance Officer.
- **Your first report will be due on 09/08/19 (or when the project is completed, if earlier than this date).**

All correspondence to the Research Governance Officer should be submitted electronically to HealthResearchGovernance@sa.gov.au.

Should you have any queries regarding these requirements, please contact me on (08) 8226 7461 or by email.

Yours sincerely

David Van der Hoek
RESEARCH GOVERNANCE OFFICER
SA DEPARTMENT FOR HEALTH AND WELLBEING

09/08/18

Government of South Australia
SA Health

Doc No: A762036

Communicable Disease Control Branch
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Professor Peng Bi
School of Public Health
The University of Adelaide
ADELAIDE SA 5000

Dear Professor Bi,

RE: RESEARCH AND DATA GOVERNANCE

As data custodian of the SA Health Notifiable Diseases Surveillance System database, I am happy to provide in principle support for the Q Fever project study.

Final approval will be considered after approval by the appropriate ethics committee.

Yours sincerely

Dr Louise Flood
A/Director
COMMUNICABLE DISEASE CONTROL BRANCH

13 / 04 / 2018

Government of South Australia
Health
Department for Health and Wellbeing

SA Department for Health and Wellbeing
Human Research Ethics Committee

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Level 5, 11 Hindmarsh Square
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PO Box 287, Rundle Mall
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15 April 2020

Professor Peng Bi
School of Public Health,
Level 9 AHMS Building,
The University of Adelaide,
Adelaide SA 5000

HREC study number: *HREC/18/SAH/47*
Report reference number: *HREC/18/SAH47/AR01*
Project title: *The One Health approach to Q fever prevention and Control in South Australia*

Dear Prof Bi

Re: HREC/18/SAH47/AR01 – Annual Study Report - Approval

The SA Department for Health and Wellbeing (DHW) Human Research Ethics Committee (HREC) Chair has considered documentation submitted in relation to your research study, and I am pleased to advise the following documents have been reviewed and approved:

Document	*Version*	*Date*
Annual Review Report	-	30 January 2020

Please note for future reports that the *total number of records accessed, number of study-related adverse events, number of protocol deviations* and *the current study protocol version* cannot be answered as 'n/a'. The responses should be 'zero' unless there is something to report.

Ethics Expiry Date: **21 June 2021**
Next Annual Progress Report Due: 21 June 2020

Site(s) covered by this Ethics Approval:

- SA Department for Health and Wellbeing

***Please note the terms under which Ethical approval is extended:**

- It is noted that the SA Aboriginal Health Research Ethics Committee (AHREC) has not reviewed this study as the researchers have indicated analysis on indigeneity will not occur for this study. Should this change, the DHW HREC must be notified prior to this occurring, and the AHREC must be contacted to discuss ethical review requirements.
- The research must be conducted in accordance with the NHMRC *National Statement on Ethical Conduct in Human Research.*
- Confidentiality of the research subjects shall be maintained at all times as required by law.
- A progress report, at least annually, must be provided to the HREC.
- Researchers are required to immediately report to the HREC anything which might warrant review of ethical approval of the protocol, including:
    a. serious or unexpected adverse events;
    b. formal complaints from participants;
    c. protocol deviations or violations;
    d. proposed changes to the protocol or study documentation before they are implemented;
    e. proposed changes to the study investigators;

f. new study documentation; and
g. unforeseen events that might affect continued ethical acceptability of the project.

- Any proposed changes to the original proposal must be submitted to and approved by the HREC before they are implemented.
- If the project is discontinued before its completion, the HREC must be advised immediately and provided with reasons for discontinuing the project.
- A report and a copy of any published material should be forwarded to the HREC at the completion of the project.
- Study data is to be retained in accordance with the State Records Act 1997

Site Specific/Governance Approval:
A copy of the annual report and this letter should be provided to all relevant site Research Governance Officers for the institutions of which are covered by this HREC approval (listed above).

Should you have any queries about the HREC's consideration of your project please contact Pip Stanford-Bluntish HREC Executive Officer on phone 08 8226 8102 or email HealthHumanResearchEthicsCommittee@sa.gov.au

Yours sincerely

Prof Annette Braunack-Mayer
Chair, Human Research Ethics Committee
SA Department for Health and Wellbeing
ABM:RW

cc Research Governance Officer, SA Department for Health and Wellbeing (DHW)

Government of South Australia | Health | Department for Health and Wellbeing

SA Department for Health and Wellbeing
Human Research Ethics Committee

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Tel 08 8226 8102
health.humanresearchethicscommittee@sa.gov.au

31 July 2020

Professor Peng Bi
School of Public Health
The University of Adelaide
Adelaide SA 5001

HREC study number: *HREC/18/SAH/47*
Report reference number: *HREC/18/SAH/47/AR02*
Project title: *The One Health approach to Q fever prevention and control in South Australia*

Dear Prof Bi

Re: HREC/18/SAH/47/AR02 – Annual Study Report - Approval

The SA Department for Health and Wellbeing (DHW) Human Research Ethics Committee (HREC) Chair has considered documentation submitted in relation to your research study, and I am pleased to advise the following documents have been reviewed and approved:

Document	*Version*	*Date*
Annual Review Report	-	24 July 2020
Publication: Rahaman. R [et al], "Spatial, temporal, and occupational risks of Q fever infection in South Australia, 2007-2017, Journal of Infection and Public Health, Vol. 13, Pg. 544-551	-	03 October 2019

Please note for future reports that the *total number of records accessed, number of study-related adverse events, number of protocol deviations* and *the current study protocol version* cannot be answered as 'n/a'. The responses should be 'zero' unless there is something to report.

Ethics Expiry Date: **21 June 2021**
Next Annual Progress Report Due: 21 June 2021

Site(s) covered by this Ethics Approval:

- SA Department for Health and Wellbeing (DHW)

***Please note the terms under which Ethical approval is extended:**

- It is noted that the SA Aboriginal Health Research Ethics Committee (AHREC) has not reviewed this study as the researchers have indicated analysis on indigeneity will not occur for this study. Should this change, the DHW HREC must be notified prior to this occurring, and the AHREC must be contacted to discuss ethical review requirements.
- The research must be conducted in accordance with the NHMRC *National Statement on Ethical Conduct in Human Research.*
- Confidentiality of the research subjects shall be maintained at all times as required by law.
- A progress report, at least annually, must be provided to the HREC.
- Researchers are required to immediately report to the HREC anything which might warrant review of ethical approval of the protocol, including:
  a. serious or unexpected adverse events;
  b. formal complaints from participants;

c. protocol deviations or violations;
d. proposed changes to the protocol or study documentation before they are implemented;
e. proposed changes to the study investigators;
f. new study documentation; and
g. unforeseen events that might affect continued ethical acceptability of the project.

- Any proposed changes to the original proposal must be submitted to and approved by the HREC before they are implemented.
- If the project is discontinued before its completion, the HREC must be advised immediately and provided with reasons for discontinuing the project.
- A report and a copy of any published material should be forwarded to the HREC at the completion of the project.
- Study data is to be retained in accordance with the State Records Act 1997.

Site Specific/Governance Approval:
A copy of the annual report and this letter should be provided to all relevant site Research Governance Officers for the institutions of which are covered by this HREC approval (listed above).

Should you have any queries about the HREC's consideration of your project please contact Pip Stanford-Bluntish HREC Executive Officer on phone 08 8226 8102 or email HealthHumanResearchEthicsCommittee@sa.gov.au

Yours sincerely

Prof Annette Braunack-Mayer
Chair, Human Research Ethics Committee
SA Department for Health and Wellbeing
ABM:RW

cc Research Governance Officer, SA Department for Health and Wellbeing (DHW)

THE UNIVERSITY of ADELAIDE

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CRICOS Provider Number 00123M

Our reference 33428

13 March 2019

Professor Peng Bi
Public Health

Dear Professor Bi

ETHICS APPROVAL No: H-2019-040
PROJECT TITLE: The One Health approach to Q fever prevention and control in South Australia

The ethics application for the above project has been reviewed by the Low Risk Human Research Ethics Review Group (Faculty of Health and Medical Sciences) and is deemed to meet the requirements of the *National Statement on Ethical Conduct in Human Research (2007)* involving no more than low risk for research participants.

You are authorised to commence your research on: 13/03/2019
The ethics expiry date for this project is: 31/03/2022

NAMED INVESTIGATORS:

Chief Investigator:	Professor Peng Bi
Student - Postgraduate Masters by Research:	Mr Md. Rezanur Rahaman
Associate Investigator:	Professor Helen Marshall
Associate Investigator:	Dr Adriana Milazzo

CONDITIONS OF APPROVAL: Thank you for your considered responses to the matters raised. The revised application provided on 05/03/19 has been approved. It is noted that the approval granted is specifically provided for Phase Two of the project, involving the use of an online survey.

Ethics approval is granted for three years and is subject to satisfactory annual reporting. The form titled Annual Report on Project Status is to be used when reporting annual progress and project completion and can be downloaded at http://www.adelaide.edu.au/research-services/oreci/human/reporting/. Prior to expiry, ethics approval may be extended for a further period.

Participants in the study are to be given a copy of the information sheet and the signed consent form to retain. It is also a condition of approval that you immediately report anything which might warrant review of ethical approval including:

- serious or unexpected adverse effects on participants,
- previously unforeseen events which might affect continued ethical acceptability of the project,
- proposed changes to the protocol or project investigators; and
- the project is discontinued before the expected date of completion.

