Investigating the feasibility of developing an efficient, validated, sustainable on-farm syndromic surveillance system for beef cattle and sheep

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Declaration

This thesis is submitted for the degree of Doctor of Philosophy (PhD) at the University of Warwick.

I declare that the research and results presented are my own work. My project was supervised by Prof Laura Green and Dr Mike Tildesley (University of Warwick). I confirm that no parts of this thesis have been submitted previously for any degree application.

This project was funded by AHDB Beef & Lamb and the University of Warwick. AHDB Beef & Lamb provided assistance in the recruitment of participating farmers for the studies conducted in this thesis (Chapter 3, Chapter 4, Chapter 5).

Summary

The initial aim of the project was to investigate the feasibility of an efficient and sustainable syndromic surveillance system where clinical signs or indicators indicative of endemic diseases in beef cattle and sheep were reported by farmers. The focus was initially on assessing whether this syndromic surveillance could be sustainable and generate valuable outputs for farmers. A bottom up approach was used to collect and analyse qualitative and quantitative data from farmers to assess the feasibility and need for a surveillance system for important clinical signs and/or endemic sheep and beef cattle diseases. Farmers were consulted to verify whether there was a need for a new, farmer-driven (i.e. active reporting of data by farmers) surveillance initiative. After conducting focus group discussions with sheep and cattle farmers, it became clear that they considered surveillance of endemic diseases to be more useful than syndromic surveillance of clinical signs. Thus, during the course of the project the focus shifted from surveillance of non-specific clinical signs towards specific endemic diseases diagnosed.

Subsequently, a pilot study was developed to investigate the feasibility of farmer reporting of disease presence on-farm in 2017 and 2018. In the pilot study, farmers were asked to indicate which endemic diseases listed were diagnosed or suspected on their farm and who identified the diseases (e.g. a veterinarian, the farmer himself or a diagnostic laboratory). After all, endemic livestock diseases cause significant losses to the individual farmer and the industry. However, most endemic sheep and beef cattle diseases are not prioritised in animal health surveillance that is currently focused on new and emerging diseases (e.g. the introduction of Bluetongue virus in the UK in 2007) or diseases with zoonotic potential (e.g. bovine tuberculosis).

In conclusion, the results from this project suggest that although farmers are interested in gaining knowledge on the health of livestock, a surveillance system that relies on farmers reporting clinical signs or diseases diagnosed in their sheep flock or beef cattle herd would not be sustainable. However, there are an increasing number of alternative sources of data that could contribute to a surveillance programme including electronic data collected on farm, through routine diagnostic laboratories e.g. testing of milk for endemic diseases and also veterinary practices.

List of recurring abbreviations

AHDB:	Agriculture and Horticulture Development Board
ANOVA:	Analysis of variance
APHA:	Animal and Plant Health Agency
BRP:	Better Returns Programme
bTB:	Bovine tuberculosis
BTV:	Bluetongue virus
BVD:	Bovine viral diarrhoea
χ^2:	Chi-square statistic
CAP:	Common Agricultural Policy
CCIR:	Collection and Communication of Inspection Results
CHAWG:	Cattle Health and Welfare Group
C.I.:	Confidence interval
CLA:	Caseous lymphadenitis
Defra:	Department for Environment, Food and Rural Affairs
df:	Degrees of freedom
EAE:	Enzootic abortion in ewes
EID:	Electronic identification
EM:	Expectation maximisation
EU:	European Union
FAWC:	Farm Animal Welfare Committee
FMD:	Foot-and-mouth disease
FSA:	Food Standards Agency
KMO:	Kaiser-Meyer-Olkin test
IBR:	Infectious bovine rhinotracheitis
LRT:	Likelihood ratio test
MCAR:	Missing completely at random
MID:	Midlands
NE:	North East England
NW:	North West England
OR:	Odds ratio
PCA:	Principal component analysis
PCs:	Principal components
PLF:	Precision livestock farming
SHAWG:	Sheep Health and Welfare Group
SE&E:	South East & East of England
SW:	South West England
TPB:	Theory of Planned Behaviour
Z:	Z-score

Chapter 1

GENERAL INTRODUCTION

1.1 An introduction to syndromic surveillance within animal health surveillance

1.1.1 Situating syndromic surveillance in human and veterinary epidemiology

In the past two decades, several new strategies have been investigated that have proven cost-effective and deliver useful outputs in human as well as animal health surveillance. One approach that has significantly gained importance is syndromic surveillance (Dórea *et al.*, 2011; Katz *et al.*, 2011).

The origin of syndromic surveillance lies in human public health, where non-specific sets of clinicals signs indicative for health threats or bioterrorism (e.g. anthrax in 2001) need to be detected as early as possible (Buehler *et al.*, 2003; Buehler *et al.*, 2004; Henning, 2004; Dórea *et al.*, 2011; Katz *et al.*, 2011). However, a universally accepted definition of the concept of syndromic surveillance is not readily available. This has been raised as an issue by various researchers in both human (Henning, 2004; Katz *et al.*, 2011) and animal health surveillance (Dórea *et al.*, 2011; Dupuy *et al.*, 2013a; Hoinville *et al.*, 2013; Dórea and Vial, 2016). Moreover, Katz *et al.* (2011) reviewed the available literature in search for syndromic surveillance initiatives launched in human health between 1998 and 2010 in low and middle income countries and found no less than 36 different definitions of 'syndromic surveillance'.

