OPEN ACCESS

Paper

Impact of Schmallenberg virus on British sheep farms during the 2011/2012 lambing season

K. A. Harris, R. D. Eglin, S. Hayward, A. Milnes, I. Davies, A. J. C. Cook, S. H. Downs

British sheep farmers were invited to complete a questionnaire about the impact of Schmallenberg virus (SBV) on animal health, welfare and their own emotional wellbeing during the 2011–2012 lambing season, through Defra and Farming Industry websites, letters to farmers who had requested SBV laboratory tests and advertisement at Sheep 2012. The 494 responders included SBV confirmed (positive by RT-PCR) (n=76), SBV suspected by farmer (n=140) or SBV not suspected (n=278). Percentage of barren ewes was similar across SBV groups, however, lamb and ewe losses were higher on responder farms where SBV was confirmed or suspected. The median percentages of all lambs born (and lambs born *deformed*) that died within one week of birth was 10.4 per cent (5.5 per cent), 7.0 per cent (2.9 per cent) and 5.3 per cent (0 per cent), respectively, on SBV confirmed, suspected and not suspected farms (P<0.001). Eight to 16 per cent of SBV confirmed or suspected farms reported lamb mortality of ≥40 per cent. Farmer perceived impact was greater where SBV was confirmed or suspected (P<0.001): 25 per cent reported a high impact on emotional wellbeing (4 per cent of SBV not suspected), 13 per cent reported a high impact on flock welfare and financial performance and 6 per cent were less likely to farm sheep next year because of SBV (<2 per cent in SBV not suspected). Overall, SBV impact has been large relative to reported sheep loss.

Introduction

Schmallenberg virus (SBV), a novel emerging infectious disease, is a member of the Simbu serogroup of the genus *Orthobunyavirus* (Goller and others 2012, Hoffmann and others 2012, van den Brom and others 2012). The emergence of SBV in Europe is the first known outbreak from a member of the Simbu serogroup in Europe (Beer and others 2013). SBV is thought to be transmitted by biting insect vectors (*Culicoides* species) (Elbers and others 2012, Rasmussen and others 2012, Veronesi and others 2013).

SBV was first detected in the Netherlands and in North-West Germany in the second half of 2011 through early warning (scanning) surveillance following an increase in the number of cases of dairy cows with diarrhoea, or milk drop or pyrexia; or a combination of these signs (G Watkins personal communication). It was first confirmed in Great Britain (GB) on January 16, 2012 (first four cases reported in Norfolk, Suffolk and East Sussex). Incursion into the UK most likely occurred as a result of the windborne spread of infected midges from Europe to the South and East coast of England. It is likely that infection with SBV would be observed in periods following vector activity and levels will fluctuate seasonally (Lievaart-Peterson and others 2012). Most countries in Europe have now reported SBV (European Food Safety Authority 2013).

SBV has been detected by RT-PCR in goats, bison, deer, moose, alpacas and buffalos as well as sheep and cattle (European Food Safety Authority 2013). In sheep, the evidence to date suggests that ewes do not display clinical signs of SBV infection. However, there have been some reports of farmers observing repeat oestrus and a higher than normal increase in the proportion of barren ewes (Lievaart-Peterson and others 2012), although other factors such as poor nutrition, dietary changes and weather effects could not be eliminated as alternative causes. There have also been anecdotal reports of milk drop in sheep from Holland (I Davies personal communication).

Infection of ewes during early gestation may cause deformities in the fetus, sometimes resulting in stillbirth. Malformations in fetuses and lambs associated with SBV infection include arthrogryposis, skeletal muscle dysplasia, deformities of the cervical and thoracic vertebral column, overshot jaw, and nervous signs (van den Brom and others 2012). Ewes can give birth to normal and deformed lambs from the same pregnancy (Dominguez and others 2012, Lievaart-Peterson and others 2012, Doceul and others 2013). SBV-affected lambs have been delivered at term, with some stillborn and a few severely deformed but still alive. Dystocia caused by lamb malformations has led to ewe mortality during labour (Lievaart-Peterson and others 2012).

Although knowledge of the clinical signs of SBV and diagnostic techniques has developed quite quickly, less is known about its epidemiology due to its recent emergence. This paper describes findings from a farmer-completed questionnaire designed to gauge the impact of SBV on British sheep farms in the 2011/2012 lambing season; assessing lamb and ewe losses and perceived impacts on farmer emotional wellbeing, animal welfare and financial performance of the farm.

Veterinary Record (2014) doi: 10.1136/vr.102295

K. A. Harris, BSc, MSc Wild Animal Biology,
A. J. C. Cook, MA, VetMB,
S. H. Downs, BSc, MSc, PhD
Department of Epidemiological Sciences, AHVLA, Weybridge, UK
R. D. Eglin, BSc Hons
S. Hayward,
Science Strategy and Planning, AHVLA, Weybridge, UK
A. Milnes, PhD, VetMB
AHVLA, Langford, UK
I. Davies, MA, VetMB,
AHVLA, Shrewsbury, UK
A. J. C. Cook, MA, VetMB,
School of Veterinary Medicine, University of Surrey, Guildford, UK

E-mail for correspondence: kate.harris@ahvla.gsi.gov.uk

Provenance: not commissioned; externally peer reviewed

Accepted April 9, 2014

Materials and methods

Design of the questionnaire

A questionnaire for completion by sheep farmers was designed by epidemiologists and scientists working at the Animal Health and Veterinary Laboratories Agency (AHVLA), to measure losses and impact of SBV. The questionnaire was reviewed by AHVLA Species Expert Groups and Defra economists and piloted by eight sheep farmers who completed the questionnaire in relation to their own flocks and provided feedback. A revised version was put online using SurveyMonkey (California, USA) and tested by members of the project team. The final version was made available online from June 21 to July 15, 2012 (see online supplementary material for copy of questionnaire).

Thirty questions were asked on farm demographics, lamb production, lamb and ewe mortality and perceived impacts at the farm level on animal welfare and financial performance and at the farmer level on their emotional wellbeing. To reduce complexity, questions were asked at the farm level and not at the flock level. AHVLA laboratory results and responses within the questionnaire were used to determine whether SBV was confirmed or suspected on the farm premises of responders.

Farms in the survey were categorised as follows:

SBV confirmed: Farms where following suspicion, there was laboratory confirmation of viral infection using real-time RT-PCR (RT-qPCR) in at least one fetus or neonate on the farm. The protocol for the RT-qPCR was kindly made available by colleagues from the Friedrich-Loeffler-Institut (Hoffmann and others, personal communication) before publication (Bilk and others 2012) and adapted to use with Qiagen chemistry and Agilent thermocyclers.

SBV suspected (by respondents): Farms with a positive response in the questionnaire that SBV was suspected for one or more lambings and/or as a cause of a deformity in one or more lambs. If a sample had been submitted for SBV laboratory tests, the results were negative.

SBV not suspected: Negative result by RT-PCR (or no samples submitted) and no report of suspected SBV.

Categories were determined according to available data and opinion from coauthors. As serological data was not collected, suspicion of SBV was based on responses to questions 14, 16 and 18 (with a negative result by RT-PCR *if* samples were submitted to the laboratory for testing.

Recruitment and administration of questionnaire

The questionnaire was open to all sheep farmers in GB and participation was voluntary. It was advertised as an online survey and publicised via a number of farming industry websites and via the farming press; through the National Sheep Association (NSA) and EBLEX (organisation for beef and lamb levy payers in England). A letter inviting participation was also sent to 620 sheep farmers who had submitted tissue samples for laboratory tests for SBV at the AHVLA and whose address was available on the AHVLA laboratory database.

The questionnaire was administered in three ways: (1) Online: English and Welsh versions of the survey could be accessed through the AHVLA website and through links from Defra's home page and sheep industry websites, (2) By post: Paper versions were available for farmers without online access and (3) NSA's biennial Sheep Event: Sheep 2012, Malvern Worcestershire 4/7/2012: for completion by hand.

Data analysis

Data consistency checks were undertaken initially. Completeness of responses to individual questions varied; internal consistency in responses for some questionnaires was poor and data were excluded where data entered for one question conflicted with another. Denominators to all responses have been reported throughout.

Possible bias in relation to differences in response rates to questions was investigated. In addition, information about flock sizes across the GB flock was derived from the 2010 Agricultural Census (Defra 2011) to enable assessment of the external validity of the survey by comparing responders with the target population.