Yours sincerely,

Ms Alison Harwood
Secretary

The University of Adelaide

SA Department for Health and Wellbeing
Human Research Ethics Committee

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REVISED 18 JUNE 2020
18 June 2020

Prof Peng Bi
School of Public Health
Level 9 AHMS Building
THe University of Adelaide
Adelaide SA 5005

HREC study number: *HREC/20/SAH/8*
Project title: *The One Health approach to Q fever prevention and control in South Australia (SA)*

Dear Prof Bi

RE: HREC/20/SAH/8 - ETHICS APPLICATION APPROVAL

Thank you for submitting the above project for ethical and scientific review. This project was first considered by the SA Department for Health and Wellbeing Human Research Ethics Committee (HREC) on 13 February 2020.

The Chair of the HREC then reviewed additional information for the above project for ethical and scientific review on 21 March, 08 May, 11 June and 16 June. The final revision by the HREC chair was on 17 June 2020.

I am pleased to advise that your submission has now been granted full ethics approval and meets the requirements of the NHMRC *National Statement on Ethical Conduct in Human Research* and the *Australian Code for the Responsible Conduct of Research*.

The documents reviewed and approved include:

Document	*Version*	*Date*
Application: HREA	AU/1/3A2B312	26 January 2020
Protocol	v13.0	17 June 2020
Covering Letter	-	25 January 2020
Peer Review Submission: University of Adelaide School of Public Health Internal Review Panel's Approval	-	11 April 2018
Investigator CV: Prof Peng Bi	no version	undated
Letter of invitation to participant: Recruitment email	v5	28 April 2020
Interview Schedules / Topic Guides: Semi-structured Interview Questions	v5	11 October 2019
Participant Information/Consent Form	v10.0	17 June 2020
Response to Request for Further Information	-	11 March 2020
Response to Request for Further Information	-	17 June 2020

Ethics Period of Approval: 18 June 2020 to 18 June 2023

Site(s) covered by this Ethics Approval:

- SA Department for Health and Wellbeing (DHW) - [CDCB]
- SA Pathology (CALHN)

Terms under which Ethical approval is granted:

- It is noted that the SA Aboriginal Health Research Ethics Committee (AHREC) has not reviewed this study as the researchers have indicated analysis on indigeneity will not occur for this study. Should this change, the DHW HREC must be notified prior to this occurring, and the AHREC must be contacted to discuss ethical review requirements.
- The research must be conducted in accordance with the NHMRC *National Statement on Ethical Conduct in Human Research.*
- Confidentiality of the research subjects shall be maintained at all times as required by law.
- A progress report, at least annually, must be provided to the HREC.
- Researchers are required to immediately report to the HREC anything which might warrant review of ethical approval of the protocol, including:
    a. serious or unexpected adverse events;
    b. formal complaints from participants;
    c. protocol deviations or violations;
    d. proposed changes to the protocol or study documentation before they are implemented;
    e. proposed changes to the study investigators;
    f. new study documentation; and
    g. unforeseen events that might affect continued ethical acceptability of the project.
- Any proposed changes to the original proposal must be submitted to and approved by the HREC before they are implemented.
- If the project is discontinued before its completion, the HREC must be advised immediately and provided with reasons for discontinuing the project.
- A report and a copy of any published material should be forwarded to the HREC at the completion of the project.
- Study data is to be retained in accordance with the State Records Act 1997.

Site Specific Assessment (SSA) / Governance Approval:

This letter constitutes ethical approval only.

You are reminded that in accordance with the SA Health Research Governance Policy, you must not commence this research project at, or in conjunction with, any SA Health site until separate governance approval from that site has been obtained via the completion of a Site Specific Assessment (SSA) form.

For assistance with the SSA process, please contact relevant site Research Governance Officer(s) pertaining to the study sites listed above.

University Personnel:

If university personnel are involved in this project, the relevant university should be notified before commencing their research to ensure compliance with university requirements including any insurance and indemnification requirements.

Further Information:

The DHW HREC is constituted in accordance with the NHMRC's *National Statement on the Ethical Conduct of Human Research* (2007).

Should you have any queries about the HREC's consideration of your project please contact Pip Stanford-Bluntish, HREC Executive Officer on phone 08 82268102 or email HealthHumanResearchEthicsCommittee@sa.gov.au

The HREC wishes you every success in your research.

Yours sincerely

Prof Annette Braunack-Mayer
Chair, Human Research Ethics Committee
SA Department for Health and Wellbeing
ABM:PSB

cc Research Governance Officer, SA Department for Health and Wellbeing (DHW)

Government of South Australia
Health
Department for Health and Wellbeing

Office for Research
Level 5, Citi-Centre Building
11 Hindmarsh Square
ADELAIDE SA 5000
Telephone: (08) 8226 4235

Professor Peng Bi
School of Public Health
Level 9, AHMS Building
The University of Adelaide
ADELAIDE SA 5005

Dear Prof Bi

RE: SITE SPECIFIC ASSESSMENT – PROJECT AUTHORISATION

Project title:	The One Health approach to Q fever prevention and control in South Australia
SSA reference:	SSA/20/SAH/63
HREC reference:	HREC/20/SAH/8
Site Name:	SA Department for Health and Wellbeing (CDCB)

Thank you for submitting the Site Specific Assessment form and associated documentation for the above named project.

Following a review of the SSA submission, and noting the project was ethically approved by the Department for Health and Wellbeing HREC, I am pleased to advise your project has been granted research governance approval.

Period of approval: 24/08/20 to 18/06/23*
** This coincides with current HREC approval expiry.*

Aside from the documentation approved by the HREC, this approval specifically encompasses the following:

- Site Specific Assessment form (AU/12/276B311)
- HREC approval letter, HREC/20/SAH/8, dated 18/06/20
- CVs, Prof. Bi, dated 2018, Dr. Milazzo, dated June 2018, Prof. Marshall, dated June 2018 and Dr. Rahaman, dated June 2020
- Q Fever Interviews Protocol, version 13, dated June 2020
- Q Fever Interview Schedule, version 5
- Q Fever Interview Invitation Email, version 5
- Q Fever Interview PICF, version 10

- University of Adelaide Public & Products Liability certificate of currency, valid until 31 December 2020
- University of Adelaide Professional Indemnity certificate of currency, valid until 31 December 2020.

Please note the following conditions of authorisation:

- Project authorisation is subject to ongoing HREC approval and strict adherence to all conditions of ethical approval.
- Project authorisation is limited to the activities of the project that involve the SA Department for Health and Wellbeing, as outlined in the SSA submission provided to the Research Governance Officer.
- The Research Governance Officer should be notified of any changes to the project that affect the SA Department for Health and Wellbeing. Project amendments should be submitted in writing to the Research Governance Officer, HealthResearchGovernance@sa.gov.au.
- If an extension of research governance approval is required, a request for an approval extension must be submitted in writing prior to the expiry of the approval period.
- Any updated certificates of insurance associated with the SSA should be sent to the Research Governance Officer upon expiry of the current certificates.
- The study must be conducted in accordance with the standards outlined in the *National Statement on Ethical Conduct in Human Research* (2007, including updates) and the *Australian Code for the Responsible Conduct of Research* (2018, including updates), along with applicable SA Health research policy requirements including the SA Health Research Governance Policy.
- You are required to provide annual progress reports and a final report for the project. A copy of the reporting template can be requested from the Research Governance Officer.
- Failure to adhere to any of the above requirements may result in SSA/research governance approval being withdrawn.

Your first annual progress report will be due by 24/08/21.

All correspondence to the Research Governance Officer should be submitted electronically to HealthResearchGovernance@sa.gov.au. Should you have any queries regarding these requirements, please contact me on (08) 8226 4235 or by email.

Yours sincerely

David Van der Hoek
RESEARCH GOVERNANCE OFFICER
SA DEPARTMENT FOR HEALTH AND WELLBEING

24 August 2020

Cc: Dr Rezanur Rahaman, The University of Adelaide

Government of South Australia
Health
Department for Health and Wellbeing

SA Department for Health and Wellbeing
Human Research Ethics Committee

Citi Centre Building
Level 5, 11 Hindmarsh Square
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PO Box 287, Rundle Mall
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Tel 08 8226 7702
health.humanresearchethicscommittee@sa.gov.au

23 March 2020

Prof Peng Bi
School of Public Health
The University of Adelaide
Adelaide SA 5000

HREC study number: *HREC/20/SAH/8*
Project title: *The One Health approach to Q fever prevention and control in South Australia (SA)*

Dear Prof Bi

RE: HREC/20/SAH/8 - Ethics Application – Request for Further Information

Thank you for submitting the above project for ethical and scientific review. Your application was considered by the SA Department for Health and Wellbeing Human Research Ethics Committee (HREC) Chairperson on 21 March 2020.

The application was reviewed in accordance with the requirements of the NHMRC *National Statement on Ethical Conduct in Human Research* *[NS]* and the *Australian Code for the Responsible Conduct of Research* *[ACRCR]*.

