ORIGINAL ARTICLE

Q Fever (*Coxiella burnetii*) Knowledge and Attitudes of Australian Cat Breeders and Their Husbandry Practices

A. J. Shapiro[1], J. M. Norris[1], K. L. Bosward[2] and J. Heller[3]

[1] Faculty of Veterinary Science, The University of Sydney, NSW, Australia
[2] Faculty of Veterinary Science, The University of Sydney, Camden, NSW, Australia
[3] School of Animal & Veterinary Sciences, Charles Sturt University, Wagga Wagga, NSW, Australia

Impacts

- Cat breeders are at risk of acquiring Q fever, due to husbandry practices and environments that may expose them to infection with *Coxiella burnetii.*
- A significant Q fever knowledge gap was identified in respondent cat breeders.
- Education forums are recommended to inform Australian cat breeders of the aetiopathogenesis of Q fever.

Keywords:
Coxiella burnetii; Q fever; cat breeders; knowledge and attitudes; breeding practices; risk

Correspondence:
A. J. Shapiro. Faculty of Veterinary Science, The University of Sydney, Building B14, Sydney, NSW 2006, Australia. Tel.: +61 2 9351 7094; Fax: + 61 2 9351 7348; E-mail: amanda.shapiro@sydney.edu.au

Received for publication January 26, 2016

doi: 10.1111/zph.12305

Summary

A Q fever outbreak in a small animal veterinary hospital, associated with a cat caesarean section, initiated a cat seroprevalence study (n = 712) that found circulating antibodies to *Coxiella burnetii* was highest in cattery-confined breeding cats (9.3%). These findings stimulated interest about potential sources of *C. burnetii* infection for cats and humans associated with cats. Cat breeders are potentially a group at increased risk of *C. burnetii* infection, and this study sought to identify potential risk factors. A cross-sectional online survey was conducted targeting all domestic cat breeders registered with an affiliate member body in Australia in 2015. Responses from 177 cat breeders across Australia were analysed. Forty per cent of responding cat breeders had not heard of Q fever. Raw meat was fed as an integral constituent of the diet by 89% of respondents. Eighty per cent of respondents allowed queens access to the home for parturition, and assistance of queens and resuscitation of kittens at the time of birth were reported by 97% of respondents. Respondents who perceived some level of exposure to Q fever through their breeding activities were three times less likely to perform mouth-to-snout resuscitation (OR 0.3 95% CI 0.1–0.9; P = 0.034) than those who did not perceive a risk of exposure. Similarly, respondents who perceived Q fever as a risk through breeding activities were close to eight times more likely to use personal protective equipment during parturition (OR 7.7 95% CI 1.5–39.9; P = 0.015) than those who did not. Husbandry practices of cat breeders that may increase the risk of *C. burnetii* transmission require further targeted investigations to assess the contribution of these risk factors to the acquisition of disease. Concurrent education forums are recommended to inform Australian cat breeders of the aetiopathogenesis of Q fever.

Introduction

Coxiella burnetii is the aetiological agent responsible for the worldwide zoonotic disease, Q fever. While Q fever in humans is well characterized, the syndrome in animals, coxiellosis, is largely uncharacterized. Domestic ruminants have traditionally been seen as the primary reservoirs of infection for humans (Guatteo et al., 2011), yet studies originating from maritime provinces of Canada have confirmed periparturient cats as an important reservoir species in that region (Marrie et al., 1985, 1988a,b, 1989). In the United Kingdom (UK), assessment of *C. burnetii* seroprevalence in prey and predatory species found that both wildlife and domestic cats may serve as important

transmitters of *C. burnetii* infection to humans (Meredith et al., 2015). Australia has one of the world's highest annual Q fever notification rates (Gidding et al., 2009), coupled with a recent increase in reports of disease not attributable to the traditional reservoir host species (Woldehiwet, 2004; Angelakis and Raoult, 2010). Consequently, a multitude of novel host animals have recently come under investigation as sources of *C. burnetii* transmission in Australia (Cooper et al., 2011, 2012a,b; Tozer et al., 2014; Shapiro et al., 2015, 2016a).

This study commenced in response to a Q fever outbreak following exposure of veterinary personnel to a *C. burnetii*-infected periparturient queen undergoing an emergency caesarean section. Serological investigations of all breeding cats from the queen's cattery of origin provided evidence of *C. burnetii* exposure in many of the cats (Kopecny et al., 2013). These findings led to the serological investigation of four feline subpopulations ($n = 712$), exploring exposure of domestic and feral cats in eastern Australia to *C. burnetii* (Shapiro et al., 2015). Circulating antibodies to *C. burnetii*, indicative of current and/or past exposure, were highest in the cattery-confined breeding cat cohort, with 9.3% of these cats seropositive. The Australian Government's Department of Health subsequently included cat breeders in the 10th edition of the Australian Immunisation Handbook as individuals at potential risk of Q fever infection in Australia with the recommendation that they be vaccinated (ATAGI, 2015).

Correspondence with a small number of local cat breeders following dissemination of the serological results above revealed that many breeders were unfamiliar with Q fever. Conversely, a few cat breeders had extensive knowledge of the disease, having themselves been, or knowing of someone medically diagnosed with Q fever. With the cat-associated outbreak of Q fever resulting from contact with a periparturient cat and the knowledge that *C. burnetii* attains highest infectious concentrations in the placenta and birth products (Abinanti et al., 1953), cat breeders are potentially at great risk of *C. burnetii* exposure if the organism is present in their breeding cats. A questionnaire was developed which aimed to (i) assess current knowledge of, and attitudes to, Q fever in cat breeders in Australia; (ii) investigate husbandry practices and procedures of cat breeders; and (iii) assess potential differences in husbandry practices between those with clinically diagnosed Q fever (personal and household cases) and those who have never been diagnosed with the disease.