Unlike specific pathogen-targeted surveillance based on diagnostic confirmation of diseases, syndromic surveillance often relies on pre-diagnostic data that, because of the low specificity, in itself is not sufficient for diagnostic confirmation (Dórea *et al.*, 2011; Triple-S Project, 2013). But even though syndromic surveillance cannot replace pathogen-targeted surveillance, it can add to already existing disease surveillance in a country or region (Dórea *et al.*, 2011; Dupuy *et al.*, 2013a; Dórea and Vial, 2016; Veldhuis *et al.*, 2016).

Animal health syndromic surveillance could be valuable for a variety of purposes, including (i) early warning or outbreak detection of new and emerging diseases, (ii) the detection of increases in incidence of endemic diseases, (iii) the monitoring of disease trends, (iv) to support claims of freedom from disease, (v) to contribute to human public health surveillance (with regard to zoonotic diseases), and (vi) to measure the health impact of environmental threats (Kahn, 2006; Dórea *et al.*, 2011; Christensen, 2012; Dupuy *et al.*, 2013a; Hoinville *et al.*, 2013; Vial and Berezowski, 2015).

1.1.2 Data used for syndromic surveillance

While originally clinical signs or syndromes were used in syndromic surveillance, a shift towards the use of other, routinely collected data such as abattoir or laboratory records has shown to provide interesting alternatives for clinical records as reported by e.g. farmers or veterinarians (Dórea *et al*., 2011; Dupuy *et al*., 2013a; Veldhuis *et al*., 2016).

Table 1-1 provides an overview with examples of studies investigating different data sources for the purpose of animal health surveillance. For example, diagnostic laboratories play an important role. Laboratory data can be used with the aim to monitor cases where a diagnosis could not be reached in order to improve the early detection of new and emerging diseases (Dórea and Vial, 2016). In this regard, Gibbens *et al.* (2008) described the use of the FarmFile system where laboratory test results were being monitored for which a diagnosis had not been found.

1.1.3 Statistical methods used in syndromic surveillance

Apart from many different data types, also many different statistical approaches have been documented in syndromic surveillance (Dórea *et al*., 2011; Dupuy *et al*., 2013a; Dórea and Vial, 2016; Vial *et al.*, 2016; Faverjon and Berezowski, 2018).

The choice of a statistical method depends on a number of factors, such as (i) the type, characteristics and availability of historical data, (ii) the need for pre-processing to remove seasonal or other patterns from the data, (iii) disease characteristics, incidence and outbreak characteristics, (iv) parameters such as sensitivity and specificity of the algorithms used for analysis, and (v) the interest of the researchers involved (Henning, 2004; Dórea *et al*., 2011; Dórea and Vial, 2016; Vial *et al*., 2016; Faverjon and Berezowski, 2018).

Faverjon and Berezowski (2018) reviewed the available literature on detection algorithms and statistical methods used in animal health syndromic surveillance and provided a framework to guide researchers in deciding which algorithms to use. They found that the methods most frequently reported for univariate analysis were (i) process control algorithms (e.g. Shewhart charts, Cumulative Sums, Exponentially Weighted Moving Averages) and (ii) regression techniques and times series analysis (e.g. generalised linear models and Holt-Winters exponential smoothing).

Table 1-1: An overview of different types of routinely collected data that have been investigated for their potential use for animal health surveillance

Type of routinely collected data	Example of publication (country)
Abattoir condemnation records	Alton *et al.*, 2010 (Canada); Dupuy *et al.,* 2014 (France); Vial and Reist, 2015 (Switzerland)
Clinical symptoms (e.g. electronical records from veterinary clinics)	McIntyre *et al.*, 2003 (New Zealand); Elbers *et al*., 2005 (The Netherlands); Amezcua *et al*., 2010 (Canada); Faverjon *et al*., 2017 (France); Hanks *et al.*, 2018 (Myanmar)
Diagnostic laboratory data	Gibbens *et al*., 2008 (UK); Dórea *et al*., 2014 (Sweden/Canada)
Post-mortem (autopsy)	Elbers *et al*., 2003 (The Netherlands)
Production and reproductive indicators	Carpenter *et al.*, 2007 (Denmark); Madouasse *et al*., 2013 (France); Marceau *et al*., 2014 (France)
Demographic data (mortality and animal movements)	Backer *et al*., 2011 (The Netherlands); Perrin *et al*., 2012 (France); Ensoy *et al*., 2014 (Belgium); Struchen *et al*., 2015 (Switzerland); Torres *et al*., 2015 (Spain); Gorsich *et al*., 2018 (US) Tongue *et al*., 2020 (UK);

1.1.4 The development and evaluation of a syndromic surveillance system

Guidelines to aid the design of syndromic surveillance systems were published resulting from the Triple-S project (Syndromic Surveillance Systems in Europe) (2010-2013), a collaboration between human and veterinary public health authorities and institutes across Europe that was also funded by the European Commission (Dupuy *et al*., 2013a; Triple-S Project, 2013). The results from the Triple-S study identified four types of animal health syndromic surveillance projects: (i) active programmes, (ii) pilot projects, (iii) completed projects and (iv) initiatives that were still in an exploratory stage (Dupuy *et al*., 2013a). Their literature search only picked up on 8 systems, while through surveying a network of researchers a total of 27 systems were identified in 12 European countries. An explanation could be that at the time, most initiatives were still under development (Dupuy *et al*., 2013a; Dórea and Vial, 2016).

The lack of standardisation (e.g. in nomenclature, methods and statistical approaches) within animal health syndromic surveillance is an important issue for the development and evaluation of such initiatives (Dórea *et al*., 2011; Dupuy *et al*., 2013a; Gates *et al.*, 2015; Dórea and Vial, 2016; Faverjon and Berezowski, 2018). Efforts have been made towards developing guidelines and frameworks for the implementation as well as the evaluation of surveillance and to improve uniformity in concepts regarding animal health surveillance (Hoinville *et al*., 2013; Drewe *et al*., 2015; Vial and Berezowski, 2015).