In order to make a determination of the ethical and scientific acceptability of your application, could you please make the following modifications/clarifications:

1. The Committee still has some concerns about the response to their question about the potential for re-identification. The response provided does not explain what will be done to assure participants that they will not be identifiable in reporting, merely that it will occur. There are well established strategies for addressing concerns about anonymity in small samples with potentially well-known people. Please seek advice from an experienced qualitative researcher on this and provide a more detailed response. *[Privacy Committee of South Australia Privacy and Open Data Guideline, NS Chapter 3.1 Element 4, NS 3.1.16]*
2. The revision of the information that has been inserted into the consent form belongs in the information sheet under the section on risks, not in the consent form itself. You should also consider providing greater detail of how you will approach this issue in the protocol than you provide to the participants. *[NS 5.2.25]*

In order to facilitate the HREC's consideration of your project, please provide the requested information as soon as possible, taking into consideration:

- Please ensure your response includes a covering letter addressing each point.
- Any documents that are revised should include a 'tracked/highlighted' and 'clean' copy.
- Any documents that are updated should have footers updated with a new version number/date.
- Please email your response letter and any revised documentation to health.humanresearchethicscommittee@sa.gov.au (do not upload to online forms).

Your response will be reviewed out-of-session by the HREC Chair.

Should you have any queries about this matter, please contact Mel Kluge, HREC Executive Officer in the first instance on 08 82267702 or Health.HumanResearchEthicsCommittee@sa.gov.au

Yours sincerely

Prof Annette Braunack-Mayer
Chair, Human Research Ethics Committee
SA Department for Health and Wellbeing
ABM:psb

Government of South Australia
Health
Department for Health and Wellbeing

SA Department for Health and Wellbeing
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20 February 2020

Prof Peng Bi
School of Public Health
The University of Adelaide
Adelaide SA 5000

HREC study number: *HREC/20/SAH/8*
Project title: *The One Health approach to Q fever prevention and control in South Australia (SA)*

Dear Prof Bi

RE: HREC/20/SAH/8 - Ethics Application – Request for Further Information

Thank you for submitting the above project for ethical and scientific review. Your application was considered by the SA Department for Health and Wellbeing Human Research Ethics Committee (HREC) on 13th February 2020.

The application was reviewed in accordance with the requirements of the NHMRC *National Statement on Ethical Conduct in Human Research* *[NS]* and the *Australian Code for the Responsible Conduct of Research* *[ACRCR]*.

In order to make a determination of the ethical and scientific acceptability of your application, could you please make the following modifications/clarifications:
1. Clarification is required about how the researchers will obtain written consent when the interviews will be conducted by telephone. When obtaining consent, please advise participants that their answers may be re-identifiable due to the sample size and small number of people working in this area. [NS2.2]
2. The HREC suggests including definitions of the scientific terms used, as some of the participants may not be familiar with the specific terminology.[NS3.1.1d]
3. Please provide more information about how the stakeholders have been selected, and explain if they will be re-identifiable. Please explain how researchers will manage the potential for re-identifiability in reporting. *[Privacy Committee of South Australia Privacy and Open Data Guideline, NS Chapter 3.1 Element 4, NS 3.1.16]*
4. Please provide an independent peer review report. Peer reviewers must not be internal and can't be a member the same department. [*ACRCR 6*, *DHW HREC Peer Review Requirement*].
5. The HREC request that researchers provide a summary of the study back to the research participants. *[NS 2.2.6k, NS 3.1.68, SA Health Research Governance Policy 3.6.1, ACRCR P3]*

In order to facilitate the HREC's consideration of your project, please provide the requested information as soon as possible, taking into consideration:

- Please ensure your response includes a covering letter addressing each point.
- Any documents that are revised should include a 'tracked/highlighted' and 'clean' copy.

- Any documents that are updated should have footers updated with a new version number/date.
- Please email your response letter and any revised documentation to health.humanresearchethicscommittee@sa.gov.au (do not upload to online forms).

Your response will be reviewed out-of-session by the HREC Chair.

Should you have any queries about this matter, please contact Pip Stanford-Bluntish, HREC Executive Officer in the first instance on 08 8226 8102 or Health.HumanResearchEthicsCommittee@sa.gov.au

Yours sincerely

Prof Annette Braunack-Mayer
Chair, Human Research Ethics Committee
SA Department for Health and Wellbeing
ABM:psb

Government of South Australia
Health
Department for Health and Wellbeing

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13 December 2019

Professor Peng Bi
School of Public Health
Level 9 AHMS Building
THe University of Adelaide
Adelaide SA 5005

HREC study number: *HREC/18/SAH/47*
Amendment reference number: *HREC/18/SAH/47/AM01*
Project title: *The One Health approach to Q fever prevention and control in South Australia*

Dear Professor Bi

RE: HREC/18/SAH/47/AM01 - Project Amendment - Rejected

Thank you for submitting an amendment request on 11 October 2019 in relation to the above project for ethical and scientific review. This documentation was considered by the Chair of the SA Department for Health and Wellbeing Human Research Ethics Committee (HREC) on 13 December 2019.

The documents reviewed include:

Document	*Version*	*Date*
Covering Letter: Request for Amendment	-	11 October 2019
Protocol	6.0	11 October 2019
Participant Information Sheet / Consent Form	4	11 October 2019
Recruitment Email Template	4	11 October 2019
Interview Schedule	5	11 October 2019

I regret to inform you that the amendment was not approved as the changes are considered too major and warrant a new application. The study objectives are new, which creates new methods, analysis, sites, and cannot be considered an amendment to the original study.

You are therefore not authorised to commence with this new design proposal until a new ethics and governance application is submitted and approved. We appreciate this may cause some difficulties, and we are happy to facilitate a new application as soon as possible. For more information on how to submit a new application, please see the DHW HREC Webpage.

If you choose to submit a new application, and close study HREC/18/SAH/47, please inform us of the closure by way of a Progress/Annual Reporting Form.

Alternatively, the project may continue in accordance with the documentation previously approved by the Committee.

Should you have any queries about the HREC's consideration of your project please contact the HREC Executive Officer on phone 08 82267702 or email HealthHumanResearchEthicsCommittee@sa.gov.au

Yours sincerely

Prof Annette Braunack-Mayer
Chair, Human Research Ethics Committee
SA Department for Health and Wellbeing
ABM:mk

THE UNIVERSITY of ADELAIDE

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CRICOS Provider Number 00123M

Our reference 34196

06 January 2020

Professor Peng Bi
Public Health

Dear Professor Bi

PROJECT TITLE: Climatic determinants of diarrheal diseases, including rotavirus among children under five years of age in Bangladesh

The ethics application for the above project has been reviewed by the Secretariat, Human Research Ethics Committee and is deemed to meet the requirements of the *National Statement on Ethical Conduct in Human Research 2007 (Updated 2018)* involving no more than negligible risk for research participants.

According to provisions within the *National Statement*, the University of Adelaide classifies research that carries only negligible risk and involves the use of existing data that contains only non-identifiable data about human beings, to be exempt from ethical review. The research conducted as part of this project meets these requirements and has been authorised as exempt from requiring ethical review.

Yours sincerely,

Miss Sarah Harman
Secretary

The University of Adelaide

Appendix D ─ Supplementary material from publication

Appendix D.1 ─ Study 1

Table S1 Logic grids showing subject headings and keywords used for searching databases until 13 June 2018.

PUBMED (Logic Grid 1)	
Q fever	One Health
"q fever"[mh] OR "q fever"[tw] OR q-fever[tiab] OR *C. burnetii**[tiab] OR acute q fever[tiab] OR chronic q fever[tiab] OR query fever[tiab]	"one health"[mh] OR one health concept[tiab] OR one health initiative[tiab] OR one medicine initiative[tiab] OR "one health"[tw] OR one health*[tiab] OR "one medicine"[tw] OR one medicine*[tiab] OR "one health"[all] OR "one medicine"[all]
EMBASE (Logic Grid 2)	
Q fever	One Health
"q fever"/syn OR "q fever":ti,ab OR "acute q fever":ti,ab OR "chronic q fever":ti,ab	"one health"/syn "one health concept"/de OR "one health initiative"/de OR "one medicine initiative"/de OR "one health":ti,ab OR "one medicine":ti,ab
CINAHL (Logic Grid 3)	
Q fever	One Health
MH q fever OR TI "q fever" OR AB "q fever" OR TI "*C. burnetii*" OR AB "*C. burnetii*" OR TI "acute q fever" OR AB "acute q fever" OR TI "chronic q fever" OR AB "chronic q fever" OR TI "query fever" OR AB "query fever"	TI "one health" OR AB "one health" OR TI "one medicine" OR AB "one medicine" OR MW "one health*" OR MW "one medicine*"
SCOPUS (Logic Grid 4)	

Q fever	One Health
“q fever” OR “q-fever” OR “acute q fever” OR “chronic q fever” OR “*C. burnetii*” OR “*C. burnetii*” OR “query fever”	“one health” OR “one medicine” OR “one health*” OR “one medicine*”
WEB OF SCIENCE (Logic Grid 5)	
Q fever	One Health
“q fever” OR “q-fever” OR “acute q fever” OR “chronic q fever” OR “*C. burnetii*” OR “query fever”	“one health” OR “one medicine” OR “one health*” OR “one medicine*”
PsycINFO (Logic Grid 6)	
Q fever	One Health
q fever.sh OR q fever.ti,ab OR q-fever.ti,ab OR acute q fever.ti,ab OR query fever.ti,ab OR q fever.tw OR q-fever.tw OR q fever.mp OR q-fever.mp OR *C. burnetii*.ti,ab OR *C. burnetii*.tw OR *C. burnetii*.mp	one health.sh OR one health.ti,ab OR one health.tw OR one health.mp OR one medicine.sh OR one medicine.ti,ab OR one medicine.tw OR one medicine.mp

Appendix D.2 ─ Study 2

Table S1 Broad occupation categories, their examples from Q fever notification dataset, 2007-2017, category specific estimated total population, and person-years at risk, South Australia.