Materials and Methods

Study design

This cross-sectional study targeted all domestic cat breeders across Australia registered with any state or territory cat breeder organization. The questionnaire was implemented using the online platform Survey Monkey® (Palo Alto, California, USA) and contained 45 questions (14 closed, 15 open and 16 semi-closed) divided across six sections concerning (i) the cat breeder and their work, (ii) knowledge and attitudes regarding Q fever, (iii) knowledge and attitudes regarding Q fever vaccine, (iv) knowledge and attitudes regarding likely exposure to Q fever, (v) husbandry procedures including diet of cattery-confined cats and (vi) practices and procedures related to cat mating and parturition. It was not compulsory for participants to answer all questions, and skip logic (feature in questionnaire design allowing participants to skip questions that are not relevant to them based on their response to a particular question) was utilized in the questionnaire. The study was approved by the Human Research Ethics Committee of the University of Sydney (Project No. 2015/032). A participant information statement was provided explaining the purpose, nature and consequences of the study, and participant consent was obtained prior to commencement of the questionnaire.

Recruitment of cat breeders

Recruitment of cat breeders took place from March to May 2015 by two methods: email invitations sent directly to cat breeders (obtained from the cat breeder organizations' websites) and/or recruitment email invitations sent to breeders by the member organizations' secretaries on the authors' behalf. The recruitment process was aided by the two overarching cat breeding organizations in Australia: Coordinating Cat Council of Australia Inc. and The Australian Cat Federation Inc. These organizations oversee 17 affiliate organizations. These include the following: New South Wales (NSW) Cat Fanciers Association, Capital Cats Inc., Feline Control Council of Victoria Inc., Feline Association of South Australia Inc., Cats Queensland Inc., Cat Control Council of Tasmania, Cats NSW Inc., Cat Association of the Northern Territory Inc., Feline Control Council of Queensland Inc., Queensland Feline Association Inc., Queensland Independent Cat Council Inc., Governing Council of the Cat Fancy of South Australia Inc., Cat Association of Tasmania, Cats Victoria Inc., Governing Council of the Cat Fancy of Australia & Victoria, Cat Owners Association of Western Australia (WA) and Cats WA. Reminder emails were sent on two occasions with an interval of three weeks between emails.

Data management and analysis

Data were extracted from Survey Monkey®, transferred to Microsoft Excel format (Microsoft Office 2010) and subsequently imported into GenStat 16.1 (VSN International,

Hemel Hempstead, UK) and into the online statistical software http://statulator.com/ (Khatkar and Dhand, 2014) for analyses. Descriptive analyses produced frequency tables, from which graphical analyses were performed. Non-dichotomous data were collapsed and recategorized to create dichotomous outcomes (e.g. for level of exposure to Q fever, five original categories were collapsed into two with either 'no' exposure (no) or 'yes' exposure (very low, low, moderate and high).

The relationship between putative risk factors and potentially risky husbandry practice were explored using univariable analyses. Five binary outcome variables were chosen: feeding of raw meat (yes/no), use of Personal Protective Equipment (PPE) (yes/no), birth location of queen (home/cattery), disinfection of birth environment (yes/no) and the use of mouth-to-snout resuscitation (yes/no). For each outcome variable, the following risk factors were explored for association using chi-squared analyses: knowledge of Q fever (yes/no), a diagnosis of Q fever in the respondent's household (yes/no), a perception of risk in relation to breeding cats and Q fever (yes/no), exposure to Q fever (yes/no), and perceptions and concern of exposure to Q fever in friends and family visiting the cattery (yes/no). *P*-values of <0.05 were considered significant, and 95% confidence intervals were calculated. Respondents who consented to the survey but failed to complete the majority (>90%) of the questions were excluded from the statistical analyses.

Results

Sampling

A total of 938 emails were sent to potential participants. Of these, 42 emails were undeliverable and one recipient responded that the email was not applicable. Therefore, a total of 895 participants were contacted for involvement in the study, and a total of 177 responses were received resulting in a response rate of 19.8%.

Demographics

The sample population of responding cat breeders consisted of 92% females and 8% males. The distribution of breeders' age was negatively skewed (median = 58 years, range = 17–78 years). Respondents currently breeding cats represented 85% of participants, and 60% of catteries had only one person working at the cattery, while the remaining catteries had two (29%), three (7%), four (3%) and five (1%) employees. Of the 67% (118 of 177) of respondents who entered a location postcode, 31 (26%) were from NSW (New South Wales), 53 (45%) from Queensland (Qld), 16 (14%) from Victoria (VIC), 8 (7%) from WA (Western Australia), 4 (3%) from South Australia (SA), 2 (2%) from Tasmania (TAS) and 4 (3%) from the Northern Territory (NT).

Knowledge and attitudes regarding Q fever disease

Of the respondents to this section, 40% (49 of 123) had not heard of Q fever. These participants did not answer any further Q fever knowledge and attitudes questions and were redirected to the Q fever vaccine section. Within those who had heard of Q fever (74 of 123), knowledge regarding this disease was obtained most commonly through word of mouth (41%), Internet (32%) and 'other' sources (34%), including incidents of Q fever disease in family members, the workplace and other breeders. Eighty-eight per cent (65 of 74) accurately identified at least one species that may transmit Q fever to humans. However, only 9% (7 of 74) correctly identified all eight species in the survey while 1.3% (1 of 74) did not think that any animals transmitted Q fever, and 26% (19/74) identified that it could be transmitted from humans (Figs 1a and b).