For example, a practical 6-step approach to improve standardisation in the design of animal health syndromic surveillance systems has been suggested by Vial and Berezowski (2015). Essential steps include (i) defining the aims of a programme with emphasis on the goals for users, stakeholders and decision-makers, (ii) selecting priority diseases and identification of current gaps in (traditional) surveillance, (iii) an inventory of available data sources and subsequently define a minimum dataset, (iv) the classification of indicators in syndromes and construct time series of syndrome case counts, (v) testing and selection of possible aberration detection algorithms, (vi) the development of a clear response protocol in case alarms are generated.

To enhance standardisation of the evaluation of surveillance systems, the SuRveillance EVALuation (SERVAL) framework was developed and can be consulted online (www.rvc.ac.uk/serval, accessed February 2020). The evaluation was done by assessing surveillance 'attributes' such as data quality, timeliness, flexibility, simplicity, usefulness, efficiency, feasibility and cost-effectiveness (Drewe *et al.*, 2015).

1.1.5 Challenges for the implementation of syndromic surveillance

Ensuring access and availability of reliable data for animal health surveillance are important challenges to consider. A large amount of data is recorded on the health and diseases of livestock, e.g. clinical signs, laboratory test requests and results, post mortem findings and abattoir reports on condemnations (Dórea *et al*., 2011; Dupuy *et al*., 2013a; Vial and Berezowski, 2015). An advantage of using these routinely collected data for syndromic surveillance is that the costs for data collection and analysis are lower compared to active surveillance for livestock diseases (Faverjon and Berezowski, 2018). However, access to animal health data for the purpose of surveillance is often limited (Dórea *et al*., 2011; Sala *et al.*, 2020). Many data are collected continuously, but often not used or readily available for surveillance purposes. Even though the technological evolution in the field of e.g. smartphones and software in recent years can make recording of clinical data quicker, easier and more straightforward, challenges include ensuring good usability (Struchen *et al*., 2015) as well as sustaining engagement from data providers (Dupuy *et al*., 2013a; Bronner *et al.*, 2014). Moreover, Gates *et al*. (2015) reported that most animal health data was still being recorded on paper, therefore affecting the process of data submission, the timeliness of data analysis, and reporting of results.

The willingness to provide data for a surveillance system is a factor that needs to be considered as well. Contribution to a surveillance system must be considered useful by the data providers. The time required to participate in surveillance through active reporting is costly, for farmers as well as veterinarians. A syndromic surveillance system is often not sustainable if the behaviour and attitudes of data providers towards collecting and submitting data are not well understood, and if recording and submitting data requires additional time and effort to what participants already do (Dórea *et al*., 2011; Dupuy *et al*., 2013a; Gates *et al*., 2015). Therefore, the time required to record and submit data should be kept to a minimum (Degroot, 2005; Dórea *et al*., 2011). Additionally, reporting by farmers might also affect data quality (Vourc'h *et al.*, 2006). Therefore, caution is warranted when interpreting outputs from a surveillance system that relies on reporting by farmers.

Costs associated with the monitoring and surveillance of animal health are often considered an issue (Dórea *et al*., 2011). The voluntary reporting of diseases is challenging since reporting the presence of a disease on-farm could lead to devastating economic losses associated with the eradication of notifiable animal diseases. Therefore, it might be necessary to consider using incentives to improve contributing, especially for systems relying on voluntary participation. Incentives such as feedback or advice for the data providers, benchmarking or financial compensations might improve the sustainability of a syndromic surveillance system (Dórea *et al*., 2011; Dupuy *et al*., 2013a).

1.2 Surveillance of endemic animal diseases

1.2.1 Definition and estimated costs related to the presence of some prominent endemic sheep and cattle diseases

Animal health surveillance systems are developed to benefit a number of purposes, such as the identification of new and emerging diseases, outbreak detection of epidemic diseases, demonstrating freedom from specific diseases, or monitoring endemic livestock diseases

(Thrusfield, 2007a; Hadorn and Stärk, 2008; Hoinville *et al.*, 2013; Rodríguez-Prieto *et al.*, 2015; Stärk and Häsler, 2015). At present, continuous monitoring of the prevalence of many endemic sheep and cattle diseases is not done in England.

Endemic diseases are defined as those that are present at a stable, though often high, level in a population (Thrusfield, 2007b; Carslake *et al.*, 2011). Endemic livestock diseases often cost individual farmers and the farming industry several millions every year. For example, the annual costs attributed to important sheep diseases in the UK such as infestation with gastrointestinal parasites, abortion, footrot and sheep scab were estimated at around £84, £32, £24 and £8 million respectively (Bennett and Ijpelaar, 2005; Nieuwhof and Bishop, 2005).

With regard to cattle, bovine tuberculosis (bTB) is a major concern in Great Britain, with an estimated annual cost of £70 million to the government for disease control and an additional cost of around £50 million to cattle farmers every year (Defra, 2018; Public Health England, 2018). Additionally, other endemic diseases such as bovine viral diarrhoea (BVD), Johne's disease and respiratory diseases cost the cattle industry £36.6 million (Bennett and Ijpelaar, 2005), £13 million (Caldow and Gunn, 2009) and £50 million (Potter, 2010) respectively.

Organisations such as the Animal Welfare Committee - previously known as Farm Animal Welfare Committee (FAWC) - advise government on priority topics in animal health and welfare. In their 2012 report, the FAWC addressed the need for robust control programmes to fill the gap in surveillance with regard to endemic diseases in livestock (FAWC, 2012).