Occupation category	Examples from notification data	N (%†)	Category population sourced from ABS	Total population in SA‡	Person-years at risk§
Farmer/contact with livestock	Beef cattle farmer; dairy farmer; farmers and farm managers; farm hands; grazier; livestock farmers; mixed crop and livestock farmers; primary products inspector; shearer; sheep farmer; skilled agricultural workers; veterinarian; wool classer	59 (35)	Animal attendants and trainers; animal attendants and trainers, and shearers; farmers and farm managers; livestock farmers; livestock farm workers; mixed crop and livestock farmers; mixed crop and livestock farm workers; primary products inspector; shearers; skilled animal and horticultural workers; veterinarians	15,035	165,385
Abattoir worker	Abattoir worker; boner; butcher; commercial cleaner; lecturer at TAFE, attends abattoirs and butchers to lecture; meat and fish process workers; meatworks labourer; meat	34 (20)	Butchers and smallgoods makers; commercial cleaners; meat boners and slicers, and slaughterers; meat, poultry, and seafood process workers; university lecturers and tutors	17,591	193,501

	tradespersons; packer; slaughter person; slicer				
No risk occupation	Child care worker; community worker; construction project manager; importer/exporter; kitchenhand; other advanced clerical and service workers; performing arts support workers; sales consultant; school teachers; supervisor transport and despatching clerks	25 (15)	Child carers; community and personal service workers; constructions managers; importers, exporters and wholesalers; kitchenhands; other clerical and office support workers; performing arts technicians; sales representatives and agents; school teachers; transport and despatch clerks	29,383	323,213
Unknown occupation	Home duties; other; retired; unemployed	23 (14)	NA	-	-
Tradesperson	Builder; construction tradespersons; electrical and electronics tradesperson; motor mechanic; tiler	9 (5)	Boat builders and shipwrights; construction and mining labourers; electrical distribution trades workers; electronics trades workers; glaziers, plasterers, and tilers; motor mechanics; roof tilers; wall and floor tilers	10,446	114,906
Transport worker	Delivery driver; road and rail transport drivers; truck drivers	9 (5)	Delivery drivers; road and rail drivers; truck drivers	13,931	153,241

Healthcare worker	Enrolled nurses; medical laboratory technical officer; medical technical officer	5 (3)	Enrolled and mothercraft nurses; medical laboratory scientists; medical technicians	8,169	89,859
Contact with animals other than livestock	Park ranger, veterinary students	3 (2)	Park rangers and veterinary students ABS data not found Park rangers' data were sourced from South Australian Skills Gateway. There were 96 park rangers in 2011. https://s.skills.sa.gov.au/Career-seekers/Explore-careers/Choose-your-career/conservation-and-land-management/park-ranger Veterinary students' data were sourced from the School of Animal and veterinary science, the University of Adelaide (only university providing veterinary degrees in SA). There were 410 veterinary students enrolled across all year levels at the start of 2019 academic year.	506	5,566

Notes. †Percentages may not add up to 100 due to rounding. ‡Population of workers for each occupation category was based on Census data, and the worker population was assumed to remain constant for the duration of the study period. §Computed through multiplication of the estimated total population in each occupation category by 11 for the 11-year study period.

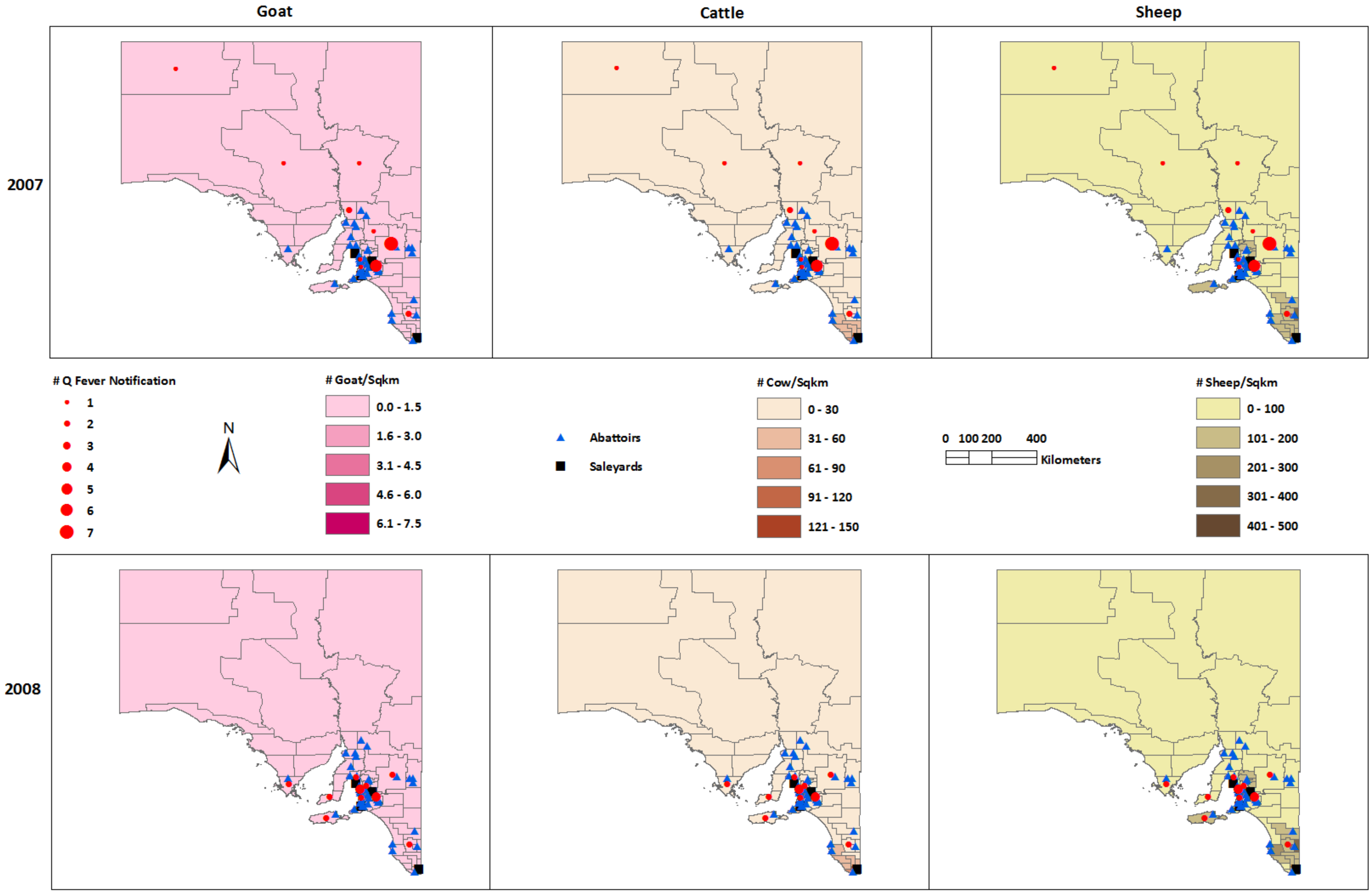

Figure S1 Spatial relationship of Q fever notifications and livestock densities, 2007–2008, and location of abattoirs and saleyards, South Australia.