Fifty-four per cent of breeders who had heard of Q fever (40 of 74) reported that breeding cats represent some level of risk in the transmission of Q fever to humans. However, 20% did not perceive cats as a species of risk (Fig. 2). Within the group that reported some level of risk from breeding cats, 80% (32 of 40) perceived they have been exposed, at some level, to the organism causing Q fever. Perceptions of Q fever risk were positively associated with the perceived level of exposure to Q fever ($P < 0.001$) (Fig. 3). The perceived level of exposure to Q fever through cat breeding activities were grouped as no exposure (30%), low exposure (43%), moderate exposure (20%) and high exposure (7%). Forty-seven per cent of respondents ($n = 34$) stated that they were concerned that people visiting their catteries could be exposed to Q fever and the majority of these respondents (30 of 34) were concerned that their families could also be exposed.

Knowledge and attitudes regarding Q fever vaccination

Only 2% of respondents ($n = 3$) were vaccinated against Q fever despite 28% ($n = 35$) being aware that a Q fever vaccine was available in Australia. However, 73% ($n = 87$) of participants noted a willingness to be vaccinated against Q fever in the future. Among the respondents that were willing to be vaccinated, 37% (32 of 87) had never heard of Q fever and 14% (12 of 87) did not perceive a Q fever risk from contact with breeding cats.

Knowledge and perceptions of Q fever exposure

Seven respondents identified that they had previously been diagnosed with Q fever (six female, one male), and we termed these 'personal Q fever cases'. The diagnoses of Q fever in these seven individuals were made by medical practitioners with six requiring hospitalization for their illness and

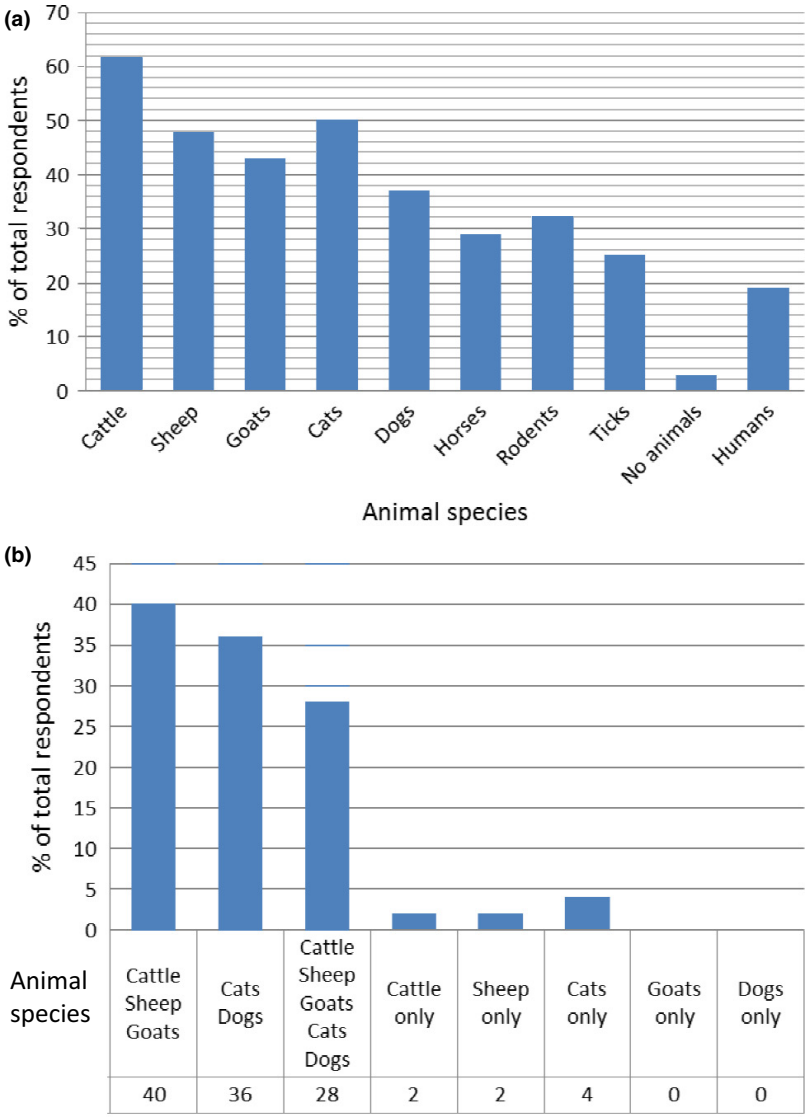

Fig. 1. Animal species identified as capable of transmitting Q fever to humans. Bar graphs represent a) individual animal species and b) combinations of animal species.

ongoing treatment. A further 26 respondents personally knew of people medically diagnosed with Q fever. A total of 61 Q fever cases were known to these 26 respondents, with 14 respondents knowing more than one person with Q fever (Fig. 4). The occupations of all known Q fever cases were classified as follows: non-animal related (46%), farming/meat works (27%), veterinary related (15%) and animal breeder (12%). In determining the relationship of the respondent to the Q fever patient, 45% of breeders identified these cases to be part of their immediate family, 37% were friends/acquaintances, 11% had no relationship with the respondent and 7% were neighbours. Four respondents without Q fever reported that an individual that lived in their household had been diagnosed with Q fever. Due to overlap of personal and familial cases, a total of 11 respondents reported a history of Q fever within their household. These respondents will subsequently be termed 'household Q fever cases'.