1.2.2 Beneficiaries and parties involved with surveillance of endemic livestock diseases in England

1.2.2.1 The role of the government in the surveillance of livestock diseases

Currently, monitoring is primarily carried out for endemic livestock diseases with a relevance in human public health. Government agencies involved in disease control mostly focus on diseases with a high political importance, such as new and emerging diseases, and the control of zoonotic diseases that could be transmitted to humans (Kosmider *et al.*, 2011; Carslake *et al*., 2011; FAWC, 2012; Stärk and Häsler, 2015; Davidson *et al.*, 2017). New or emerging diseases, e.g. Bluetongue virus in 2007 (Hateley, 2009) or Schmallenberg in January 2012 (Anonymous, 2012; Beer *et al.*, 2013), and zoonotic diseases (e.g. bTB) have a high political profile and often affect animals and humans over larger geographical areas. Therefore, the government contributes more resources for the control of such diseases (Carslake *et al*., 2011;

Velasova *et al*., 2017). The monitoring and surveillance of endemic diseases requires accurate and reliable baseline data, which is often absent (Velasova *et al.*, 2017).

The Animal and Plant Health Agency (APHA) play an important role in diagnosing and monitoring livestock diseases. Monthly scanning surveillance reports are published online by APHA on all livestock species farmed in the UK (GOV.UK, 2020). These reports provide an overview of data and information collected by APHA veterinary investigation centres and other contributors to the Veterinary Investigation Diagnosis Analysis (VIDA) (Anonymous, 2020). Subsequently, APHA, together with Scotlands' Rural College (SRUC), developed interactive online surveillance dashboards for multiple livestock species including cattle, sheep, pigs and poultry presenting the data for the diseases diagnosed in their laboratories or post-mortem facilities (Surveillance Intelligence Unit, 2020).

However, only data collected through diagnostic services from APHA and SRUC are presented in the reports and the online dashboards. Data from other laboratories or sources are not included. Data and information arising from extensively-managed systems in particular is scarce. Sheep and beef cattle are mostly farmed in extensively-managed livestock operations. Therefore, the Centre of Expertise in Extensively-Managed Livestock was set up by the APHA division in Wales and aims to improve the surveillance and the dissemination of information to farmers and veterinarians (CHAWG, 2018; Mitchell, 2019).

1.2.2.2 Current state of affairs on sheep and beef cattle surveillance in England

Important endemic diseases that constitute major concerns for sheep health and welfare were identified by the Sheep Health and Welfare Group (SHAWG) and included the so-called 'iceberg diseases'. Iceberg diseases such as Border disease, caseous lymphadenitis (CLA), Maedi Visna, ovine Johne's disease, and ovine pulmonary adenomatosis (OPA) are endemic sheep diseases of an infectious nature that cause severe production losses (SHAWG, 2018; Ogden *et al.*, 2019; Robinson *et al.*, 2019). Iceberg diseases progress slowly, often go unnoticed for a long time, no antibiotics are currently available to treat these diseases and the cases that are detected are only considered to be 'the tip of the iceberg' (Ogden *et al.*, 2019; Robinson *et al.*, 2019). Data on the prevalence of iceberg diseases and other endemic sheep diseases are lacking and no compulsory control or eradication programmes are currently operational.

More research has been published on cattle diseases compared to sheep and, overall, more publications are available on dairy than beef cattle. Velasova *et al*. (2017) recently investigated the presence of endemic diseases in dairy cattle through testing for antibodies in bulk milk tank samples and subsequently found high herd prevalence for e.g. Johne's disease (68.3%, C.I. = 59-77%), leptospirosis (46.9%, C.I. = 34-60%), BVD (66.0%, C.I. = 56-77%), and fasciolosis (55.1%, C.I. = 48-62%).

1.2.2.2.1 Compulsory government-led surveillance of bovine tuberculosis

Bovine tuberculosis, caused by the zoonotic pathogen *Mycobacterium bovis,* is a notifiable, endemic disease that, when detected, requires the implementation of measures that cause significant losses for farmers such as movement restrictions and mandatory slaughter (Abernethy *et al.*, 2013; Godfray *et al*., 2013; Defra, 2018). The UK is subject to the testing and control programme according to EU legislation in order to uphold the export of animal produce to EU member states and ensure the safety of the products (Abernethy *et al*., 2013; Defra, 2014; Defra, 2018). Because of its potential to affect human public health, bTB is considered highly politically important and therefore funding, surveillance and eradication are under government control (Carslake *et al*., 2011; Defra, 2014). So, in order to comply with domestic and EU legislation, Defra and the APHA monitor the spread and presence of bTB.

Initiatives to inform farmers and other stakeholders on the disease include maintaining and updating the webpage ibtb.co.uk, displaying the breakdowns of bTB across England and Wales for the past five years (Anonymous, 2015; Defra, 2015). Practical advice for cattle farmers on the disease is also provided online via the TB hub (www.tbhub.co.uk, accessed February 2020) published by AHDB and supported by government agencies (i.e. Defra and APHA) as well as the British Cattle Veterinary Association (BCVA), and the National Farmers' Union (NFU) and Landex.

Quarterly reports on the spread and incidence of bTB in cattle are produced by APHA and published online (GOV.UK, 2019). The latest report published in December 2019 presented herd incidence and herd prevalence estimated of bTB in England from October 2018 until the end of September 2019. The herd prevalence of bTB in England was 5.3%, but in high risk areas (HRA) prevalence was as high as 10.1%, in edge areas 5.6%, and in low risk areas (LRA) 0.4% (Defra, 2019).