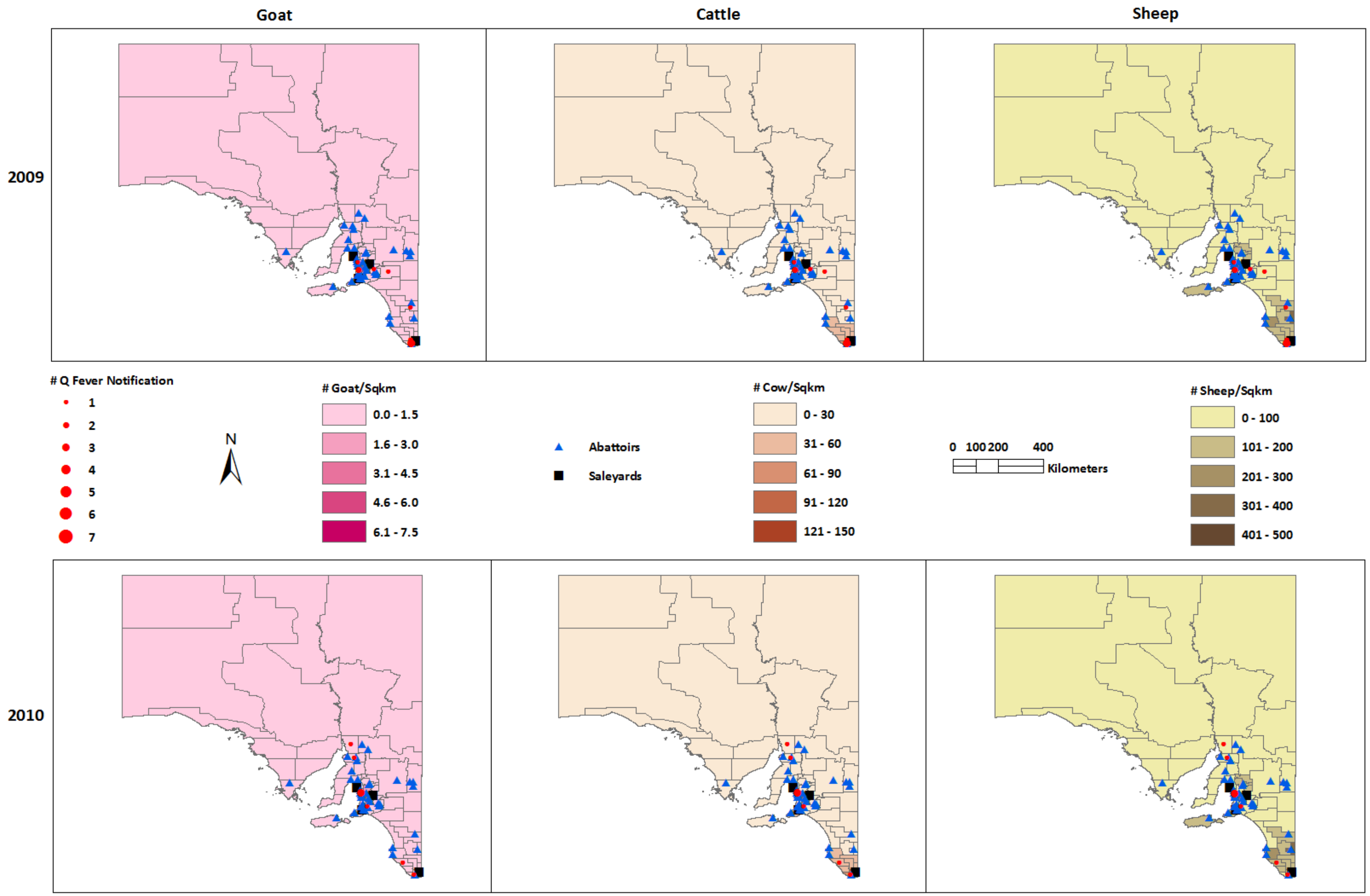

Figure S2 Spatial relationship of Q fever notifications and livestock densities, 2009–2010, and location of abattoirs and saleyards, South Australia.

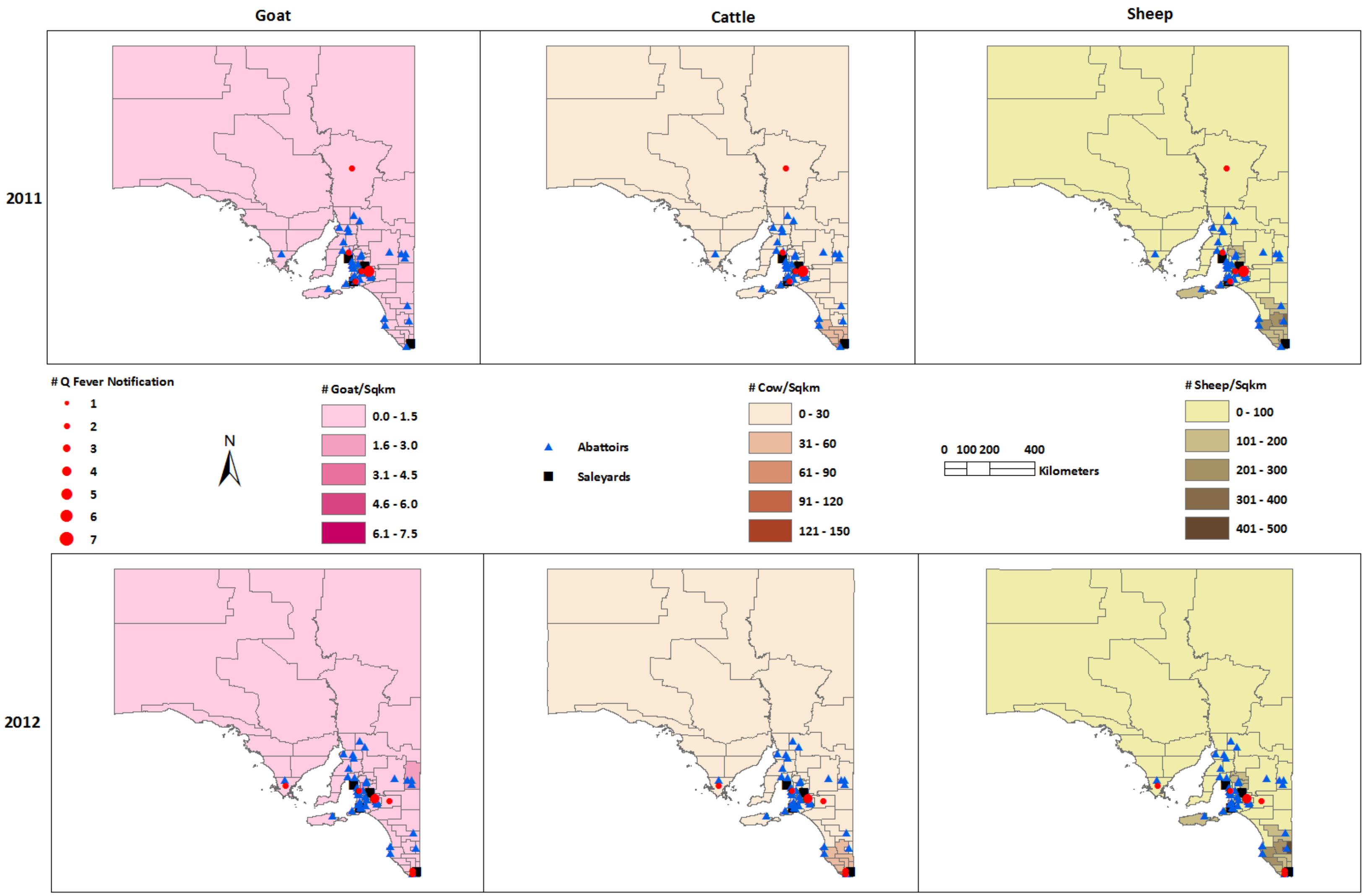

Figure S3 Spatial relationship of Q fever notifications and livestock densities, 2011–2012, and location of abattoirs and saleyards, South Australia.

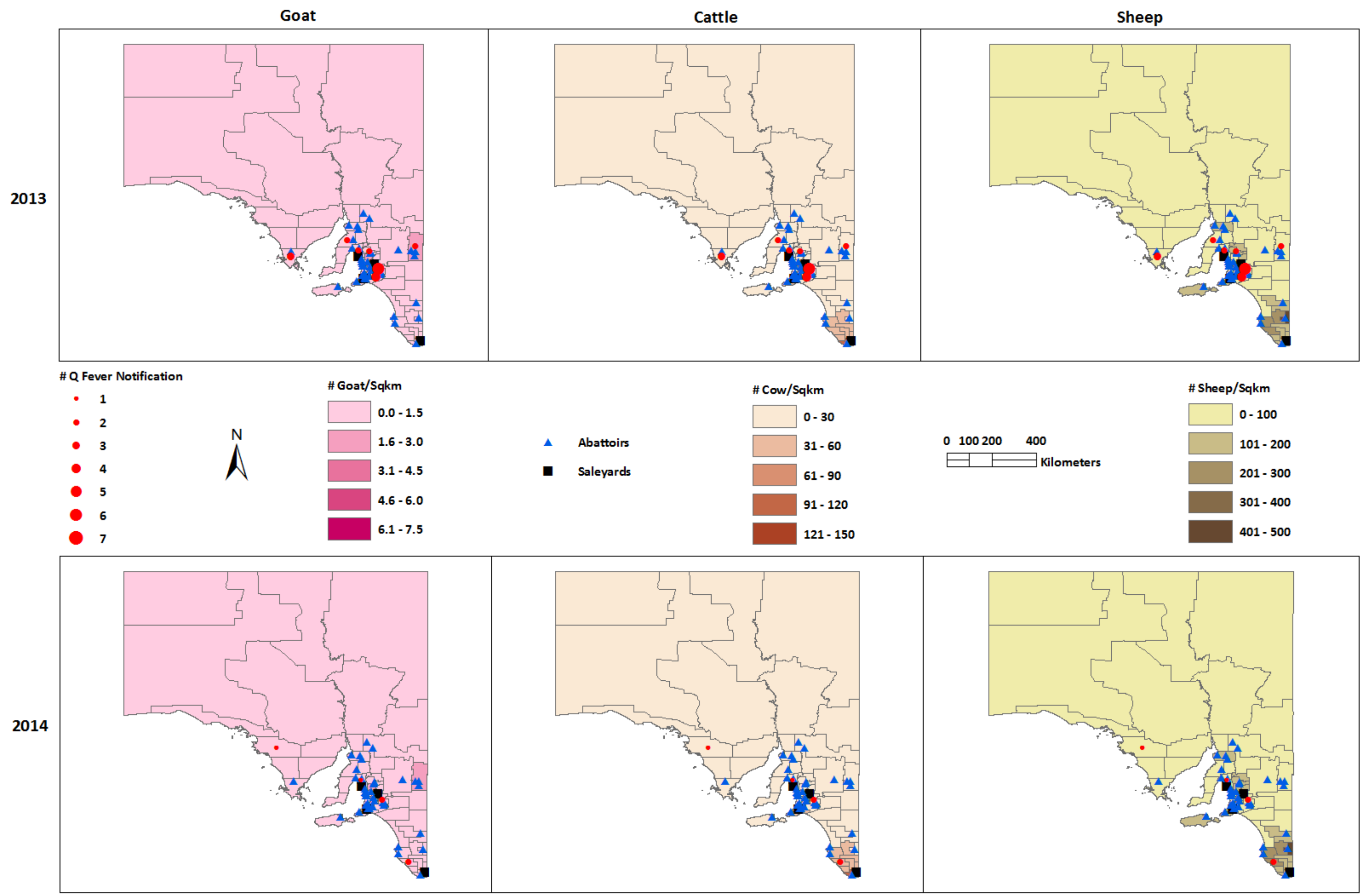

Figure S4 Spatial relationship of Q fever notifications and livestock densities, 2013–2014, and location of abattoirs and saleyards, South Australia.