The median (50th percentile) has been reported in the results as it is less affected by outliers and skewed data. The IQR represents the 25th percentile and 75th percentile of the given data.

Impact scores

Mortality and frequency of malformations in lambs, mortality in ewes and other adverse events associated with lambing that were measured in the questionnaire were compared across SBV categories. In addition, an impact score was developed based on frequency of mortality in lambs and ewes and malformations in lambs and these are reported in the results.

Lamb mortality score

1. 0–<5 per cent of lambs stillborn or died within one week of lambing
2. 5–<10 per cent of lambs stillborn or died within one week of lambing
3. 10–<20 per cent of lambs stillborn or died within one week of lambing
4. 20–<40 per cent of lambs stillborn or died within one week of lambing
5. At least 40 per cent or more lambs stillborn or died within one week of lambing

(Where per cent indicates per 100 lambs born dead or alive)

Ewe mortality score

1. 0–<0.5 per cent of ewes died during lambing
2. 0.5–<1 per cent of ewes died during lambing
3. 1–<5 per cent of ewes died during lambing
4. 5–<10 per cent of ewes died during lambing
5. At least 10 per cent of ewes died during lambing

(Where per cent indicates per 100 ewes)

A combined score was also created which was the sum of the lamb and ewe mortality score with a possible range of 2–10.

The following calculations for ewes and lambs were used in the analyses (and definitions referred to in the results):

Lamb mortality=((lambs dead from any cause within one week/total lambs born)×100)

Lambing mortality=(Total number of lambs dead from any cause/(tupped minus barren ewes))×100

Lambing percentage=((Total number of lambs (dead+reared)/(tupped minus barren ewes))×100

Ewe mortality=((number of ewes that died during lambing/(tupped minus barren ewes))×100

Ewe (malformed lamb) mortality=((number of ewes that died during lambing due to difficulties giving birth to deformed lambs)/(tupped minus barren ewes))×100

Mortality rates, frequency of malformations and other impacts were compared across SBV categories. Differences were compared using one-way analysis of variances. Highly positively skewed data were log transformed to obtain normal distributions before comparing means. For impact results, frequencies in tables with more than two rows or columns were compared by the χ^2 test. A Fisher's exact test was used to compare data in tables with observed cell frequencies lower than 5. The statistical significance level was set to $P<0.05$.

Descriptive and statistical analyses were conducted using STATA software V.12.0 and maps were prepared using ARCGIS, V.10 (ESRI, Redlands, California, USA).

Thematic analysis

The data from the free text question; requesting any further comment from responders on the impact of SBV, was interpreted using a thematic analysis. Responses were repeatedly read by the researchers and analytical memos made about potential emergent themes. The data was then imported into MAXQDA software V.10 and line-by-line coding conducted until the point of saturation had been reached; a term used in Grounded Theory to describe the method of constant comparison of categories until no new categories are identified. The codes were then categorised into themes. A process diagram was developed using Defra's 4Es framework (Engage, Enable, Exemplify and Encourage). Recurring themes were grouped under an encompassing theme of uncertainty.

Individual quotes from this data set have also been used to illustrate and give further insight to the rankings for perceived impacts on financial performance, animal welfare and emotional wellbeing.

Results

Response rates and farm demographics

After removal of duplicates, there were 494 questionnaires from responder farmers available for analysis (420 online, 66 completed at Sheep 2012, 8 returned by post). A total of 24.2 per cent (157/649) of farmers that completed a questionnaire had also submitted tissue samples to AHVLA for laboratory investigation for SBV (Fig 1).

The majority of responders (64 per cent, 314/494) in England were farmers from the Eastern and South-East regions and comprised approximately 7 per cent of sheep farms recorded by the 2010 Agricultural census for those regions (Defra 2011).

SBV was confirmed by RT-PCR in at least one sheep on 76 farms of responders to the survey (and 34.2 per cent of all AHVLA submissions that were confirmed), was suspected on 140 farms and was not suspected on 278. All responders where SBV was confirmed were from lowland farms compared with 91.4 per cent (128/140) of SBV suspected and 79.5 per cent (221/278) of SBV not suspected farms (P<0.001). Forty-two per cent (32/76) of SBV confirmed farms had at least one pedigree ewe on their farm compared with 57.8 per cent (81/140) of SBV suspected and 58.3 per cent (162/278) of SBV not suspected farms (P=0.035). Eighty per cent (61/76) of SBV confirmed farms were located in the Eastern and South-East regions (Fig 2); the geographical distribution of SBV suspected or SBV not suspected was more diverse (Table 1).

The distribution of total numbers of sheep and lambs on farms in the survey were similar to the totals reported for farms in the UK 2010 June Agricultural Census (Defra 2011) (Table 2). There was a similar result in the median number of breeding ewes on SBV confirmed, suspected and not suspected farms (131 (IQR 44.5–344.5), 153 (IQR 46–400) and 122 IQR 41–425, respectively).

Lambing season and lambing percentage

The range of start and end dates of the lambing season on SBV suspected farms was similar to the SBV confirmed farms but was slightly larger for SBV not suspected farms (starting earlier and finishing later). There were more outliers in lambing season duration on SBV suspected and not suspected farms than on SBV confirmed farms. The distribution of duration was positively skewed in all categories but the median lambing season duration was slightly longer on SBV confirmed farms than on suspected or not suspected farms. The percentage of tupped ewes that were barren, and the median lambing percentage, was similar across SBV groups (Table 1).

Lamb mortality

Fifty per cent of responses to questions relating to lamb survival and mortality could not be included, due to missing data (17.4 per cent) or because responses were inconsistent (32.1 per cent) with earlier responses relating to numbers of tupped and barren ewes.

Of the responses that could be analysed, a significantly higher percentage of lambs born that died within one week was observed on SBV confirmed farms compared with other groups (Table 3). A higher percentage of SBV confirmed (8.3 per cent, 3/36) and SBV suspected (15.9 per cent, 10/63) farms had lamb mortality (proportion died or stillborn within one week per 100 lambs born) of more than 40 per cent compared with SBV not suspected farms (2.7 per cent, 4/149). Lambing mortality (proportion died or stillborn within one week per 100 (tupped-barren) ewes) was significantly higher on SBV confirmed farms (Table 3, Fig 3).

Abnormalities in lambs

Eighty-eight per cent (67/76) of responders on SBV confirmed farms reported at least one of the following abnormalities in at least one lamb: Twisted limbs, curved back, overshot jaw, deformed head or nervous signs. The most common abnormalities observed were twisted limbs, curved back and overshot jaw (Fig 4).

Responders reported at least one abnormality in 85 per cent (119/140) of SBV suspected farms. Of the remaining 21 SBV suspected responders, 57 per cent (12/21) reported observing another abnormality ('other') and 81 per cent (17/21) were located in Eastern and South-East regions where SBV confirmed responders predominated. SBV suspected farms included 70 per cent (98/140) where samples were submitted for tests but results were negative. Thirty-six per cent (101/278) of SBV not suspected farms reported at least one abnormality (including 'other) (Fig 6).

Malformed lamb mortality

The overall proportion of lambs that were stillborn or died during birth due to malformations was significantly higher among responders from SBV confirmed farms compared with those from SBV suspected and SBV non-suspected farms (Table 3). On SBV confirmed farms, more ewes produced at least one deformed lamb compared with SBV suspected and SBV not suspected farms (P<0.001, Table 4).