The aim for the bTB control programme is to achieve the official bTB free (OTF) status by 2038-2039 (Defra, 2018; Public Health England, 2018). However, it is remarkable that while the bTB control programme is compulsory for cattle farmers (Velasova *et al*., 2017), the disease has also been described in other animal species such as sheep (van der Burgt *et al.*, 2012), wildlife (White *et al.*, 2008; Enticott *et al.*, 2012), and even camelids, cats and dogs (Broughan *et al.*, 2013; Godfray *et al*., 2013). These are all species for which monitoring and control of bTB is not under any regulation and not compulsory. This illustrates the complexity of the process to eradicate and control livestock diseases such as bTB.

1.2.2.2.2 Voluntary and industry-led initiatives: the examples of bovine viral diarrhoea and Johne's disease in cattle

Although bTB is the only disease for which a compulsory control programme is run in England, voluntary or industry-led initiatives exist (e.g. herd health schemes) for the control of other endemic livestock diseases such as for BVD, leptospirosis and Johne's disease in cattle (Drewe *et al*., 2014).

Following the example of the Scottish eradication plan for BVD initiated in 2010 (gov.scot, 2019), a voluntary industry-led scheme was launched in England in July 2016 to eliminate BVD in English cattle herds: the BVDFree Scheme (Anonymous, 2019). In 2018, 1242 cattle farms were participating in the scheme (CHAWG, 2018). BVD statuses could be uploaded online and in the future, the online database could be used to calculate the prevalence of BVD in the country.

Another example is the National Johne's Management Plan (NJMP), launched by the Action Group on Johne's in April 2015, that means to engage dairy farmers in Johne's disease control. A survey conducted in 2016 indicated that on 86% (n = 1412) of farms testing for Johne's disease is performed whereas no testing was done on 14% (n = 222) of farms. Subsequently, control strategies for Johne's disease were implemented on 83% of farms (CHAWG, 2018).

1.2.2.3 Who could benefit from the outputs of surveillance of endemic diseases?

A surveillance system for endemic sheep and beef cattle diseases could generate useful outputs for individual farmers (e.g. for the purpose of benchmarking) as well as for other stakeholders from the sheep and beef industry. The Agriculture and Horticulture Development Board is a farmer funded, statutory levy board concerned with improving productivity and competitiveness of English farms by targeting applied research and knowledge exchange around themes such as sustainable animal health systems, or providing skills programmes for farmers (AHDB, 2020a; AHDB, 2020b). Outputs from a surveillance system could be used by AHDB to inform farmers and target resources. The division AHDB Beef & Lamb co-financed the current PhD project in order to investigate whether farmer-driven surveillance of sheep and beef cattle diseases would be sustainable and efficient. Therefore, AHDB is an important stakeholder and beneficiary.

AHDB run the Better Returns Programme (BRP) that aims to provide beef and sheep farmers with the knowledge, guidance, tools and resources needed to improve e.g. performance and production on their farm. Outputs of the BRP comprise sheep as well as beef diseases directories to provide livestock farmers with information on how to recognise diseases, implications and guidance on their management and control. Sheep diseases discussed included enzootic abortion (EAE), CLA, sheep scab, endoparasites (e.g. *Nematodirus battus*), Jaagsiekte, Johne's disease, footrot, fasciolosis, Maedi-Visna and vector-borne diseases such as Schmallenberg and Bluetongue (AHDB, 2018b). The beef diseases directory included leptospirosis, neosporosis, BVD, Johne's disease, fasciolosis, lungworm, parasitic gastro-enteritis, infectious bovine rhinotracheitis and vector-borne diseases (AHDB, 2018a).

AHDB also supports the SHAWG and the Cattle Health And Welfare Group (CHAWG), who represent farmers and organisations in the sheep and cattle industries. Members of CHAWG and SHAWG include amongst others farmers and representatives from AHDB, Defra, APHA, National Farmers' Union (NFU), Livestock Auctioneers Association (LAA), and British Cattle Veterinary Association (BCVA) and Sheep Veterinary Society (SVS) respectively.

SHAWG and CHAWG publish reports where key welfare issues are identified, evidenced and subsequently recommendations are made such as for the surveillance of and the reaction to (endemic) livestock diseases and subsequently decision-making (SHAWG, 2018; CHAWG, 2018). Current state of affairs concerning the advances in the control of important livestock diseases (e.g. BVD and Johne's disease in cattle) are addressed in the reports as well. Outputs from a surveillance system on disease presence and prevalence of sheep and beef cattle diseases could therefore also benefit both SHAWG and CHAWG.

1.3 Precision livestock farming and its potential for syndromic surveillance

Although the current study did not cover or investigate the use of precision livestock farming (PLF) for syndromic surveillance of diseases as such, recent advances in technology have the potential to add to animal health surveillance in general and syndromic surveillance in particular. PLF is an approach adopted from process engineering, with the aim to provide farmers with help in the management of intensive and extensive livestock and guarantee the quality of the animal product (Wathes, 2007; Berckmans, 2014). European countries such as Belgium, Denmark, Germany and the UK, as well as Australia, have played a pivotal role in the development of PLF (Banhazi *et al.*, 2012).

PLF can be applied to (i) monitor animal health (e.g. specific livestock diseases, non-specific health indicators, benchmarking), (ii) improve the efficiency of production (e.g. milk yield), animal feed uptake, and welfare in real-time, (iii) provide an early warning which can be used for decision-making, and (iv) inform adjustments of the management policy on-farm via information and communication technologies (Wathes, 2007; Banhazi *et al*., 2012; Berckmans, 2014; Berckmans, 2017; Ramirez *et al*., 2019).