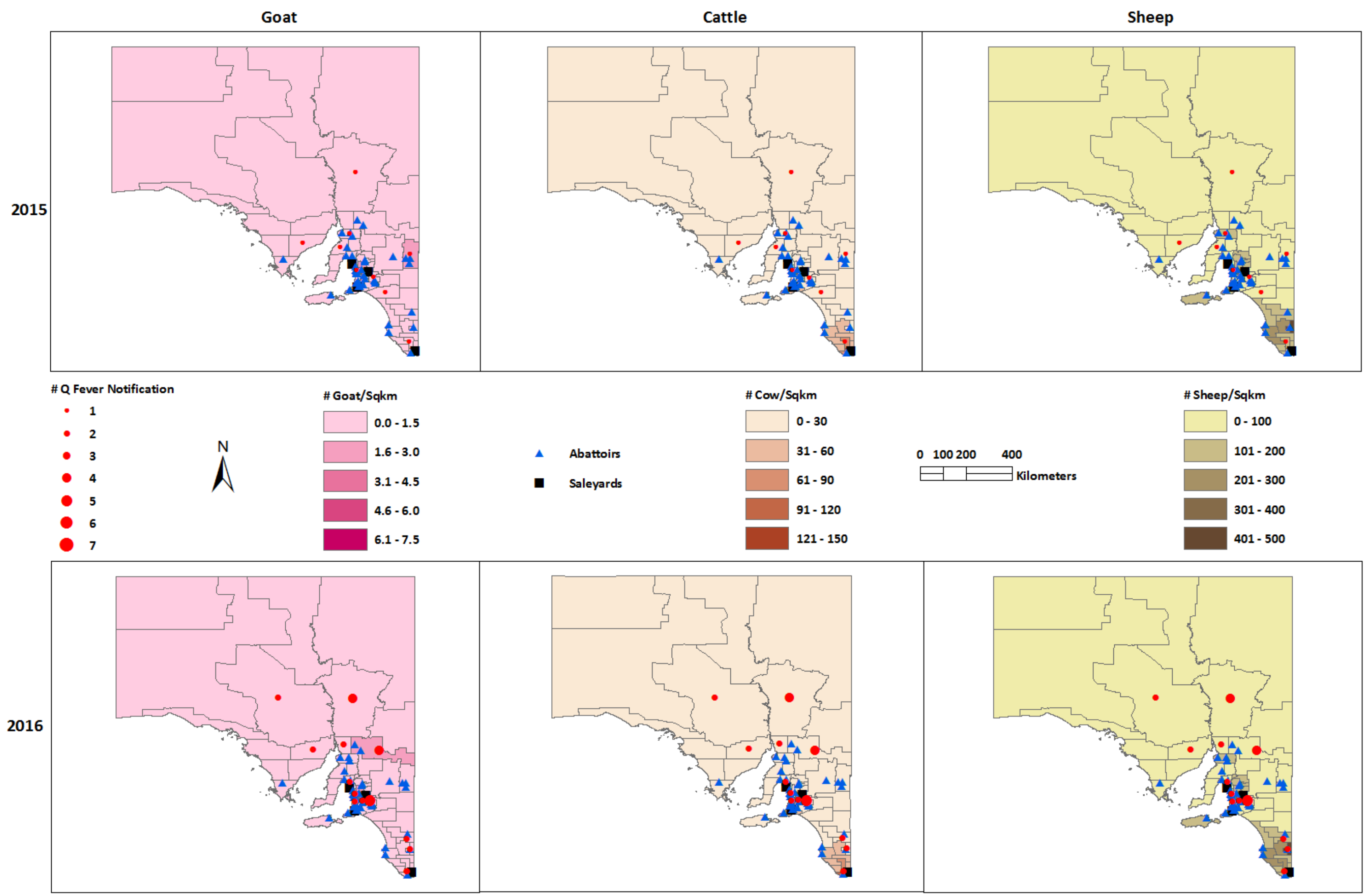

Figure S5 Spatial relationship of Q fever notifications and livestock densities, 2015–2016, and location of abattoirs and saleyards, South Australia.

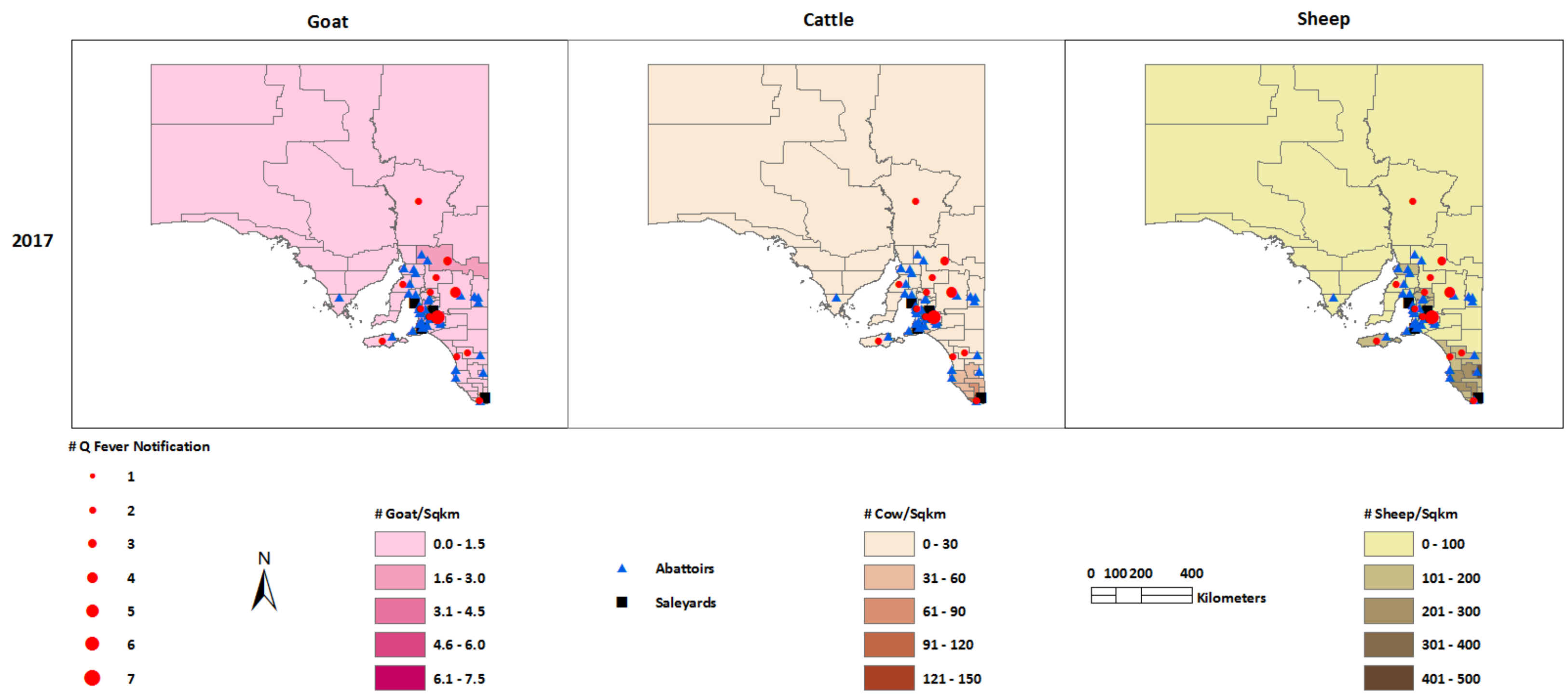

Figure S6 Spatial relationship of Q fever notifications and livestock densities, 2017, and location of abattoirs and saleyards, South Australia.

Appendix D.3 ─ Study 3

Table S1 Q fever prevention practices among animal and veterinary science students by their self-reported knowledge, 2019.