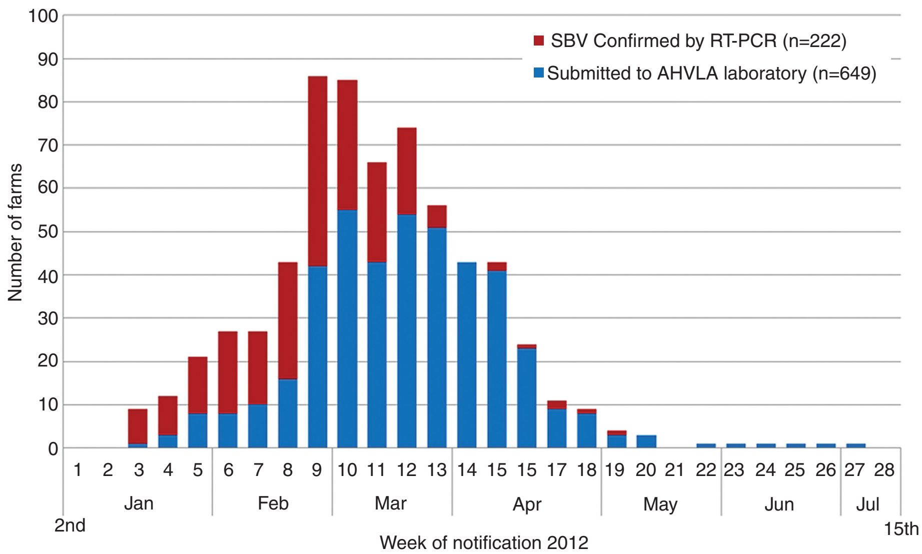

FIG 1: Temporal distribution of submissions* to the AHVLA for laboratory tests for SBV in sheep. *Responders to the survey who submitted samples for tests are a subset of the total submissions: SBV confirmed (n=76); SBV suspected (n=69). AHVLA, Animal Health and Veterinary Laboratories Agency; SBV, Schmallenberg virus

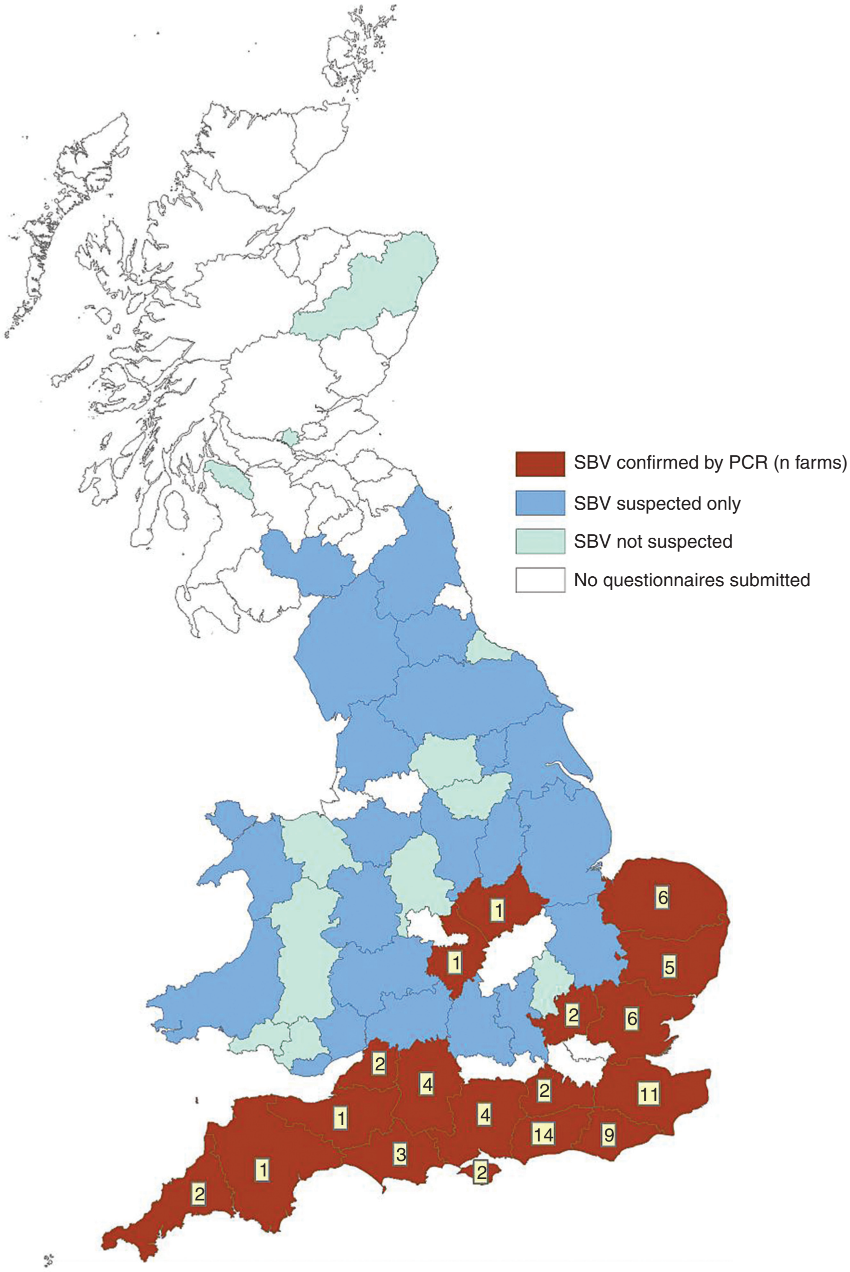

FIG 2: Distribution of questionnaire respondents (counties where one or more questionnaires were submitted from at least one farm according to SBV status, with total SBV confirmed farms overlaid). SBV, Schmallenberg virus

Ewe losses

More births were assisted by a vet (P<0.001) or were by caesarean section (P=0.002) on SBV confirmed farms than SBV suspected and SBV non-suspected farms (Table 4). The proportion of total ewes that died during lambing was similar on farms by SBV category, but the proportion that died due to giving birth to malformed lambs was higher on SBV confirmed farms (Table 5).

Impact-mortality scores

There were significant differences in mortality-impact scores for ewes, lambs and a combined ewe/lamb score across SBV groups. The largest differences were noted in the lamb mortality scores (P<0.001, Table 6 and Fig 5); a higher proportion of SBV suspected farms had the highest score, 5, (15.8 per cent, 10/63) compared with SBV confirmed (8.3 per cent (3/36)) indicating that at least 20 per cent of lambs born on these farms had died before one week of birth.

Almost 15 per cent (5/34) of SBV confirmed farms had a combined ewe and lamb mortality impact score of at least 7 out of a possible maximum of 10 compared with 12 per cent (7/59) on SBV suspected and 3.5 per cent (5/145) on SBV not suspected flocks (P=0.003).

Farmer-perceived impacts

There were differences across farms by SBV category according to the level of negative impact reported (animal welfare, financial performance and emotional wellbeing) (P<0.001, Table 7). In summary, a larger proportion of responders from SBV confirmed or suspected farms reported that the disease had an impact on animal welfare, financial performance and emotional wellbeing, compared with SBV not suspected farms. Responders from SBV confirmed farms reported a greater frequency of high impact scores (5 out of 5) compared with SBV suspected and not suspected farms. Responders from SBV not suspected farms reported higher frequencies for scores of 'no impact'. The differences across groups were much smaller, however, when comparing scores for emotional wellbeing, since nearly half of SBV not suspected farms still reported some impact.

Almost 6 per cent of responder farmers from SBV confirmed or suspected farms reported that the experience of SBV had made them less

TABLE 1: Farm location, lambing season and lambing percentage by SBV confirmed, SBV suspected and no SBV responders

		Valid responses to question/denominator						
		SBV confirmed by PCR		SBV suspected		SBV not suspected		
Q number	Summary description	n=76*	Per cent	n=140*	Per cent	n=278*	Per cent	p Value†
1	Location of responder farm							
	Scotland	0/76	0	1/140	0.7	3/277	1.1	
	Wales	0/76	0	9/140	6.4	23/277	9	
	English regions:							
	Eastern	19/76	25	20/140	14	13/277	4.7	
	North-East	0/76	0	6/140	4.3	8/277	2.9	
	North-West	0/76	0	6/140	4.3	14/277	5.1	
	South-East	42/76	55.3	42/140	30	48/277	17.3	
	South-West	13/76	17.1	27/140	19	90/277	32.5	
	West Midlands	1/76	1.3	9/140	6.4	38/277	13.7	
	Yorks and Humberside	0/76	0	7/140	5	14/277	5.1	
	Jersey	0/76	0	1/140	0.7	1/277	0.4	
8	Lambing season							*0.497*
	Number of responses	76		138		266		
	Earliest start date	17/11/2011		01/11/2011		01/09/2011		
	Latest start date	01/04/2012		24/04/2012		23/06/2012		
	Season duration							
	Median	49.5		48.5		44.5		
	Min	18		4		3		
	Max	171		374		211		
	IQR	32–84		32–71		30–69		
10–11	Per cent of tupped ewes that were barren							*0.255*
	Number of responses	74		136		265		
	Median	4		4.3		3.3		
	Min	0		0		0		
	Max	95		100		100		
	IQR	2.6 to 8.3		1.8 to 7.7		1.8 to 5.8		
13	Lambing percentage‡							*0.155*
	Number of responses	34		59		146		
	Median	169.1		166.7		164.2		
	Min	137		100		100		
	Max	217.4		265.1		237.5		
	IQR	152.2 to 183.3		150 to 192.6		143.8 to 182.4		

*The number of responders within each subgroup is shown at the top of the tables. As not all questions were answered by each farmer, the number of responses per question is displayed
†χ^2 and Fisher's exact tests were conducted for comparing questionnaire results between SBV groups. Geometric means of continuous variables with skewed distributions were compared. Results were considered statistically significant where the P value was <0.05
‡Lambing percentage=total lambs (dead+reared)/(tupped-barren ewes)
SBV, Schmallenberg virus

likely to farm sheep the following year, compared with 1.8 per cent of farmers of SBV not suspected farms (P<0.001, Table 7).