Most PLF systems currently used are in intensively managed livestock enterprise types within the poultry sector (e.g. egg counting, feed systems), pigs (e.g. measuring weight), and dairy cattle industry e.g. milk robots (Banhazi *et al*., 2012) which were first used in 1986 (John *et al.*, 2016). Although in recent years more studies have been published on the use and potential of PLF, it is used less in extensive farming systems (Bahlo *et al.*, 2019; Waterhouse *et al.*, 2019). With regard to the beef industry, virtual fencing applications have been reported (Banhazi *et al.*, 2012; Terrasson *et al.*, 2017). An example for PLF within the sheep industry is linking the collection of production data to electronic ear tags in EID. Farmers in extensive livestock systems are concerned about the cost effectiveness of PLF (Waterhouse *et al*., 2019), although, the cost of an automated PLF system is lower than the cost of regular farm visits (Berckmans, 2014). Many farmers also have beliefs about their own role as a farmer, e.g. sheep farmers' use of EID is limited because they believe modern technology cannot replace good stockmanship or the farmer's contact with their animals (Lima *et al.*, 2018; Kaler and Ruston, 2019).

Modern technology and software can be used to integrate all the information generated from the different types of data collected from the individual animals (Berckmans, 2014). PLF offers tools to improve the efficiency of farming and reduce the costs by using electronic methods to collect and process data (Banhazi *et al.*, 2012). Types of sensors used in PLF include cameras, microphones, thermistors and infrared imaging, accelerometers, radio frequency identification, optical character recognition and facial recognition (Benjamin and Yik, 2019). Combining and integrating different data streams into PLF tools provides more complete and robust information for users of the system (Ramirez *et al.*, 2019) and the large amount of data related to animal health and production can be analysed for the purpose of syndromic surveillance. PLF can be used to generate different types of information, according to the needs and interest of the user, since not every user is interested in the same information (Banhazi *et al*., 2012). Stakeholders that might benefit from PLF are e.g. farmers, retailers, consumers, industry and government (Berckmans, 2014; Ramirez *et al*., 2019).

1.4 How might the UK exiting the European Union affect beef and sheep farmers?

The UK leaving the EU and whether or not a new free trade deal can be negotiated with the EU after the exit, will impact farmers and the livestock industry. For the year 2015, it was estimated that France and Germany imported approximately 55-65% of British sheep meat, while in total more than 95% of English sheep meat was exported to the EU (British Meat Processors Association, 2019). Especially the British sheep farmers fear the sheep market collapsing and farmers will be compelled to cull a large number of sheep (Loeb, 2019). New regulations might imply additional costs for the industry and the farmers in case new or additional measures need to be implemented in view of new trade agreements with the EU, e.g. when the UK needs to provide evidence for the health status of the national flock/herd, or for absence of certain livestock diseases.

The UK has to comply with EU legislation on the monitoring of animal diseases and the communication thereof, at least until the end of the transition period (i.e. 31st December 2020). The 2016 Animal Health Law considers the control of animal diseases and covers the identification, registration, tracing and movements of animals, as well as prevention, control and eradication strategies (Regulation (EU) No. 429/2016, 2016). After leaving the EU, the UK and the EU will need to cooperate closely to ensure biosecurity and the dissemination of information on animal health threats since the UK might no longer automatically have access to services such as the Animal Disease Notification System (ADNS) (House of Lords, 2018).

Apart from the potential changes in legislation, changes to the economics of farming might also affect individual farmers and thus resources farmers are able or willing to spend on disease surveillance. After 2020, the UK will no longer be a member of the Common Agricultural Policy which will also raise questions such as how resources will be assigned. However, the UK government plans to ensure the same financial resources will be made available as under the Common Agricultural Policy (CAP), which over 2014-2020 came down to £24.6 billion in total (Downing and Coe, 2018).

1.5 Methods used in the current project

1.5.1 Systematic literature reviews

While narrative literature reviews sufficiently outline the knowledge on a topic, systematic literature reviews are conducted to evidence a specific research question using a predefined protocol, ensuring that the reviewer's opinions do not bias the selection process and by means of which the study can be repeated by other researchers (Green *et al.*, 2008; Dohoo *et al.*, 2009a).

Examples of the use of systematic reviews with regard to sheep health include (i) estimating the prevalence of oestrosis (Ahaduzzaman, 2019), (ii) investigating the effect of vaccination on the reduction of shedding *Coxiella burnetii* (O'Neill *et al*., 2014), (iii) assessing factors influencing anthelmintic resistance (Falzon *et al.*, 2014), (iv) assessing the effect of worm infestation on performance (Mavrot *et al.*, 2015), and (v) identifying and validating sheep welfare indicators (Llonch *et al.*, 2015).

Examples in cattle health include (i) the review of immunological tests for brucellosis (Ducrotoy *et al.*, 2018), (ii) the assessment of the distribution of cysticercosis (Hendrickx *et al.*, 2019), (iii) the identification of the effect of drinking frequency on performance (Williams *et al.*, 2017), (iv) comparing prevalence and antimicrobial resistance of entero-pathogens in cattle and other species (Young *et al.*, 2009), (v) the financial and economic effect of prevention and mitigation strategies for BVD worldwide (Pinior *et al.*, 2017).

Three systematic reviews were conducted in the current project with the aim to gain information on (i) existing syndromic surveillance initiatives in cattle and sheep (Review 1), (ii) surveillance of endemic diseases worldwide (Review 2), and (iii) human health surveillance and data collection in low resource environments (Review 3). The knowledge gained from these reviews was also used to feed the focus group discussions (Chapter 3) and the development of a pilot system (Chapter 4).