Five of the 11 household Q fever cases strongly agreed that cat breeders in general are at risk of Q fever while four disagreed with this statement and two had a neutral response. Two household Q fever cases felt that they had had no personal exposure to Q fever over the course of their cat breeding careers, five felt that they had received low, two moderate and two high levels of exposure. Of the four respondents above who did not perceive a risk of Q fever from contact with breeding cats, three felt they had been exposed to Q fever during the course of their cat breeding activities. The availability of a Q fever vaccine was not known by three of the 11 household Q fever cases. Q

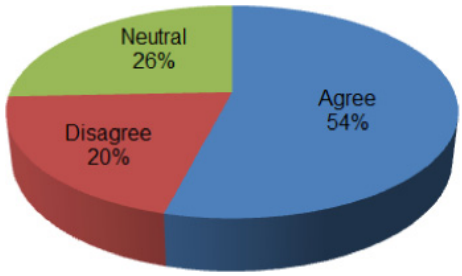

Fig. 2. Cat breeders' perception of Q fever risk from breeding cats. Responses of breeders (n = 74) who identified that they had heard of Q fever to the statement: 'Cat breeders are at risk of Q fever from contact with breeding cats.'

fever household cases knew of a total of 21 other people diagnosed with Q fever. Four of the seven people who reported having Q fever themselves also lived in a household with other Q-fever infected people.

Three of the seven personal Q fever cases responded that veterinarians have in the past suspected Q fever in their cattery cats. Of the 11 household Q fever cases, three (one a personal case) had their cats tested serologically for *C. burnetii* based on routine pregnancy checks or as a cause for reproductive abnormalities. Of these 11 household Q fever cases, two were from NSW, five from QLD and one from the NT, and the remaining three Q fever cases did not enter postal codes. Personal Q fever cases were reported to have occurred between the years 2000 and 2012. No significant difference in Q fever knowledge was evident between respondents from the different states and territories.

Husbandry practices within the cattery

Movement of cats

Catteries are often classified as being either closed or open, where open refers to allowing movement of resident cats to and from the cattery, as well as visiting cats into the breeding establishment, while closed prevents all movement of breeding cats to and from the cattery. Sixty-two per cent of respondents identified that their catteries were closed. Respondents were requested to detail, under specified locations, the time spent by their breeding cats within different living environments. It was reported that kittens as well as queening, non-pregnant and pregnant cats were located within the home environment 83–95% of the time. In comparison, male cats were allowed within rooms of the home only 25% of the time.

Dietary constituents

When analysing the multiple dietary constituents fed to cats, 89% of respondents reported feeding raw meat to their cats as an integral part of their diets, together with commercial dry (65%), commercial wet (59%) and home cooked (27%) food. Further assessment of the raw dietary constituents revealed that 50% fed raw beef, 36% raw chicken, 31% raw kangaroo and 23% raw bones. Raw meat products were reported to be sourced from supermarkets (80%), local butchers (47%), pet food stores (38%) and abattoir outlets (16%).

Mating locations

Mating locations occurred on the property with only resident cats in 62% (76 of 122) of respondents to this section. Twenty per cent (25 of 122) of respondents to this section reported mating of cats on the property with both resident and external cats, and 18% (22 of 122) reported mating occurring on external properties with cats from other properties.

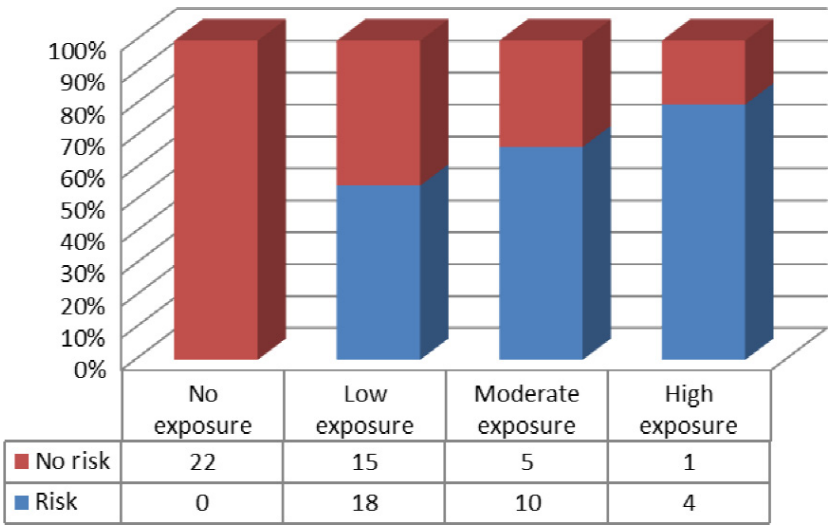

Fig. 3. Positive association between cat breeders' perceptions of Q fever risk due to contact with breeding cats, and their perceived level of Q fever exposure as a result of cat breeding activities ($P < 0.001$).

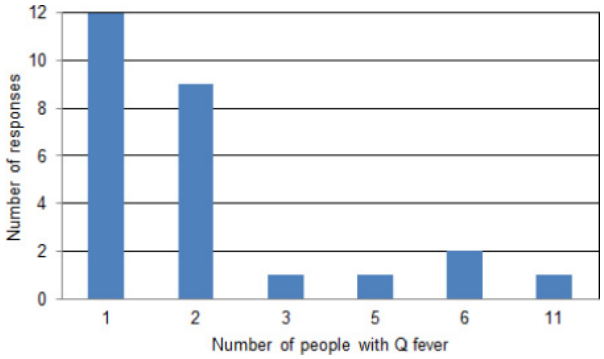

Fig. 4. Q fever patients known to breeders. Number of people medically diagnosed with Q fever who are known to survey respondents.