Q fever preventive practice	**Level of self-reported Q fever knowledge**		**Fisher's exact p**
	A great deal or some (n=168)	**Little or nil (n=145)**	
Wearing work clothes (%)			
Always	68 (40.5)	44 (30.3)	
Often	71 (42.3)	59 (40.7)	
Sometimes	17 (10.1)	33 (22.8)	0.019
Rarely/never	11 (6.5)	9 (6.2)	
Missing/unknown	1 (0.6)	0	
Wearing work boots (%)			
Always	88 (52.4)	63 (43.4)	
Often	73 (43.5)	66 (45.5)	
Sometimes	7 (4.2)	13 (9.0)	0.050
Rarely/never	0	3 (2.1)	
Missing/unknown	0	0	
Wearing a facemask (%)			
Always	1 (0.6)	0	
Often	8 (4.8)	2 (1.4)	
Sometimes	46 (27.4)	29 (20.0)	0.028
Rarely/never	113 (67.3)	111 (76.6)	
Missing/unknown	0	3 (2.1)	
Handwashing after contact with animals (%)			
Always	104 (61.9)	83 (57.2)	
Often	53 (31.5)	49 (33.8)	

Sometimes	9 (5.4)	10 (6.9)	0.817
Rarely/never	2 (1.2)	2 (1.4)	
Missing/unknown	0	1 (0.7)	
Before contact changing into uniform/boots (%)			
Always	62 (36.9)	47 (32.4)	
Often	62 (36.9)	45 (31.0)	
Sometimes	25 (14.9)	40 (27.6)	0.053
Rarely/never	19 (11.3)	13 (9.0)	
Missing/unknown	0	0	
After contact changing out of uniform/boots (%)			
Always	62 (36.9)	45 (31.0)	
Often	64 (38.1)	46 (31.7)	
Sometimes	24 (14.3)	43 (29.7)	0.012
Rarely/never	18 (10.7)	11 (7.6)	
Missing/unknown	0	0	
Showering after contact (%)			
Always	13 (7.7)	12 (8.3)	
Often	28 (16.7)	17 (11.7)	
Sometimes	41 (24.4)	47 (32.4)	0.412
Rarely/never	85 (50.6)	67 (46.2)	
Missing/unknown	1 (0.6)	2 (1.4)	
Using hand gloves (%)			
Always	8 (4.8)	6 (4.1)	
Often	56 (33.3)	27 (18.6)	
Sometimes	60 (35.7)	57 (39.3)	0.024
Rarely/never	43 (25.6)	54 (37.2)	
Missing/unknown	1 (0.6)	1 (0.7)	

Using eye goggles (%)			
Always	4 (2.4)	0	
Often	5 (3.0)	1 (0.7)	
Sometimes	22 (13.1)	21 (14.5)	0.123
Rarely/never	135 (80.4)	118 (81.4)	
Missing/unknown	2 (1.2)	5 (3.4)	
Using an N-95 respirator (%)			
Always	0	0	
Often	0	0	
Sometimes	5 (3.0)	0	0.003
Rarely/never	150 (89.3)	120 (82.8)	
Missing/unknown	13 (7.7)	25 (17.2)	
Vaccination status (%)			
Not vaccinated	21 (12.5)	35 (24.1)	
Vaccinated	135 (80.4)	86 (59.3)	<0.001
Missing/unknown	12 (7.1)	24 (16.6)	

Note. Percentages (%) may not add up to 100 due to rounding.

Appendix D.4 ─ Study 4

Table S1 Farmers' perceptions about Q fever transmission by their self-reported knowledge.

Q fever transmission methods	Level of self-reported Q fever knowledge				Fisher's exact p
	A great deal or some (n=249)		Little or nil (n=100)		
	n	%*	n	%*	
Eating undercooked meat					
Unlikely	182	73	53	53	
Neither likely nor unlikely	16	6	3	3	
Likely	13	5	9	9	<0.001
Missing/unknown	38	15	35	35	
Consumption of unpasteurized dairy products					
Unlikely	155	62	46	46	
Neither likely nor unlikely	18	7	4	4	
Likely	35	14	13	13	0.001
Missing/unknown	41	16	37	37	
Inhalation of aerosols or dusts in the environment occupied by animals					
Unlikely	17	7	9	9	
Neither likely nor unlikely	16	6	6	6	
Likely	205	82	56	56	<0.001
Missing/unknown	11	4	29	29	
Laundering the clothes of a person who has had contact with animals					
Unlikely	81	33	38	38	
Neither likely nor unlikely	40	16	10	10	
Likely	95	38	21	21	<0.001
Missing/unknown	33	13	31	31	
Sexual intercourse with a person who has had contact with animals					

Unlikely	180	72	51	51	
Neither likely nor unlikely	12	5	3	3	
Likely	11	4	8	8	<0.001
Missing/unknown	46	18	38	38	
Culling of infected animals					
Unlikely	33	13	12	12	
Neither likely nor unlikely	15	6	5	5	
Likely	166	67	59	59	0.182
Missing/unknown	35	14	24	24	

Note. * Percentages may not add up to 100 due to rounding.

Table S2 Q fever prevention practices among farmers by their self-reported knowledge.

Q fever prevention practice	**Level of self-reported Q fever knowledge**				**Fisher's exact p**
	A great deal or some (n=249)		**Little or nil (n=100)**		
	n	**%***	**n**	**%***	
Wearing work clothes					
Always	202	81	73	73	
Often	41	16	23	23	
Sometimes	5	2	2	2	0.199
Rarely/never	0	-	1	1	
Missing/unknown	1	0.4	1	1	
Wearing work boots					
Always	208	84	75	75	
Often	34	14	21	21	
Sometimes	6	2	0	-	0.012
Rarely/never	0	-	1	1	
Missing/unknown	1	0.4	3	3	
Wearing a facemask					

Often	1	0.4	0	-	
Sometimes	14	6	4	4	
Rarely/never	222	89	88	88	0.618
Missing/unknown	12	5	8	8	
Handwashing after contact with animals					
Always	95	38	40	40	
Often	94	38	38	38	
Sometimes	43	17	16	16	0.580
Rarely/never	16	6	4	4	
Missing/unknown	1	0.4	2	2	
Before contact changing into uniform/boots					
Always	92	37	37	37	
Often	69	28	22	22	
Sometimes	32	13	18	18	0.556
Rarely/never	48	19	18	18	
Missing/unknown	8	3	5	5	
After contact changing out of uniform/boots					
Always	27	11	12	12	
Often	41	16	11	11	
Sometimes	73	29	38	38	0.385
Rarely/never	103	41	36	36	
Missing/unknown	5	2	3	3	
Showering after contact					
Always	38	15	12	12	
Often	47	19	8	8	
Sometimes	77	31	32	32	0.030
Rarely/never	82	33	43	43	

Missing/unknown	5	2	5	5	
Use of hand gloves					
Always	4	2	3	3	
Often	13	5	9	9	
Sometimes	68	27	22	22	
Rarely/never	159	64	59	59	0.069
Missing/unknown	5	2	7	7	
Use of eye goggles					
Always	3	1	0	-	
Often	12	5	6	6	
Sometimes	30	12	8	8	0.385
Rarely/never	197	79	80	80	
Missing/unknown	7	3	6	6	
Use of an N95 respirator					
Sometimes	3	3	2	2	
Rarely/never	235	94	89	89	0.163
Missing/unknown	11	4	9	9	
Vaccination status					
Not vaccinated	82	33	52	52	
Vaccinated	154	62	30	30	<0.001
Missing/unknown	13	5	18	18	

Note. *Percentages may not add up to 100 due to rounding.

Table S3 Farmers' perceptions about Q fever vaccination promotion strategies by their self-reported knowledge.

Q fever vaccination promotion strategy	Level of self-reported Q fever knowledge				Fisher's exact p
	A great deal or some (n=249)		Little or nil (n=100)		
	n	%*	n	%*	
Radio					
Unlikely	10	4	2	2	
Neither likely nor unlikely	27	11	10	10	<0.001
Likely	192	77	62	62	
Missing/unknown	20	8	26	26	
Newspaper					
Unlikely	13	5	9	9	
Neither likely nor unlikely	38	15	11	11	<0.001
Likely	178	71	48	48	
Missing/unknown	20	8	32	32	
Social media					
Unlikely	4	2	1	1	
Neither likely nor unlikely	23	9	5	5	<0.001
Likely	202	81	65	65	
Missing/unknown	20	8	29	29	
Subsidized vaccination					
Unlikely	1	0.4	0	-	
Neither likely nor unlikely	15	6	4	4	<0.001

Likely	216	87	73	73	
Missing/unknown	17	7	23	23	
Mass vaccination at specific events e.g. farmers get vaccinated at farming events such as Royal Adelaide Show					
Unlikely	17	7	4	4	
Neither likely nor unlikely	14	6	7	7	0.001
Likely	201	81	67	67	
Missing/unknown	17	7	22	22	
Improving access to a trained vaccine provider					
Unlikely	1	0.4	0	-	
Neither likely nor unlikely	18	7	10	10	<0.001
Likely	212	85	66	66	
Missing/unknown	18	7	24	24	
Improving general practitioners' knowledge					
Unlikely	2	1	0	-	
Neither likely nor unlikely	12	5	11	11	<0.001
Likely	215	86	68	68	
Missing/unknown	20	8	21	21	
Improving veterinary practitioners' knowledge					
Unlikely	7	3	4	4	
Neither likely nor unlikely	29	12	17	17	<0.001
Likely	188	76	51	51	
Missing/unknown	25	10	28	28	

Improving knowledge of the occupational groups who have contact with animals					
Unlikely	1	0.4	0	-	
Neither likely nor unlikely	5	2	4	4	<0.001
Likely	228	92	72	72	
Missing/unknown	15	6	24	24	

Note. *Percentages may not add up to 100 due to rounding.

SA producers urged to participate in University of Adelaide Q Fever survey

Monday, March 25, 2019 by Livestock SA

SA livestock producers have been invited to participate in an online survey on the topic of "The One Health approach to Q Fever prevention and control in SA".

This study examines the feasibility of adopting a One Health approach to Q Fever prevention in South Australia.

As Q Fever is transmitted from animals to humans, a One Health approach has recently been recognised to be efficient in disease prevention because of its interdisciplinary nature linking human, animal and ecological sectors together.

The aim of the survey is to get producer opinions and perspectives concerning Q Fever prevention and control.

The survey will take approximately 15 minutes to complete. The online survey seeks information on your understanding, views, and practices about Q Fever and its prevention.

Participation in this survey is entirely voluntary, and that you may withdraw prior to the submission of your response.

Your responses will be anonymous and there is no foreseeable risks of participating in this survey.