1.5.2 Qualitative study: Focus group discussions

Quantitative research methods often lack the ability to capture, analyse and interpret complex data such as the many different opinions, understandings, the behaviour of the population under study and previous social and historical experiences (Christley and Perkins, 2010; May, 2018). Qualitative methods are able to take these complex data, provide in-depth understanding that is otherwise challenging to unveil, and target further research (Britten and Fisher, 1993; Pope and Mays, 1995) rather than quantify results from structured surveys (Christley and Perkins, 2010; May, 2018).

Qualitative results therefore add greatly to the understanding of a poorly understood concept, thus providing results with a high validity (Britten and Fisher, 1993; Pope and Mays, 1995; Christley and Perkins, 2010; May, 2018). Moreover, although qualitative and quantitative research methods might seem to be adversaries (Pope and Mays, 1995) and generate different types of outputs, they have great potential to complement each other (Britten and Fisher, 1993; Pope and Mays, 1995; Ritchie, 2003; Christley and Perkins, 2010; May, 2018).

Focus group discussions distinguish themselves from individual interviews in a way that the participants drive the focus group discussion through engaging with and talking to each other, explaining their own beliefs and experiences whilst taking in opinions of others (Finch and Lewis, 2003; May, 2018). Previously, focus group discussions have been used (i) to capture qualitative data to capture beliefs and practices affecting the transmission of *Bacillus anthracis* in cattle (Sitali *et al.*, 2018), (ii) to improve the understanding of the use of antibiotics in pigs (Coyne *et al.*, 2014), (iii) to investigate the experience of dairy farmers with herd health management programmes offered by veterinary organisations (Svensson *et al.*, 2018), and (iv) to identify thoughts and opinions on how veterinarians are involved with sheep flock health management (Kaler and Green, 2013).

Focus group discussions were used in the current project to obtain qualitative data from sheep and beef cattle farmers to assess their opinions and beliefs towards the usefulness and sustainability of sheep and beef cattle health surveillance.

1.5.3 Online and postal questionnaires

Questionnaires are used to collect quantitative data from a representative sample of the entire population under study in an easy and straightforward manner (Mann, 2003; Thrusfield, 2007c). Apart from the ability to target a large sample of the population, other important advantages for the use of self-completed questionnaires in veterinary epidemiology include their low cost compared to some other types of epidemiological study and the possibility for participants to remain anonymous (Thrusfield, 2007c).

A limitation of questionnaires concerns the possibility of generating a low response percentage and therefore an increased risk of non-response bias (Dohoo *et al.*, 2009b). Therefore, it was attempted to send out the questionnaires at convenient times for the farmers wherever possible (Martin *et al.*, 1987) and reminders were sent to non-respondents (Dean, 2015).

Questionnaires were distributed by email with a link to an online survey (Chapter 3, Chapter 5) and by post (Chapter 5). As presented in Chapter 5, the postal version obtained a better response percentage than the online version of the same questionnaire. The route of distribution might have affected the response percentage (Dean, 2015).

1.6 Summary of the current knowledge relevant to animal health surveillance

Syndromic surveillance can be used to estimate and monitor the incidence of endemic diseases. Syndromic surveillance is a relatively novel approach that has been investigated for use in animal health surveillance for the past two decades. However, the lack of standardisation in syndromic surveillance poses challenges: different researchers are interested in different outputs and a variety of data sources have been used depending on the objective of the individual systems. Originally, clinical data were used. Since issues have been reported concerning the data collection and reporting of clinical observations by farmers and veterinarians, the interest has shifted to routinely collected data, e.g. abattoir records and laboratory test requests, to reduce the burden of data collection which affected the sustainability of syndromic surveillance.

Endemic livestock diseases are currently not well-recorded in animal health surveillance. Surveillance and control of these diseases has proven difficult and faces severe issues with regard to funding and uptake of a programme. History has shown that eliminating endemic livestock diseases is possible: foot-and-mouth disease (FMD) was once endemic in the UK and has been eliminated after its last outbreak dating back to 2001 (Carslake *et al*., 2011).

Livestock farmers have a unique perspective on their animals and are well placed to collect disease data for surveillance due to their knowledge and previous experience, but it is challenging to get them to engage in surveillance initiatives. Their willingness to report disease occurrence not only depends on their ability to notice and identify clinical signs displayed by their animals, but also on the financial consequences of the disease (Velasova *et al.*, 2015). Therefore, potential incentives to improve and sustain cooperation from farmers need to be identified as well as alternative data sources for implementation in a surveillance system.

1.7 Aims and objectives of the current project

The initial focus of this project was to assess if a sustainable surveillance system could be developed in which farmers would provide non-specific clinical data that are indicative of specific, endemic livestock diseases using a bottom up approach where farmers were consulted and provided data for the studies presented in this thesis. This reporting of non-specific clinical signs or indicators is considered syndromic surveillance. The usefulness of this concept was explored during focus group interviews with English sheep and beef cattle farmers (Chapter 3). However, the results of the focus groups indicated that although some participants believed syndromic surveillance of clinical signs or indicators would be useful, most farmers agreed that surveillance of specific, endemic diseases would be more relevant and informative. Because of this finding, the original plan to investigate the feasibility of syndromic surveillance relying on clinical signs or indicators was adjusted and the focus within the project shifted towards surveillance of endemic diseases that were diagnosed or suspected on-farm. The objectives of the project were also modified accordingly.