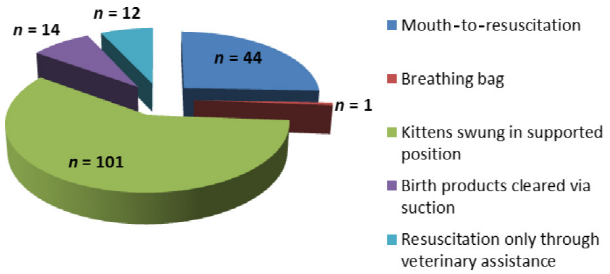

Fig. 5. Methods of kitten resuscitation practiced by survey respondents $n = 113$. Note some respondents practiced more than one method of resuscitation.

Birthing process

Many respondents allowed queening cats to give birth within the home environment (80%, 91 of 114), with a large percentage of these within the bedroom or bathroom (37%, 42 of 114) of the breeder. Confining the queening cat to a cattery enclosure was reported to occur less frequently (22%, 25 of 114).

Assistance at the time of birth is given to queens by 97% of breeders (113 of 116), including resuscitation of non-breathing kittens. Methods of resuscitation varied in frequency; 101 (89%) respondents reported that they swing kittens in a supported position, 44 (39%) performed mouth-to-snout resuscitation, and 14 (12%) cleared birth products from airways via a suction catheter, while 12 (11%) allow for resuscitation of kittens through veterinary assistance (Fig. 5). Those respondents who thought that they had at least some level of exposure to Q fever through breeding activities had a third of the odds of performing mouth-to-snout resuscitation compared to those who did not think that they were exposed to Q fever through breeding activities (OR 0.3 95% CI 0.1–0.9; $P = 0.034$) (Table 1).

When assisting queens at the time of birth, 53% ($n = 57$) of breeders stated they did not use any form of PPE. Of those using PPE (47%, $n = 50$) all used gloves, seven wore overalls, four wore a mask and one reported wearing goggles/protective glasses (Fig. 6). A significant association was identified between the use of PPE and perception of the risk of Q fever transmission in breeding catteries. Those respondents who perceived a risk of Q fever through cat breeding activities were approximately eight times more likely to use PPE at the time of birth than those who did not perceive this same risk (OR 7.7 95% CI 1.5–39.9; $P = 0.015$) (Table 1).

Following the birth process, 35% (41 of 117) of respondents stated that the birth environment was thoroughly cleaned and disinfected with chemical disinfectants. With respect to disposal of the birth products, 43% of respondents report feeding part or the entire placenta to the queen, 23% discarded the products in the rubbish bin, 3% allow it to remain with the queen, 2% place it in biological waste containers, and 1% of breeders bury the products of birth. The remaining breeders mentioned various other methods of disposal such as 'flush down toilet', place birth products single or double bag then discard placed in bin or incinerate.

Discussion

This study investigated Australian cat breeders' knowledge of, and attitudes to, Q fever, together with an evaluation of their husbandry practices that may potentially place them at risk of acquiring Q fever. The large number of

Table 1. Logistic regression analysis of variables with a statistically significant association; mouth-to-snout resuscitation (M to S) and perceived level of exposure to Q fever and personal protective equipment (PPE) and risk perception of Q fever through contact with breeding cats

Risk factor	Categories	B	SE	Odds ratio	Lower 95%	Upper 95%	*P* value
M to S	Constant	0.182	0.428	0.3	0.1	0.9	0.034
	Exposure	−1.127	0.531				
PPE	Constant	−1.705	0.768	7.7	1.4	39.8	0.015
	Risk perceptions	2.041	0.839				

B, estimate; SE, standard error.

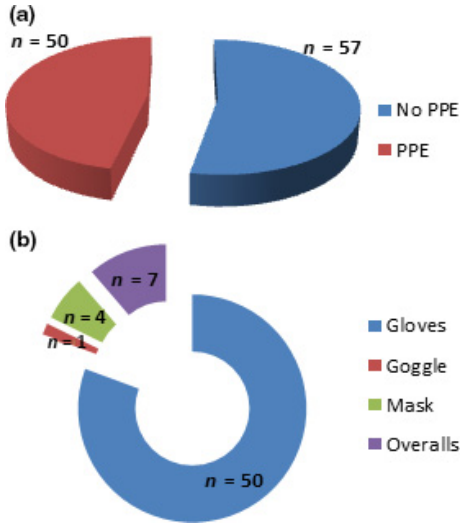

Fig. 6. (a) Personal Protective Equipment usage by cat breeders. a) Survey respondents (n = 107) use of Personal Protective Equipment (PPE) at the time of kitten birth; and b) Breakdown of the type of PPE used by the respondents (n = 50) who reported routinely using PPE at the time of birth.

participating cat breeders in this survey with medically diagnosed Q fever (6% of study population) compared with the mean annual notification rate of the general population (0.002%) is supportive of the identification of cat breeders as an at-risk group of acquiring Q fever. The findings obtained from this study, allow a greater understanding of the potential risk factors for *C. burnetii* transmission from cats to humans that will allow for the implementation of national cat breeder education forums, empowering the cat breeding community with knowledge of Q fever to inform their practices. Cat breeders should be informed of the availability of and need for Q fever vaccination for those at risk and also be made aware of the potential for *C. burnetii* transmission from cats to humans during the periparturient period with a critical need for PPE and other biosecurity measures at this time.