Read the flyer

Take the survey

Supplement S4 Initial survey advert on Livestock SA website, March 2019.

SA producers urged to participate in University of Adelaide Q Fever survey

Wednesday, April 10, 2019 by Livestock SA

SA livestock producers have been invited to participate in an online survey on the topic of "The One Health approach to Q Fever prevention and control in SA".

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The survey will take approximately 15 minutes to complete. The online survey seeks information on your understanding, views, and practices about Q Fever and its prevention.

Participation in this survey is entirely voluntary, and that you may withdraw prior to the submission of your response.

Your responses will be anonymous and there is no foreseeable risks of participating in this survey.

Read more

Take the survey

Supplement S5 Reminder survey advert on Livestock SA website, April 2019.

Producers urged to prepare stock for season break

By **ANDREW CURTIS**

As we hope "the break" nears, it is important producers begin setting themselves up to be in the best position possible for the growing season.

With the latest forecast from the Bureau of Meteorology stating a low probability of rain until June, it's crucial producers do their sums and explore options to ensure stock remain in good condition.

This is particularly important to not only maximise the vitality of sheep but to ensure ewes remain in the best condition for joining and parturition.

As available feed resources across the state continue to dwindle, producers should understand the available options for confinement feeding. To this end, Livestock SA will be working with members and service providers to roll out a series of workshops across the Mallee, Mid North, Upper North, Eyre Peninsula and Pastoral regions next month to focus on available options.

Livestock SA has continued to help coordinate fodder donations, working with state and national bodies to facilitate the distribution of donated fodder to SA producers.

Livestock SA has also continued to advocate for members through discussions with State Government and Federal Government parties on lasting drought management policy. As part of this, Board member Allan Piggott met with national drought coordinator Major General Stephen Day on his most recent trip to SA to discuss the impact of drought on the state's livestock producers.

Livestock SA has continues to highlight the adverse impact interstate freight subsidies have had on the price and availability of fodder in SA.

Many producers in drought-affected areas across the state have already spent significant resources and time hand feeding sheep and cattle. It is a hard job and there is nothing uplifting about it.

However, it is important for producers to ensure they not only look after their stock but also themselves, their families, neighbours and friends.

In recent discussions with members, it has been reassuring to hear many producers have contacted Rural Business Support's team of Rural Financial Counsellors. Livestock SA encourages all affected producers to get in touch with RFCs to learn about available options and possible funding available to them.

RBS's Farm Business Strategic Reviews are also an important resource producers should look to consider this month.

Accessing these types of services will help ensure producers set themselves up appropriately for when the break comes.

News in brief

Applications open for robotics shearing study

Australian Wool Innovation are currently seeking woolgrowers to join their new Robotics Advisory Group. Following the success of AWI's scoping study into robotic shearing, they are establishing a group to assist in the development of AWI's robotics program. Interested members are encouraged to apply.

Details: Visit https://bit.ly/2I8N7S6 before 30 April

SA producers urged to complete Q Fever survey

SA livestock producers have been invited to participate in an online survey on the topic of "The One Health approach to Q Fever prevention and control in SA". This study examines the feasibility of adopting a One Health approach to Q Fever prevention in South Australia. As Q Fever is transmitted from animals to humans, a One Health approach has recently been recognised to be efficient in disease prevention because of its interdisciplinary nature linking human, animal and ecological sectors together. The aim of the survey is to get producer opinions and perspectives concerning Q Fever prevention and control.

Details: https://bit.ly/2I8OpMW

Skin cancer awareness regional roadshow in SA

South Australians living in rural areas have a higher chance of developing skin cancer. Driven by Cancer Council SA and Country SA PHN, the Skin Cancer Awareness Regional Roadshow will visit eight locations across the state between March and June 2019. Roadshows are being held across SA in the following locations:

- Naracoorte 22 May
- Tanunda 5 June
- Yorketown 24 June
- Kadina 25 June

Details: https://bit.ly/2IF3CXY

Technology at the forefront of Aust FMD preparedness

Response strategies for foot-and-mouth disease (FMD) are being tested by an Australian research project. The Outbreak Decision Support Tools subproject is part of the FMD Ready Project. Computer simulation software, known as the Australian Animal Disease Spread model (AADIS), is used to model possible FMD outbreak scenarios and compare the impact of different response strategies. Dr Tim Capon, Economist at CSIRO and leader of the Outbreak Decision Support Tools subproject said the project aims to help decision-makers understand the social and economic impacts of alternative response strategies during and after an outbreak of FMD. AADIS will also analyse the costs of different vaccination control strategies and the implications of using vaccination on proving that Australia is free of FMD after the outbreak is controlled.

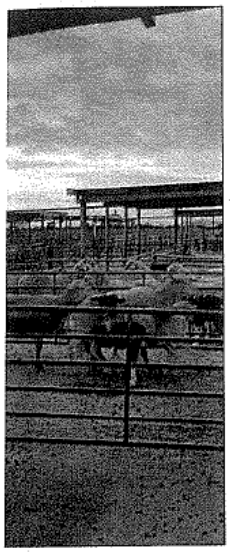
Details: Visit https://research.csiro.au/fmd/

GROWING SA

The 2019 GROWING SA Conference promises to be the biggest yet, with a new format set to provide delegates with farm business, research and policy information relevant to South Australia's grain and livestock industries. Hosted by Grain Producers SA and Livestock SA, the 2019 event will be held over two days at the Adelaide Hills Convention Centre, Hahndorf, on Monday 26 August and Tuesday 27 August. GPSA and Livestock SA will host their annual general meetings on the Monday, which will be followed by a conference dinner in the evening. The dinner will celebrate the region's fine produce and enable producers and industry representatives from across the state, and from all industries, to network. Tuesday will offer a full day of plenary speakers, attracting local, national and international guests to stimulate discussion and introduce new ideas, with a mix of in-depth and short, sharp presentation styles.

Details: Visit www.growingsa.com.au

Supplement S6 Survey advert in Livestock SA newsletter, April 2019.



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ARITY WANING

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dence must be top priority in
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e itself is an activist group,
on behalf of its members -
er, BASF, Corteva, NuFarm,
Sumitomo - and donates to
es.
that CropLife's letter fudges
GM crop performance and

prospects.

For example, its letter trumpets that 17 million farmers in 24 countries grew GM crops in 2017.

But the global GM industry was already in decline by then. At its peak, in 2015 more than 18 million farmers grew GM, while in 2011 GM cotton, soy, corn and canola were grown in 29 countries.

GM crops are not a global industry. Of the 24 countries growing GM in 2017, just five grew more than 91 per cent of all GM crops - the United States, Brazil, Argentina, Canada and India.

Australia ran 12th at 0.9 million hectares and other countries' GM acreages were vanishingly small.

CropLife points to Australian field trials as a sign that GM crops have a future.

But crop plant field trials date back to the late 1980s and publicly-funded trials only produced some herbicide tolerant and Bt insect resistant GM cotton varieties, using Monsanto's patented genes on which it levies a hefty fee. The drought and salt tolerant cotton that was promised has not appeared.

As CropLife agrees, transition to a sustainable future for Australian agriculture is urgently needed.

But it will be based on regenerative farming systems, integrated pest management, and small soil husbandry, not GM crop plants, animals or microbes.

The oil, phosphates and other rapidly depleting inputs on which intensive industrial farming depends will soon be too scarce and expensive to be used on farms.

So public research and development resources should be redirected from input dependent, intensive and industrial agriculture into the systems that will still work with climate change, scarce water and soil.

This change should be a top priority for whoever governs Australia next, as we and our kids must be reliably fed, clothed and housed into the future.

Bob Phelps,
Gene Ethics executive director.

PPSA

NRM change: Primary Producers SA is pleased with the proposed new Landscape SA bill. Before the last state election, PPSA had called for Natural Resource Management boards to have control of both staff and budgets and with a greater emphasis for "on ground" projects. It is hoped that replacing NRM boards with nine new regional landscape boards will give local communities and landholders a greater voice, while delivering effective water management, pest, plant and animal control, soil and land management and support for broader sustainable primary production programs.
▮ Details: Rob Kerin 0439 933 103.

Barley update: Grain Producers SA has provided an update on market access for imidazolinone-tolerant barley varieties as part of the ongoing anti-dumping investigation against Australian barley. This recommends growers carefully consider the use of imidazolinone chemicals on their imi-tolerant barley varieties. Industry groups are working with key markets such as South Korea and Japan to establish appropriate import tolerances for imazamox, imazapic and imazapyr. Growers should be mindful of their intended grain sales options for the 2019 harvest.
▮ Details: Caroline Rohdes 1300 734 884.

Q fever survey: Livestock SA invites livestock producers to participate in an online survey onThe One Health approach to Q fever prevention and control in SA. The aim is to get producer opinions and perspectives concerning Q fever prevention and control. As Q fever is transmitted from animals to humans, a One Health approach has recently been recognised to be efficient in disease prevention because of its interdisciplinary nature linking human, animal and ecological sectors.
▮ Details: surveymonkey.com/r/SBTXTY5

Underpasses for dairy: The SA Dairyfarmers' Association is looking for partners to participate in an application to the Regional Growth Fund to build underpasses to improve the commerciality of the dairy industry. There are challenges surrounding underpasses and the adverse effects the absence of underpasses can have. As SADA meets the requirements to be a project entity, it is calling for expressions of interest in a proposed underpass project.
▮ Details: John Elferink 08 8293 2399.

IDELINES

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