This was illustrated by a comment from one responder where SBV was confirmed:

My farming partner has given up because of the stress

Recurring themes in thematic analysis of comments by responders

Review of comments from 176 responders at the end of the survey revealed a number of recurring themes. Six themes emerged from the analysis: impact, knowledge, perception of disease importance, lambing deviations (health of ewes and lambs and ewe productivity), geographical (spread) and change of behaviour. The distribution of themes for SBV confirmed and suspected farms were similar. The thematic analysis and the specific impact questions highlighted the negative impact of the threat of SBV on emotional wellbeing.

Responders from all categories commented that they were worried about the disease, some of which were concerned with the uncertainty of the disease:

> The uncertainty of the final outcome with little support affected staff and family (SBV confirmed)

TABLE 2: Distribution of total sheep and lamb population sizes

		Distribution of total number of sheep and lambs on farms						Total sheep and lambs across all farms
Data source*	Number of farms	Mean	Min	Max	p25	median	p75	
Ag. census	49,936	450.3	1	25,655	46	174	569	22,500,000
Total questionnaire	494	392.1	2	6000	53	160	480	1,93,760
SBV confirmed	76	328.9	6	3473	52	150	405	24,995
SBV suspected	140	417.4	2	6000	59.5	186	490	58,482
SBV not suspected	278	396.7	3	6000	53	149	500	110,283

*The data is derived from the 2010 Agricultural Census, collated from the Data Systems Workgroup at AHVLA, which included questions related to sheep farming
Ag. census, agricultural census; AHVLA, Animal Health and Veterinary Laboratories Agency; SBV, Schmallenberg virus

TABLE 3: Lambing losses by SBV confirmed, SBV suspected and SBV not suspected

Q number	Summary description	SBV confirmed by PCR n=36†	SBV suspected only n=64†	SBV not suspected n=149†	p Value*
13–14	Lambs that died‡ per 100 lambs born (including stillborn)				
	Number of responses	36	63	149	*<0.001*
	Median	10.4	7.0	5.3	
	Min	2.2	0.0	0.0	
	Max	100.0	100.0	80.6	
	IQR	5.4 to 16.2	2.7 to 17.1	2.9 to 8.6	
13–14	Lambs that died‡ per 100 ewes				
	Number of responses	34	59	146	*<0.001*
	Median	18.2	11.3	8.6	
	Min	3.3	0	0	
	Max	140	130.9	114.6	
	IQR	10 to 24	6.8 to 23.3	4.6 to 13.6	
15–16	Deformed lambs that died‡ per 100 ewes				
	Number of responses	32	57	142	*<0.001*
	Median	5.5	2.9	0.0	
	Min	0.5	0.0	0.0	
	Max	140	50.0	28.6	
	IQR	3.5 to 11.7	0.5 to 8	0 to 0.2	

*The number of responders within each subgroup is shown at the top of the tables. As not all questions were answered by each farmer, the number of responses per question is displayed
†χ^2 and Fisher's exact tests were conducted for comparing questionnaire results between SBV groups. Geometric means of continuous variables with skewed distributions were compared. Results were considered statistically significant where the P value was <0.05
‡Within 1 week of birth
SBV, Schmallenberg virus

> 2012 lambing was a very worrying time for me (SBV suspected)

> We worry about next year (SBV not suspected)

Responders' comments to the distressing nature of the disease included:

> awful deformed lambs, distressing for sheep and farmer, it was horrific (SBV confirmed)

A large proportion of the questions asked by responders from SBV not suspected farms were related to prevention of the disease:

> Would it be advisable to alter the tupping time to reduce the risk in the early stages of pregnancy?, Now the problem is in the UK I would like to know more about the spread likelihood, What chance of vaccine?

Several questions from SBV confirmed or SBV suspected farms were concerning reoccurrence of the disease but the themes were still similar to those of the responders from SBV not suspected farms:

> would tupping later be safer when midge activity has slowed down?, we need to develop a vaccine quickly, the extent to which immunity has or has not been conveyed to ewes which have the virus and those that have not, we are unsure what to do for next lambing period

Based on the results a model was developed to illustrate how farmers' uncertainty impacts on their emotional wellbeing, how the emotional impact of SBV to British sheep farmers could be reduced, that a package of interventions could benefit the wellbeing of farmers and options for implementation are suggested (Fig 6).

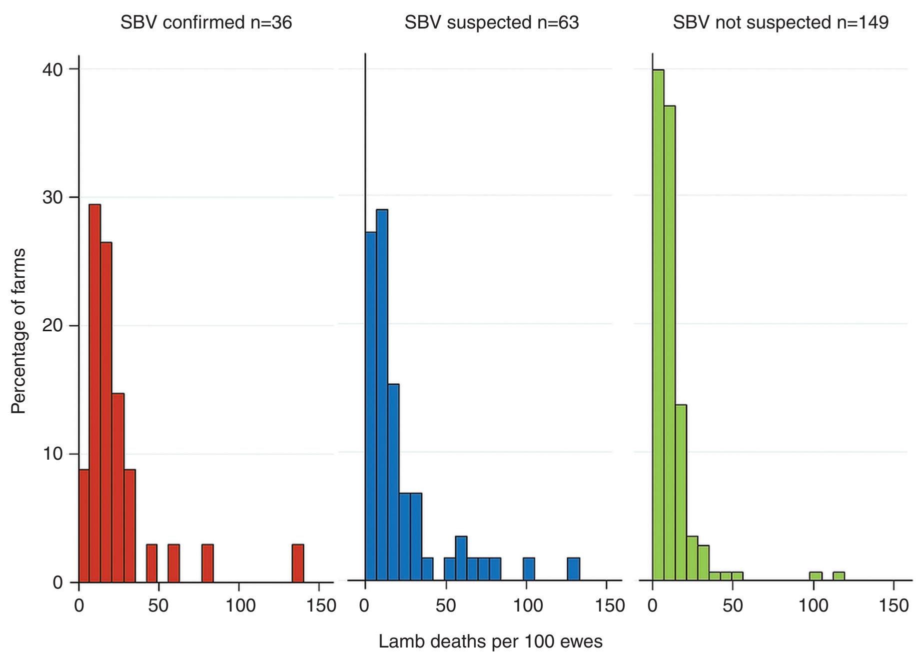

FIG 3: Distribution of lambing mortality by SBV status of farm. SBV, Schmallenberg virus

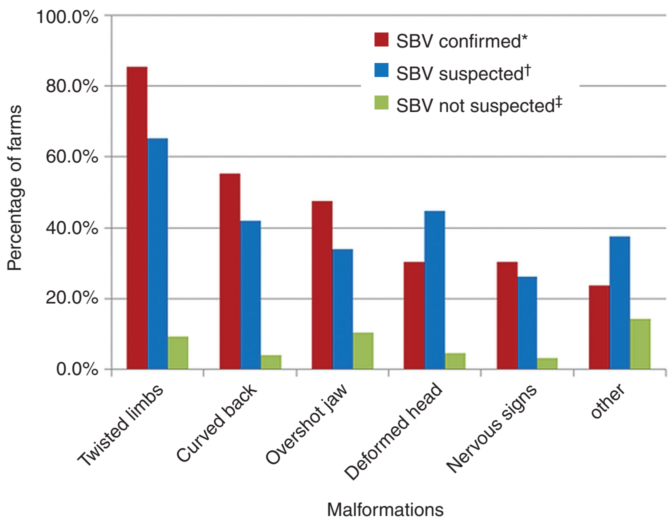

FIG 4: Percentage of farms where SBV was confirmed, suspected or not suspected, who reported abnormalities seen in lambs. *Under SBV confirmed, 18 farmers reported the following abnormalities under 'Other': blind, brain dead, not fully formed, fused joints (2), late abortion, join/limb malformations (7), respiratory problems, mouth deformity (undershot jaw), very large lambs, and watery belly. †Under SBV suspected, 53 farmers reported the following 'Other' abnormalities: spina bifida, extra limb (2), thick mucus around lamb, week/unable to sustain life (12), joint/limb malformations (11), blind/deaf, broad shoulders, concave chest, mouth deformities (4), not fully formed (5), furry mouth, mouth deformity (5), fused joints (3), like borders disease, lump on spine, mummified, enlarged stomach, watery belly. ‡Under SBV unsuspected (No SBV): 40 farmers reported the following 'Other' abnormalities: spinal deformity (1), blind (2), fused bones (1), undershot jaw (3), abdominal wall/swollen (4), stillborn (2), joint/limb malformations (8), enlarged head (1), blind anus (2), cleft mouth (1), extra limb (1), other deformities (4), unable to stand (1), long limbs (2), single eyes (1), Siamese twin (1), mummified (1). SBV, Schmallenberg virus