Comparison of cat breeder distributions across Australia indicates that those from QLD were more likely to respond to the questionnaire than breeders from other states and territories in Australia. A possible explanation for the greater response rate from QLD cat breeders may be the higher Q fever notification rates in QLD with suspected greater disease awareness compared to other states and territories in Australia. Household Q fever cases (n = 11) were recorded between the years 2000 and 2012 and were from NSW (n = 2), QLD (n = 5) and the NT (n = 1). Mean annual Q fever notification rates in NSW, QLD and the NT from 2000 to 2012 were 335, 412 and 4 cases, respectively (NNDSS – Australian Government, 2015). Q fever among cat breeders follows a similar state distribution to that of expected notifications in the general population. Cat breeders comprise a small proportion of the overall Australian population but appear to be an occupational group that are over-represented with respect to Q fever notifications based on the current study. National Q fever notification rates per 100 000 population over the years 2000–2012; mean notifications for NSW, QLD and the NT were 5, 6 and 1 per 100 000 population, respectively (NNDSS – Australian Government, 2015). According to the member affiliate organizations, registered cat breeder numbers are as follows: NSW ($n \approx 500$), QLD ($n \approx 200$) and the NT (n = 6) Using these numbers, conversion of the cat breeder reported Q fever cases equates to 400, 2500 and 17 cases per 100 000 population, and this is with the very conservative assumption that no other cases exist outside those reported in this questionnaire. These crude calculations emphasize that cat breeders must be considered at increased risk of Q fever infection and disease from cat breeding activities in Australia and possibly elsewhere where Q fever is reported.

It must be acknowledged that self-selection bias which is defined as a subgroup of the sample population with significantly different experiences of the survey topic from the general population, responding to a survey in higher proportions than those with similar experiences to the general population (Whitehead, 1991). Therefore, the potential for survey selection bias may have existed among cat breeders who suffered as Q fever patients, making them more likely to respond than those unaffected by the disease. However, research has shown that self-selection bias may not have large impacts on some prevalence and exposure-outcome association studies (Søgaard et al., 2004; Nilsen et al., 2009). Yet, it remains probable that the potential for self-selection bias by respondents may have led to a high rate of inclusion of Q fever patients, creating a potential over-representation of Q fever cases in the survey. Additionally, the response rate of 19.8% may introduce a further limitation into this study through unknown biases as a result of a smaller sample population surveyed. However, even if the total number of medically diagnosed Q fever cases (n = 11) reported in this study were the only Q fever cases within the entire group of cat breeders that were approached (n = 895), this would equate to a prevalence of 1.2%, which is 200 times greater than the prevalence (0.006%) in the general QLD Australian population.

Hospitalization was required for six of the seven (86%) Q fever cases identified in the respondents of this study. This rate of hospitalization far exceeds overall reports in the literature that estimate Q fever hospital admissions at 4% of all symptomatic cases (Angelakis and Raoult, 2010), with the possibility that these individuals may be exposed to higher infective bacterial loads as a result of resuscitation

methods performed at parturition. The severity of Q fever experienced by these respondents suggests that only severely symptomatic Q fever diagnoses have been reported in this study, with the possibility of undiagnosed, unreported and asymptomatic cases of Q fever highly prevalent within the study population. As cat breeders have not previously been recognized as a Q fever risk group, the disease prevalence estimated by this study population is likely to be conservative and underestimated. Based on reported Q fever outbreaks worldwide, the majority (60%) of Q fever disease in studied patients is asymptomatic, or mild and brief (Dupuis et al., 1987), requiring no medical intervention (Maurin and Raoult, 1999). It is highly probable that a far greater percentage of the cat breeding community than reported may have current or past infection with *C. burnetii,* with seroconversion serving as the only evidence. A future nationwide serosurvey of all cat breeders would provide valuable information on the overall immune status of cat breeders in Australia.

Potential sources of *C. burnetii* infection for humans include contact with *C. burnetii*-contaminated tissues, birth products and neonates. Importantly, four potential risk factors for the transmission of *C. burnetii* in breeding catteries have emerged from this study: feeding and handling raw meat, location of parturition, assistance provided at time of birth and the use of PPE. The first putative factor to be explored is the widespread inclusion of raw meat as an integral constituent of the diet of cattery-confined breeding cats. Raw meat intended for pet consumption in Australia falls under the control of the Primary Industries Standing Committee (PISC) Technical Report 88 – Amended 2009 '*Standard for the Hygienic Production of Pet Meat*' (PISC, 2009). Microbial contamination of these raw meat products is not monitored. The current study identified cat breeders as a subpopulation with higher prevalence of Q fever, with 89% of respondents frequently handling raw meat products, a far greater proportion compared to that of the general population. These findings lead to the creation of a hypothesis that raw meat intended for pet consumption may serve as a source of *C. burnetii* for cats and humans. This hypothesis was explored in a recent pilot study demonstrating *C. burnetii* DNA in raw meat of primarily kangaroo origin produced for the pet meat industry in Australia (Shapiro et al., 2016b). Further large-scale investigations are required to definitively determine the implications of these findings, yet the overarching conclusion from the pilot study was that DNA with 100% homology to *C. burnetii* was present in 64% of the raw meat samples examined and 100% of these samples contained kangaroo as a constituent. Raw meat intended for pet consumption warrants further investigation and pre-emptive implementation of food safety education forums for cat breeders handling all fresh food products is required.

The second and third *C. burnetii* risk factors identified were location of, and assistance given to, the queen at the time of parturition. Inhalation of *C. burnetii*-infected aerosols arising from the feline birth environment, foetal membranes and neonates has been responsible for numerous Q fever outbreaks (Kosatsky, 1984; Langley et al., 1988; Marrie et al., 1989; Pinsky et al., 1991; Kopecny et al., 2013). The majority of respondents stated that queens are brought into the home environment at the time of birth, thereby increasing potential contact between infectious *C. burnetii* excreta and humans. Within the cat breeding industry, breeders are favoured for kittens born and raised within the family home and this is promoted on their websites. The veterinary community can exercise their duty of care towards cat breeding clients by recommending that designated birthing environments, wherein infection can be controlled and be solely used for queening cats and that parturition should not occur near the living environments of people. Respondents also indicated that mouth-to-snout resuscitation is a common method of reviving non-breathing kittens at the time of birth. The Compendium of Veterinary Standard Precautions for Zoonotic Disease Prevention in Veterinary Personnel lists *C. burnetii* as a common zoonotic pathogen present in birth fluids and advises that veterinary personnel never blow into the mouth or nose of non-respiring neonates (Turra et al., 2006). However, as demonstrated from this study, the outdated practice of neonatal mouth-to-snout resuscitation still exists in many parturient environments despite the recent availability of devices that safely allow for resuscitation of kittens and puppies. In addition, results of this study indicate that those breeders perceiving a level of *C. burnetii* exposure through their breeding activities are three times less likely to practice mouth-to-snout resuscitation. While we cannot speculate on the reason for this association, it is hoped that knowledge of risk drives good practice, eliminating this potentially dangerous resuscitation method, and knowledge of zoonotic pathogen transmission to those present at the time of birth of cats is speedily disseminated.

The final *C. burnetii* risk factor is the use of PPE during the periparturient stage by those assisting the queen and kittens or involved in disinfection and disposal activities around the time of birth. Respondents perceiving Q fever as a risk through breeding activities were close to eight times more likely to use PPE. It is recommended to veterinarians that barrier precautions including the use of gloves, facial protection, sleeves and impermeable outerwear be worn for all obstetric cases in the prevention of exposure to infective zoonotic agents (Turra et al., 2006). Similar guidelines, along with those pertaining to the location of parturition and assistance at the time of birth, require urgent communication to the cat breeding community. Imparting knowledge on *C. burnetii* transmission from

animals to humans as well as control and prevention of transmission to humans is a primary and crucial responsibility of the veterinary community, especially in the face of increasing Q fever cases in the absence of traditional reservoir host species.

Assessment of differences in *C. burnetii* risk factors between those having been, or never having been medically diagnosed with clinical Q fever, either personally or within the home environment, found no statistically significant associations. The small sample size of household Q fever cases and potential undiagnosed Q fever cases within the non-Q fever group creating limitations and bias in correctly identifying and comparing the two groups may contribute to the inability to find associations if present. Interestingly, a substantial percentage (40%) of those identifying a perceived level of Q fever exposure through contact with breeding cats do not think these cats pose a risk of Q fever. Those respondents who identified that they did not think that exposure to the causative agent occurred through cat breeding activities also did not perceive any risk of Q fever from breeding cats (Fig. 3). However, a (decreasing) proportion of those who perceived some level (low, moderate or high) of exposure to Q fever through their cat breeding activities also reported that cat breeders are not at risk of Q fever from contact with breeding cats. The exact cause of these trends in perceived Q fever exposure and risk are unclear. Pathways of Q fever causation in those who reported having Q fever were not able to be studied, and the presence of Q fever infection was not observed to influence current behaviours with respect to infection control procedures by those affected by the disease identified in this study. However, it may be that breeding practices changed for those participants following their clinical Q fever diagnoses, and therefore, the practice of risky behaviours were not able to be correlated with infection status in this study because participants only reported their current practice.

Conclusion

Cat breeders engage in husbandry practices as part of their daily work that vastly differs from the general cat-owning community in Australia, with potential exposure to sources of *C. burnetii* infection from frequent contact with birth products, fluids and *C. burnetii*-contaminated environments. A significant knowledge gap on Q fever (epidemiology, clinical disease, vaccination and prevention) is present among cat breeders in Australia. Risk perceptions of Q fever influence overall attitudes towards the disease in study respondents. Potentially risky husbandry practices in relation to cat breeding were identified, leading to the crucial need for further studies investigating sources of *C. burnetii* for cats and cat breeders. The identified risk factors require the implementation of education forums, aimed at equipping cat breeders with current and evidence based standard operating procedures during the periparturient period, to help prevent the transmission of this emerging zoonotic infectious disease.

Acknowledgements

The authors would like to thank Navneet Dhand of The University of Sydney for statistical advice and Damien McMonigal of The University of Sydney for data management assistance. The authors would also like to thank the Coordinating Cat Council of Australia Inc. and The Australian Cat Federation Inc. for their assistance in administering the online survey.

Funding

This research was supported by a competitive grant obtained from the Australian Companion Animal Health Foundation (Australian Veterinary Association).

Conflict of Interest

The authors do not have any potential conflict of interests to declare.

References

Abinanti, F. R., H. H. Welsh, E. H. Lennette, and O. Brunetti, 1953: Q fever studies. 16. Some aspects of the experimental infection induced in sheep by the intratracheal route of inoculation. *Am. J. Hyg.* 57, 170–184.

Angelakis, E., and D. Raoult, 2010: Q fever. *Vet. Microbiol.* 140, 297–309.

ATAGI, A. T. A. G. o. I., 2015: Part 4.15 Q fever. In: A. G. D. o. Health (ed.), The Australian Immunisation Handbook (2015 Update), 10th ed, pp. 355–362. Australian Technical Advisory Group on Immunisation, Canberra.

Cooper, A., R. Hedlefs, N. Ketheesan, and B. Govan, 2011: Serological evidence of *Coxiella burnetii* infection in dogs in a regional centre. *Aust. Vet. J.* 89, 385–387.

Cooper, A., T. Barnes, A. Potter, N. Ketheesan, and B. Govan, 2012a: Determination of *Coxiella burnetii* seroprevalence in macropods in Australia. *Vet. Microbiol.* 155, 317–323.

Cooper, A., M. Goullet, J. Mitchell, N. Ketheesan, and B. Govan, 2012b: Serological evidence of *Coxiella burnetii* exposure in native marsupials and introduced animals in Queensland, Australia. *Epidemiol. Infect.* 140, 1304–1308.