Discussion

These results provide an indication of the impact of SBV on British sheep farmers during the 2011/2012 lambing season, the first lambing season thought to have been affected by incursions of the virus into GB. The survey was advertised through Defra and Farming Industry websites, letters to farmers who had requested SBV laboratory tests and at Sheep 2012. Although overall ewe and lamb mortality was relatively low for responders from farms where SBV was confirmed or suspected, it was higher than on farms where SBV was not suspected. In addition, some farms where SBV was confirmed or suspected reported substantial losses. Malformations in lambs were also more common on farms of responders where SBV was confirmed or suspected. There was a measurable impact of SBV on flock welfare, flock financial performance and farmer emotional wellbeing regardless of absolute measured sheep loss. The emotional impact associated with SBV was highest on farms where SBV was confirmed or suspected, but half of the farmers from farms where SBV was not suspected reported that SBV had caused some impact on their emotional wellbeing.

Comparison with agricultural census data suggested that the sheep farms within the survey were similar to the general population of sheep farms in GB. However, the survey was not conducted using a probability based sampling frame, participation was voluntary and the number of responders was small in some categories. Therefore the results should be interpreted as a guide to the nature of the impact on the sheep industry, rather than comprehensively quantifying loss. Farmers who suspected or had SBV confirmed in their flock were specifically targeted and, as a consequence, the results of this impact study may over-represent their losses. Responders to the survey included 25 per cent of all farmers who had submitted samples to the AHVLA for testing and 95 per cent of the farms on the AHVLA database where SBV was confirmed by RT-PCR. In addition, farms that experienced significant lambing problems unrelated to SBV, where farmers had no obvious explanation of losses, may also be over-represented. However, the survey data may under-represent farms with more subtle effects of SBV infection, due to differential diagnosis or farmers not suspecting infection. As SBV is not a notifiable disease, if lambs did not display associated clinical signs such as malformations they were unlikely to have been tested for SBV, therefore the numbers truly affected could be underestimated (Martinelle and others 2012). Where there were no clinical signs in ewes or lambs, farms would not be included in the SBV confirmed or suspected categories.

The predominant clinical signs associated with SBV in sheep have been malformations in fetuses, stillborn and newborn lambs which affect the lambs' ability to thrive (European Food Safety 2012). Twisted limbs, curved back and deformed head were most commonly reported on farms where SBV was confirmed or suspected and similar proportions of abnormalities associated with SBV were observed in these categories.

Responses from farms where SBV was not suspected also reported abnormalities in lambs but a lower proportion of abnormalities that have been specifically associated with SBV. The majority of farms where SBV was suspected were located in East and South-East England where the potential for exposure for SBV was highest: Only 2 per cent (4/140) of SBV suspected farms did not report any abnormality in their flock and were not located in East or South-East England.

Given the transient presence of the virus, it was not possible to ascertain the true level of SBV on responder farms. It relied on laboratory submissions and the only available confirmatory test at the time was the RT-qPCR which only detects infection while the virus is actually present in the fetus/lamb. Serological surveys (using ELISA for antibody detection) have indicated exposure of flocks in the absence of PCR confirmation (European Food Safety 2012) however there was no serological data available for this study. Surveys in France show that surveillance based on detection of the congenital disease alone is likely to significantly underestimate the true prevalence of the disease (Dominguez and others 2012; Gache and others 2013).

Lamb and ewe deaths, including deaths from malformations in lambs have a number of causes and it is not possible to attribute causality between the evidence for SBV exposure in the flock and all reported losses (Binns and others 2002). However, mortality due to malformations in the survey was more strongly associated with SBV confirmation status than overall mortality. Lamb mortality due to malformations was higher on farms where SBV was confirmed compared with farms where SBV was suspected and three to six times higher than on farms where SBV was not suspected. Saegerman and others' (2013) study on the impact of SBV on sheep flocks in Belgium also reported higher lamb mortality in SBV-positive flocks (13.2 per cent) compared with SBV-negative flocks (9.5 per cent) which was comparable with Dominguez and others (2012); 13 per cent of SBV-positive flocks were born dead or died within 12 hours of birth.

No baseline data were available for the farms in the study to determine if there was a change in mortality associated with SBV exposure within farms, for example, between periods of presence and absence of exposure to the virus on the farm. Mortality was compared across rather crude categories for SBV exposure. Lamb mortality was substantial on a small number of farms. Eight to 16 per cent of responders from farms where SBV was confirmed or suspected had lamb mortality of ≥40 per cent. Despite the differences observed across SBV categories, lamb mortality in the survey overall was similar to mortality risk reported in a 1997 study of UK sheep farms (Binns and others 2002) before the incursion of SBV in 2011. This study included 108 sheep farms and reported median lamb mortality of 9 per cent (IQR 6–12 per cent). Average losses of around 20 per cent of lambs per ewe have also been reported elsewhere (Vipond 2004). Binns and others (2002) also showed that a range of management factors are associated with lamb mortality. Unfortunately, small sample sizes precluded simultaneous adjustment for factors that may be related to selection of farms and mortality rates in the statistical analyses for the current

TABLE 4: Ewe losses by SBV confirmed, SBV suspected and SBV not suspected

		Valid responses to question/denominator						
		SBV confirmed by PCR		SBV suspected		SBV not suspected		
Q number	Summary description	n=76†	Per cent	n=141†	Per cent	n=278†	Per cent	P value*
19	Number of ewes that produced at least one deformed lamb							<0.001
	0	8/68	11.8	42/133	1.6	200/232	86.2	
	1–5	44/68	64.7	70/133	52.6	30/232	12.9	
	6–10	7/68	10.3	11/133	8.3	0/232	0	
	>10	9/68	13.2	10/133	7.5	2/232	0.9	
21	Number of ewes assisted by a vet because of a deformed lamb							<0.001
	0	43/67	64.2	95/118	80.5	180/189	95.2	
	1	15/67	22.4	17/118	14.4	7/189	3.7	
	>1	9/67	13.4	6/118	5.1	2/189	1.1	
21	Caesarean sections because of a deformed lamb							0.002
	0	57/65	87.7	104/117	89	181/184	98.4	
	1	7/65	10.8	9/117	7.6	1/184	0.5	
	>1	1/65	1.5	4/117	3.4	2/184	1.1	
22	Number of breeding ewes that died during the lambing period							<0.001
	0	22/66	33.3	46/140	32.9	107/235	45.5	
	1–5	33/66	50	62/140	44.3	93/235	39.6	
	6–10	3/66	4.6	17/140	12.1	13/235	5.5	
	>10	8/66	12.1	15/140	10.7	22/235	9.4	
22	Number of ewes that died giving birth to a deformed lamb							<0.001
	0	41/65	63.1	109/131	83.2	205/221	92.8	
	1	11/65	16.9	6/131	4.6	6/221	2.7	
	>1	13/65	20	16/131	12.2	10/221	4.5	
22	Number of ewes lost during the lambing period per 100 ewes							
	Number of responses	64		134		232		
	Median	1.1		0.9		0.5		
	Min	0		0		0		
	Max	72		33.3		31.9		
	IQR	0 to 2.8		0 to 2.8		0 to 1.7		
22	Number of ewes lost because of deformed lamb at birth per 100 ewes							
	Number of responses	63		128		219		
	Median	0		0		0		
	Min	0		0		0		
	Max	7.8		17.8		4.7		
	IQR	0 to 0.5		0 to 0		0 to 0		

*The number of responders within each subgroup is shown at the top of the tables. As not all questions were answered by each farmer, the number of responses per question is displayed

†χ^2 and Fisher's exact tests were conducted for comparing questionnaire results between SBV groups. Geometric means of continuous variables with skewed distributions were compared. Results were considered statistically significant where the P value was <0.05

SBV, Schmallenberg virus

survey. However, restricting analyses to groups comparable in terms of questionnaire administration and type of farm did not change our findings.