Dupuis, G., J. Petite, O. Peter, and M. Vouilloz, 1987: An important outbreak of human Q fever in a Swiss alpine valley. *Int. J. Epidemiol.* 16, 282–287.

Gidding, H. F., C. Wallace, G. L. Lawrence, and P. B. McIntyre, 2009: Australia's national Q fever vaccination program. *Vaccine* 27, 2037–2041.

Guatteo, R., H. Seegers, A. F. Taurel, A. Joly, and F. Beaudeau, 2011: Prevalence of *Coxiella burnetii* infection in domestic ruminants: a critical review. *Vet. Microbiol.* 149, 1–16.

Khatkar, M. S., and N. K. D hand, 2014: Statulator: An online tool for basic statistical analysis., http://statulator.com/ Glide Analytics

Kopecny, L., K. L. Bosward, A. Shapiro, and J. M. Norris, 2013: Investigating *Coxiella burnetii* infection in a breeding cattery at the centre of a Q fever outbreak. *J. Feline Med. Surg.* 15, 1037–1045.

Kosatsky, T., 1984: Household outbreak of Q fever pneumonia related to a parturient cat. *Lancet* 2, 1447–1449.

Langley, J. M., T. J. Marrie, A. Covert, D. M. Waag, and J. C. Williams, 1988: Poker players pneumonia - an urban outbreak of Q fever following exposure to a parturient cat. *N. Engl. J. Med.* 319, 354–356.

Marrie, T. J., J. Vanburen, J. Fraser, E. V. Haldane, R. S. Faulkner, J. C. Williams, and C. Kwan, 1985: Seroepidemiology of Q fever among domestic animals in Nova Scotia. *Am. J. Public Health* 75, 763–766.

Marrie, T. J., H. Durant, J. C. Williams, E. Mintz, and D. M. Waag, 1988a: Exposure to parturient cats - a risk factor for acquisition of Q fever in maritime Canada. *J. Infect. Dis.* 158, 101–108.

Marrie, T. J., A. Macdonald, H. Durant, L. Yates, and L. McCormick, 1988b: An outbreak of Q fever probably due to contact with a parturient cat. *Chest* 93, 98–103.

Marrie, T. J., D. Langille, V. Papukna, and L. Yates, 1989: Truckin pneumonia – an outbreak of Q fever in a truck repair plant probably due to aerosols from clothing contaminated by contact with newborn kittens. *Epidemiol. Infect.* 102, 119–127.

Maurin, M., and D. Raoult, 1999: Q fever. *Clin. Microbiol. Rev.* 12, 518–553.

Meredith, A. L., S. C. Cleaveland, M. J. Denwood, J. K. Brown, and D. J. Shaw, 2015: *Coxiella burnetii* (Q-Fever) seroprevalence in prey and predators in the United Kingdom: evaluation of infection in wild rodents, foxes and domestic cats using a modified ELISA. *Transbound. Emerg. Dis.* 62, 639–649.

Nilsen, R. M., S. E. Vollset, H. K. Gjessing, R. Skjaerven, K. K. Melve, P. Schreuder, E. R. Alsaker, K. Haug, A. K. Daltveit, and P. Magnus, 2009: Self-selection and bias in a large prospective pregnancy cohort in Norway. *Paediatr. Perinat. Epidemiol.* 23, 597–608.

NNDSS – Australian Government, D. o. H., 2015: National Notifiable Diseases Surveillance System. Available at: http://www9.health.gov.au/cda/source/cda-index.cfm.

Pinsky, R. L., D. B. Fishbein, C. R. Greene, and K. F. Gensheimer, 1991: An outbreak of cat associated Q fever in the United States. *J. Infect. Dis.* 164, 202–204.

PISC, P. I. S. C., 2009: Australian standard for the hygienic production of pet meat. AS 4841:2006 PISC Report 88 — Amended 2009. pp. 1–40. CSIRO PUBLISHING, Collingwood, Victoria, Australia.

Shapiro, A. J., K. L. Bosward, J. Heller, and J. M. Norris, 2015: Seroprevalence of *Coxiella burnetii* in domesticated and feral cats in eastern Australia. *Vet. Microbiol.* 177, 154–161.

Shapiro, A. J., J. M. Norris, J. Heller, G. Brown, R. Malik, and K. L. Bosward, 2016a: Seroprevalence of *Coxiella burnetii* in Australian dogs. *Zoonoses Public Health* 63, 458–466.

Shapiro, A. J., K. L. Bosward, J. M. Norris, K. Mathews, G. Vincent, J. Stenos, and P. A. Sheehy, 2016b: Molecular Detection of *Coxiella burnetii* in Raw Meat Intended for Pet Consumption. Zoonoses Public Health, Oxford, UK.

Søgaard, A. J., R. Selmer, E. Bjertness, and D. Thelle, 2004: The Oslo Health Study: the impact of self-selection in a large, population-based survey. *Int. J. Equity Health* 3, 1–12.

Tozer, S. J., S. B. Lambert, C. L. Strong, H. E. Field, T. P. Sloots, and M. D. Nissen, 2014: Potential animal and environmental sources of Q fever infection for humans in Queensland. *Zoonoses Public Health* 61, 105–112.

Turra, M., G. Chang, D. Whybrow, G. Higgins, and M. Qiao, 2006: Diagnosis of acute Q fever by PCR on sera during a recent outbreak in rural South Australia. *Ann. N. Y. Acad. Sci.* 1078, 566–569.

Whitehead, J. C., 1991: Environmental interest group – behaviour and self-selection bias in contingent valuation mail surveys. *Growth Change* 22, 10–21.

Woldehiwet, Z., 2004: Q fever (coxiellosis): epidemiology and pathogenesis. *Res. Vet. Sci.* 77, 93–100.