There was no evidence for an effect of SBV on conception and/or early gestational losses from the survey. The proportion of barren ewes or lambing percentages did not differ between SBV groups. However, gestational loss is difficult to measure because sheep are not continually monitored. Furthermore, the questionnaire did not measure whether ewes on SBV affected farms had problems conceiving or reabsorbed so early on in pregnancy that it resulted in them returning to the ram.

Internal consistency in responses within some questionnaires was poor and data were excluded where data entered for one question conflicted with data entered for another. Fifty per cent of responses to questions relating to lamb survival and mortality were not included. Comparison of information about ewes across questionnaires with complete and incomplete information about lambing mortality suggested that there was no selection bias; however, the missing data means that there is more uncertainty regarding the estimates for lambing mortality than for ewe mortality.

In 2012, AHVLA introduced enhanced surveillance initiatives for SBV in England and Wales. Free testing of fetal deformities was introduced in January 2012 for cases that met certain criteria in previously unaffected counties. By the end of 2012, SBV had been identified in most counties of England and Wales. Accordingly, it was considered that the enhanced surveillance had served the purpose for which it was introduced: to identify cases in previously unaffected areas as early as possible and free testing ceased with effect from December 14, 2012. The majority of farms of responders in the current survey where SBV was confirmed or suspected, were located in the East and South-East regions of England; the sum of these and the additional records of SBV submissions on the AHVLA database is less than 5 per cent of the total number of sheep farms based on the census results for these regions. This proportion is slightly lower than

TABLE 5: Proportion of ewes on farms in questionnaire survey that died during lambing

	Farms	Total ewes	Ewes died during lambing		Ewes died during birth due to malformations in lamb	
	n	n	n	Per cent	n	Per cent
All	494	145,248	1806	1.24	224	0.15
SBV confirmed	76	18,853	245	1.30	56	0.30
SBV suspected	140	50,849	589	1.16	110	0.22
SBV not suspected	278	75,546	972	1.29	58	0.08

SBV, Schmallenberg virus

TABLE 6: Mortality impact scores by SBV confirmed, SBV suspected and no SBV responders

Summary description	SBV confirmed by PCR n=76	Per cent	SBV suspected n=140	Per cent	SBV not suspected n=278	Per cent	P value†
	Valid responses to question/denominator*						
Lamb mortality impact score							<0.001
1	8/36	22.2	20/63	31.8	70/149	47.0	
2	9/36	25.0	17/63	27.0	52/149	34.9	
3	14/36	38.9	14/63	22.2	17/149	11.4	
4	2/36	5.6	2/63	3.2	6/149	4.0	
5	3/36	8.3	10/63	15.8	4/149	2.7	
Ewe mortality impact score‡							0.050
1	23/64	35.9	51/134	38.1	119/232	51.3	
2	8/64	12.5	18/134	13.4	21/232	9.1	
3	28/64	43.8	44/134	32.8	76/232	32.8	
4	3/64	4.7	15/134	11.2	12/232	5.2	
5	2/64	3.1	6/134	4.48	4/232	1.7	
Combined mortality impact score							0.003
2	3/34	8.8	7/59	11.9	44/145	30.3	
3	5/34	14.7	10/59	17.0	30/145	20.7	
4	7/34	20.6	15/59	25.4	29/145	20.0	
5	8/34	23.5	12/59	20.3	29/145	20.0	
6	6/34	17.7	8/59	13.6	8/145	5.5	
7	3/34	8.8	3/59	5.1	5/145	3.5	
8	1/34	2.9	0/59	0.0	0/145	0.0	
9	0/34	0.0	2/59	3.4	0/145	0.0	
10	1/34	2.9	2/59	3.4	0/145	0.0	

*The number of responders within each subgroup is shown at the top of the tables. As not all questions were answered by each farmer, the number of responses per question is displayed
†χ^2 and Fisher's exact tests were conducted for comparing questionnaire results between SBV groups. Geometric means of continuous variables with skewed distributions were compared. Results were considered statistically significant where the P value was <0.05
‡Denominator is larger for ewe mortality because a large proportion of responses about lamb deaths were inconsistent (see Discussion)
SBV, Schmallenberg virus

reported in Europe which indicates that the maximum proportion of confirmed SBV flocks per region is 6.6 per cent for sheep (European Food Safety 2012). Numbers in the subsequent breeding season have been generally low (European Food Safety Authority 2013).

The perceived impact of SBV was high to farmers regardless of animal losses. SBV manifests as neurological signs and/or head, spine or limb malformations in lambs (Garigliany and others 2012). Musculoskeletal defects include brachygnathia inferior and curvature of the spine (torticollis, kyphosis, lordosis or scoliosis) (Herder and others 2012, van den Brom and others 2012). These malformations are distressing to see (figures in (Herder and others 2012, van den Brom and others 2012)) which could have contributed to the high emotional impact of SBV to responder farmers in the survey, as well as the novel nature of the disease and uncertainty regarding its impact. Twenty-five

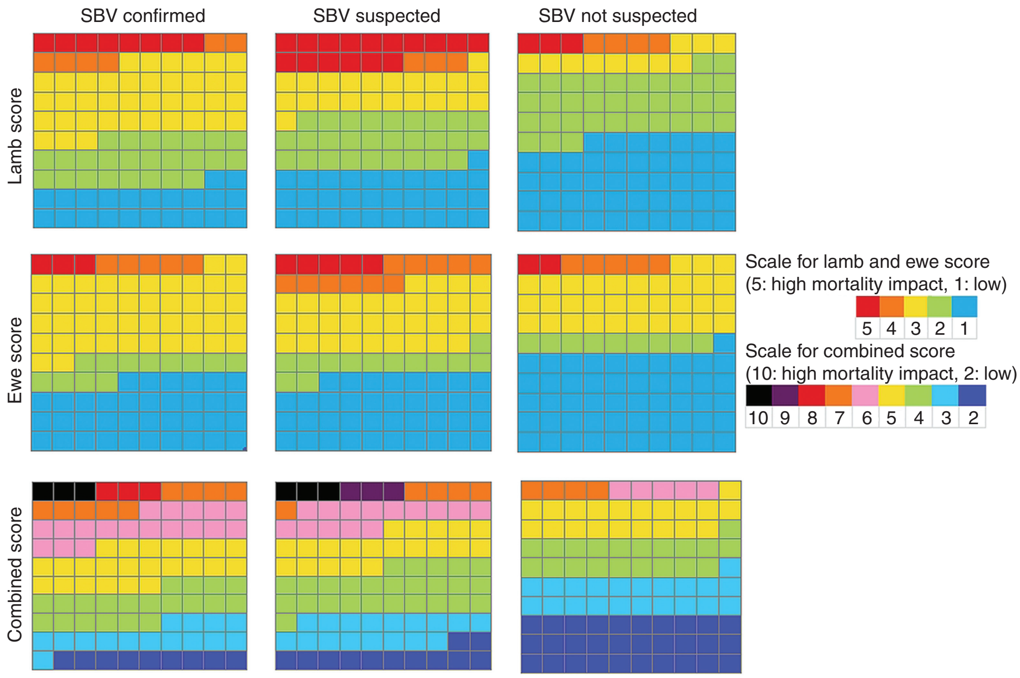

FIG 5: Distribution of mortality impact scores across SBV confirmed, suspected and not suspected farm populations. SBV, Schmallenberg virus

TABLE 7 Farmer perceived impact by SBV status: confirmed, suspected and not suspected

		Valid responses to question/denominator						
		SBV confirmed by PCR		SBV suspected only		SBV not suspected		
Q number	Summary description	n=76	Per cent	n=140	Per cent	n=278	Per cent	P value*
24	Impact of SBV on the welfare of sheep flocks on the farm							<0.001
	0 (Don't know/NA)	0/68	0.0	4/124	3.2	11/220	5.0	
	1 (No impact)	10/68	14.7	54/124	43.6	202/220	91.8	
	2	22/68	32.4	28/124	22.6	5/220	2.3	
	3	11/68	16.2	16/124	12.9	1/220	0.5	
	4	12/68	17.7	11/124	8.9	1/220	0.5	
	5 (High impact)	13/68	19.1	11/124	8.9	0/220	0.0	
25	Impact of SBV on the financial performance of sheep flocks on the farm							<0.001
	0 (Don't know/NA)	1/67	1.5	4/119	3.4	13/213	6.1	
	1 (No impact)	11/67	16.4	59/119	49.6	177/213	83.1	
	2	23/67	34.3	18/119	15	15/213	7.0	
	3	10/67	14.9	14/119	11.8	3/213	1.4	
	4	11/67	16.4	11/119	9.2	2/213	0.9	
	5 (High impact)	11/67	16.4	13/119	10.9	3/213	1.4	
26	Impact of SBV on the farmers' emotional wellbeing							<0.001
	0 (Don't know/ NA)	1/69	1.5	4/135	3.0	9/229	3.9	
	1 (No impact)	13/69	18.8	25/135	18.5	110/229	48.0	
	2	5/69	7.3	33/135	24.4	55/229	24.0	
	3	16/69	23.2	25/135	18.5	40/229	17.5	
	4	14/69	20.3	16/135	11.9	6/229	2.6	
	5 (High impact)	20/69	29.0	32/135	23.7	9/229	3.9	
29	Less likely to sheep farm next year because of SBV							0.067
		4/70	5.7	8/135	5.9	4/223	1.8	

*χ^2 and Fisher's exact tests were conducted for comparing questionnaire results between SBV groups. Geometric means of continuous variables with skewed distributions were compared. Results were considered statistically significant where the P value was <0.05
SBV, Schmallenberg virus

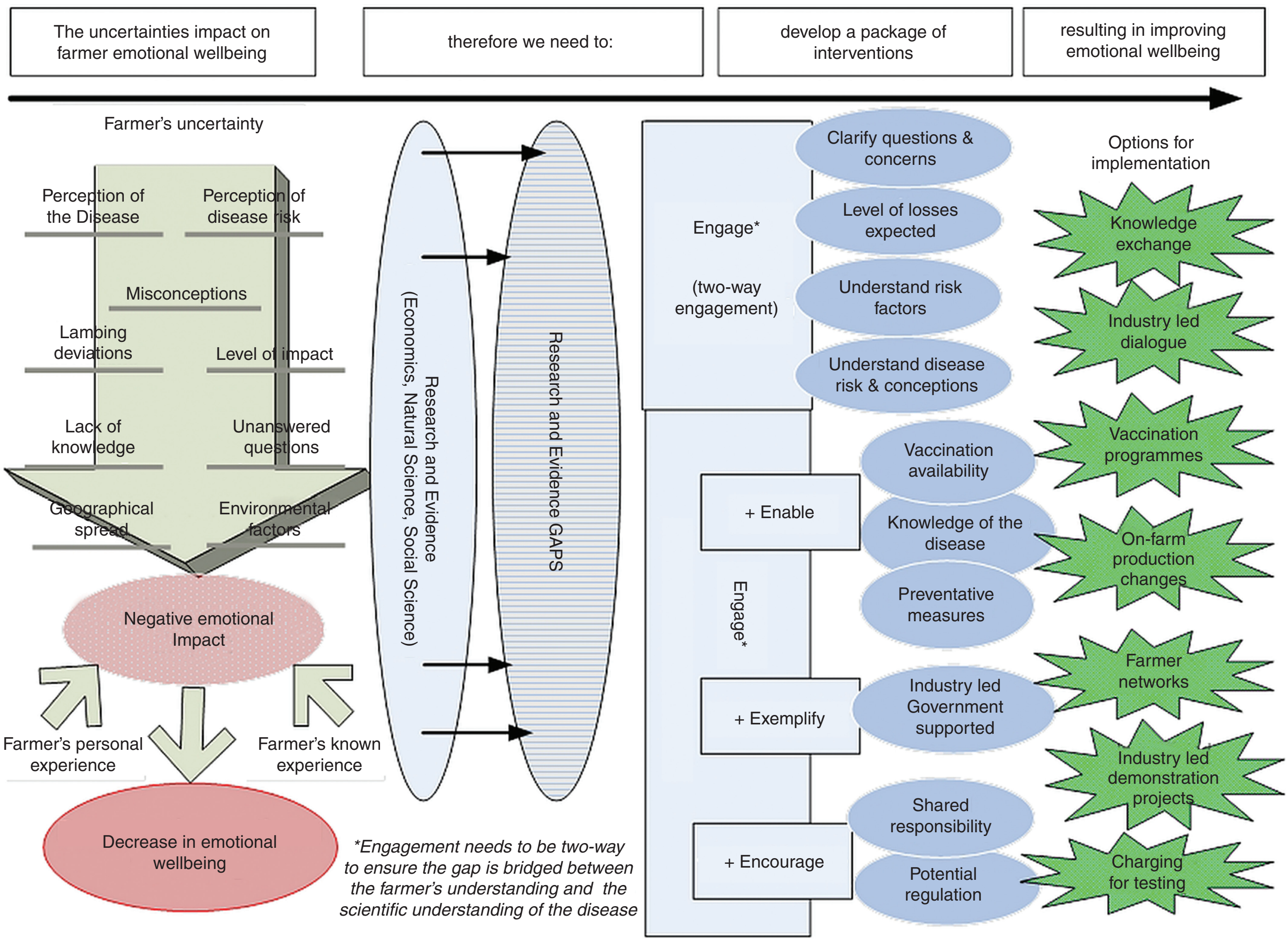

FIG 6: Process diagram to illustrate the relationship and possible route to improve the emotional impact of SBV on farmers. SBV, Schmallenberg virus

per cent of responders from farms where SBV was confirmed or suspected reported a high impact on emotional wellbeing (4 per cent where SBV was not suspected) and 6 per cent were less likely to farm sheep next year because of SBV.

Thirteen per cent of responder farms reported a high impact on flock welfare and financial performance. On SBV confirmed and suspected responder farms, 36 per cent and 19 per cent, respectively had at least one ewe that required vet assistance during lambing. Dominguez and others (2012) reported 15 per cent of ewes had lambing problems (6165/40,635), 33 per cent of which (n=2006) gave birth to normal and deformed lambs and 12 per cent (722) died within 15 days following delivery. Saegerman and others (2013) showed a significantly higher rate of flock dystocia in positive flocks (mean 18.5 per cent, median 13 per cent compared with negative flocks (mean 6.4 per cent, median 0 per cent)).

Over a third of responders included a response in the free text question requesting any further comment on the impact of SBV. There is conflicting opinion of the usefulness of these responses and the rationale for including them. The responses mainly differ in two ways; first, they have a potential to be quite long and secondly, they can cover a wide variety of topics (Garcia and others 2004). However, comments were fairly specific in this survey and the thematic analysis enabled a deeper understanding and insight into how SBV was impacting farmers. Thematic analysis is a categorising strategy for qualitative data that goes beyond simply counting phrases or words in a text and moves on to identifying implicit and explicit ideas within the data. Styled as a data analytical strategy, it helps researchers move their analysis from a broad reading of the data towards discovering patterns and developing themes (Boyatzis 1998).

A major issue highlighted from this survey was the lack of available information about this disease and its impact which led to uncertainty. Uncertainty about possible impacts, future recurrence and effective control strategies and the resultant increase in stress could have a negative impact on emotional wellbeing. Farmers remain in a group of occupations within the UK which have an elevated risk to suicide (Centre for Suicide Research 2011). Mental health problems were found to be the most common single factor (82 per cent) in farmer suicides (Gregoire 2002). The ability of Government and the scientific community to provide timely, robust and comprehensive information about SBV was compromised because the disease was novel and newly emerging. Defra has developed a framework that could be adapted for future exotic disease incursions (Defra 2005). Fig 6 shows a range of interventions that could be put in place in the future which may improve engagement with the farming community and reduce impacts, particularly with regards to emotional wellbeing.

The results from the survey do not support high animal losses at a population level from the disease across GB sheep farms in 2011/2012 due to SBV. However, some individual farms did experience greatly elevated mortality and generally, the perceived impact of the disease was high to farmers. Further work to better understand the nature of SBV effects on sheep farms and possible control strategies could assist farmers in addressing future incursions. In addition, further work to improve two-way engagement between the farming industry and Government might reduce the impact of newly emerging diseases.

Acknowledgements

The authors thank the farmers and Animal Health veterinarians who assisted with piloting the questionnaire, Hannah Wright who created the online survey using SurveyMonkey and Defra communications who posted the questionnaire on the Defra website. A particular thanks to the NFU, NSA, BVA, CHAWG/SHAWG and EBLEX who advertised the survey to their members including providing internet links. We also thank the NSA for allowing us to advertise the survey at Sheep 2012 and the Sheep Veterinary Society for allowing us to use their stand at the NSA's Sheep 2012 event. Thanks to Rachel Muckle for her advice and guidance on the process diagram (Fig 6), Gavin Watkins and Helen Roberts for their advice and responses to questions, Rachelle Avigad for her inputs in Stages 1 and 2 of the study and also to Trevor Drew, Kate Sharpe and Falko Steinbach for their critical reading of a penultimate draft of the manuscript and helpful advice. The work was funded by Defra under projects ED1043 and ED1100.

▶ Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/vr-2013-102295)

Correction notice This article has been corrected since it was published Online First. In the title 'The impact of Schmallenberg virus…' has been changed to 'Impact of Schmallenberg virus…' to match house style.

References

BEER, M., CONRATHS, F. J. & VAN DER POEL, W. H. M. (2013) 'Schmallenberg Virus' – a novel orthobunyavirus emerging in Europe. *Epidemiology and infection* **141**, 1–8

BILK, S., SCHULZE, C., FISCHER, M., BEER, M., HLINAK, A. & HOFFMANN, B. (2012) Organ distribution of Schmallenberg virus RNA in malformed newborns. *Veterinary Microbiology* **159**, 236–238

BINNS, S. H., COX, I. J., RIZVI, S. & GREEN, L. E. (2002) Risk factors for lamb mortality on UK sheep farms. *Preventive Veterinary Medicine* **52**, 287–303

BOYATZIS, R. E. (1998) Transforming Qualitative Information: Thematic Analysis and Code Development. Thousand Oaks, London, & New Delhi: SAGE Publications

CENTRE FOR SUICIDE RESEARCH, U. O. O. (2011) Suicide in high risk occupational groups - farmers, doctors, female nurses, veterinary surgeons. cebmh.warne.ox.ac.uk/csr/reshighrisk.html. Accessed 11/02/2013

DEFRA (2005) Securing the future – delivering UK sustainable development strategy. www.defra.gov.uk/publications/files/pb10589-securing-the-future-050307.pdf

DEFRA (2011) 2011 June Agricultural Census. www.defra.gov.uk/statistics/foodfarm/landuselivestock/junesurvey/junesurveyresults/ Accessed 09/11/2012

DOCEUL, V., LARA, E., SAILLEAU, C., BELBIS, G., RICHARDSON, J., BREARD, E. & OTHERS, A. (2013) Epidemiology, molecular virology and diagnostics of Schmallenberg virus, an emerging orthobunyavirus in Europe. *Veterinary Research* **44**, 31

DOMINGUEZ, M., CALAVAS, D., JAY, M., LANGUILLE, J., FEDIAEVSKY, A., ZIENTARA, S., HENDRIKX, P. & TOURATIER, A. (2012) Preliminary estimate of Schmallenberg virus infection impact in sheep flocks - France. *Veterinary Record* **171**, 426

ELBERS, A. R. W., LOEFFEN, W. L. A., QUAK, S., DE BOER-LUIJTZE, E., VAN DER SPEK, A. N., BOUWSTRA, R., MAAS, R., SPIERENBURG, M. A. H., DE KLUIJVER, E. P., VAN SCHAIK, G. & VAN DER POEL, W. H. M. (2012) Seroprevalence of Schmallenberg virus antibodies among dairy cattle, the Netherlands, Winter 2011–2012. *Emerging Infectious Diseases* **18**, 1065–1071

EUROPEAN FOOD SAFETY, A. (2012) "Schmallenberg" Virus: Analysis of the Epidemiological Data and Assessment of Impact. Supporting Publications EN-360, 22 pp.

EUROPEAN FOOD SAFETY AUTHORITY (2013) 'Schmallenberg' Virus: Analysis of the Epidemiological Data. Supporting Publications EN-429, 22 pp.

GACHE, K., DOMINGUEZ, M., PELLETIER, C., PETIT, E., CALAVAS, D., HENDRIKX, P. & TOURATIER, A. (2013) Schmallenberg virus: a seroprevalence survey in cattle and sheep, France, winter 2011–2012. *Veterinary Record* **173**, 141

GARCIA, J., EVANS, J. & RESHAW, M. (2004) "Is there anything else you would like to tell us" – Methodological issues in the use of free-text comments from postal surveys. *Quality & Quantity* **38**, 113–125

GARIGLIANY, M.-M., BAYROU, C., KLEIJNEN, D., CASSART, D., JOLLY, S., LINDEN, A. & DESMECHT, D. (2012) Schmallenberg virus: a new Shamonda/Sathuperi-like virus on the rise in Europe. *Antiviral Research* **95**, 82–87

GOLLER, K. V., HOPER, D., SCHIRRMEIER, H., METTENLEITER, T. C. & BEER, M. (2012) Schmallenberg virus as possible ancestor of Shamonda virus. *Emerging Infectious Diseases* **18**, 1644–1646

GREGOIRE, A. (2002) The mental health of farmers. *Society of Occupational Medicine* **52**, 471–476

HERDER, V., WOHLSEIN, P., PETERS, M., HANSMANN, F. & BAUMGAERTNER, W. (2012) Salient Lesions in Domestic Ruminants Infected With the Emerging So-called Schmallenberg Virus in Germany. *Veterinary Pathology* **49**, 588–591

HOFFMANN, B., SCHEUCH, M., HOPER, D., JUNGBLUT, R., HOLSTEG, M. & SCHIRRMEIER, H. (2012) Novel orthobunyavirus in cattle, Europe, 2011. *Emerging Infectious Diseases* **18**, 469–472

LIEVAART-PETERSON, K., LUTTIKHOLT, S. J. M., VAN DEN BROM, R. & VELLEMA, P. (2012) Schmallenberg virus infection in small ruminants - First review of the situation and prospects in Northern Europe. *Small Ruminant Research* **106**, 71–76

MARTINELLE, L., DAL POZZO, F., GAUTHIER, B., KIRSCHVINK, N. & SAEGERMAN, C. (2012) Field Veterinary Survey on Clinical and Economic Impact of Schmallenberg Virus in Belgium. *Transboundary and Emerging Diseases* **61**, 285–288

RASMUSSEN, L. D., KRISTENSEN, B., KIRKEBY, C., RASMUSSEN, T. B., BELSHAM, G. J., BODKER, R. & BOTNER, A. (2012) Culicoids as Vectors of Schmallenberg Virus. *Emerging Infectious Diseases* **18**, 1204–1206

SAEGERMAN, C., MARTINELLE, L., DAL POZZO, F. & KIRSCHVINK, N. (2013) Preliminary Survey on the Impact of Schmallenberg Virus on Sheep Flocks in South of Belgium. *Transboundary and Emerging Diseases* Published Online First: 7 Jan 2013. doi:10.1111/tbed.12047

VAN DEN BROM, R., LUTTIKHOLT, S. J. M., LIEVAART-PETERSON, K., PEPERKAMP, N. H. M. T., MARS, M. H., VAN DER POEL, W. H. M. & VELLEMA, P. (2012) Epizootic of ovine congenital malformations associated with Schmallenberg virus infection. *Tijdschrift Voor Diergeneeskunde* **137**, 106–111

VERONESI, E., HENSTOCK, M., GUBBINS, S., BATTEN, C., MANLEY, R., BARBER, J., HOFFMANN, B., BEER, M., ATTOUI, H., MERTENS, P. & CARPENTER, S. (2013) Implicating *Culicoids* biting midges as vectors of Schmallenberg virus using semi-quantitative RT-PCR. *PLoS One* **8**, e57747

VIPOND, J. (2004) Lambing Management. Hybu Cig Cymru (HCC)/Meat Promotion Wales

CrossMark