In order to assess the potential interest of farmers and how useful outputs could be generated from surveillance, the objectives of this project were to (i) identify farmers' needs and opinions towards disease surveillance in livestock and how they believe surveillance could be used, (ii) identify sheep and cattle diseases of interest to the individual farmers, (iii) develop and assess the results from a pilot study where data on diseases of interest are reported by farmers, and (iv) identify other sources that own or collect useful data according to farmers.

1.8 Thesis structure

Chapter 2 is an overview of three systematic literature reviews on (i) the use and development of 'Syndromic surveillance in cattle and small ruminants', (ii) 'Surveillance of endemic animal diseases', and (iii) 'Human health surveillance and data collection in low resource environments' to identify cost-effective methods when limited financial resources are available that could similarly be used in the sector of livestock farming in England where farmers' margins are tight and they are often not able to spend much resources on animal health surveillance.

In Chapter 3, the qualitative results are presented from focus group discussions conducted with English sheep and beef cattle farmers in 2016 to investigate farmers beliefs in the value of surveillance of endemic diseases and the diseases of interest to participants.

Chapter 4 describes the development and results from a pilot study to collect disease data from farmers for two consecutive years, namely 2017 and 2018. Although the initial aim of the project was on syndromic surveillance of clinical signs or indicators, the focus had shifted towards surveillance of specific, endemic diseases based on the results presented in Chapter 3.

Chapter 5 presents the results from questionnaires sent to sheep and beef cattle farmers to quantify and validate the results from the focus group discussions (Chapter 3) on recording production and disease and attitudes towards use of surveillance data.

Chapter 6 is the general discussion of the findings from the thesis and future work.

Chapter 2

APPRAISAL OF THE LITERATURE ON SYNDROMIC AND ENDEMIC DISEASE SURVEILLANCE IN ANIMAL HEALTH AND DATA COLLECTION FOR HUMAN HEALTH SURVEILLANCE IN LOW RESOURCE ENVIRONMENTS: THREE SYSTEMATIC REVIEWS

2.1 Introduction

Syndromic surveillance has significantly gained importance over the past two decades in both human and veterinary medicine and might generate useful outputs on the presence of endemic diseases in animals (Doréa *et al*., 2011; Dupuy *et al*., 2013a; Vial and Berezowski, 2015). A systematic literature review was conducted on 'Syndromic surveillance in cattle and small ruminants' to gain more knowledge on (i) how feasibility studies, pilot studies and active syndromic surveillance systems were developed, (ii) how animal health syndromic surveillance of cattle and small ruminant health has been used previously and is currently used and (iii) its advantages, challenges and limitations.

A second systematic review ('Surveillance of endemic animal diseases') was carried out to assess how monitoring and surveillance of endemic animal diseases was done worldwide. Current monitoring and surveillance initiatives in farm animal health are often aimed at detecting new and emerging diseases (e.g. Bluetongue virus) and zoonoses (e.g. bTB) (Kosmider *et al*., 2011; FAWC, 2012; Stärk and Häsler, 2015). However, endemic diseases also cause severe economic losses for the farming industry (Bennett *et al*., 1999a; Bennett *et al*., 1999b; Bennett and Ijpelaar, 2005; Nieuwhof and Bishop, 2005). The results of this review focused on reporting the challenges around the surveillance of endemic diseases in animals and the types of data used for this purpose.

A third systematic review was conducted on 'Human health surveillance and data collection in low resource environments', considering health surveillance in countries or regions where components such as funding or the ability to use electronic equipment for data recording were limited. The literature was searched to gain more knowledge on surveillance initiatives in developing or low and middle income countries (LMIC) and how financial or logistic challenges were overcome. Similar as for the literature review on the surveillance of endemic animal diseases, the main objective of the third review was to define challenges surrounding health surveillance when financial as well as logistic resources are limited.

Together, the outcome from the three reviews were used to inform and design focus group discussions with sheep and beef cattle farmers (Chapter 3) to capture their opinions and beliefs on surveillance in sheep and cattle health and how a new system to collect data from farmers on the presence of endemic diseases in their flocks or herds can be developed.

2.2 Methodology

2.2.1 Study design and purpose

Evidence-based systematic reviews maximise the robustness of the results by identifying all relevant publications. The Cochrane Handbook for Systematic Reviews of Interventions provides a framework to conduct a systematic review (O'Connor *et al.*, 2008; Dohoo *et al.*, 2009a). As a first step, a clearly defined research question was formulated for the systematic reviews conducted:

(i) 'What initiatives have been launched worldwide with regard to syndromic surveillance in cattle and small ruminants?'

(ii) 'Which endemic animal diseases have been monitored worldwide or targeted through a surveillance system and how?'

(iii) 'How are surveillance systems in humans developed and data being collected in low resource settings?'

Subsequently, a straightforward, objective protocol considering inclusion and exclusion criteria was drawn up for each of the reviews. Once the research questions were formulated and protocols designed, searches were conducted using relevant search terms. All publications found through the systematic searches were assessed for inclusion, based on title, keywords, abstracts and eventually full texts. When all publications to be included were identified, data was extracted and summarised.

2.2.2 Building the search terms and the selection of databases

A list was created with all relevant words and word groups to include in the final search term for each of the three systematic reviews. Boolean operators (AND, OR, AND NOT, "", *) were used to ensure all forms of the search terms (e.g. plurals) were captured. Different words or word groups were added, omitted and trialled in every database to obtain a final search term.

Useful databases were identified by investigating the available databases through the library of the University of Warwick (www2.warwick.ac.uk/services/library/, accessed February 2020) per subject or type of database and by looking at other systematic reviews in the field of veterinary and human epidemiology. Only publications written in English were considered for inclusion in the systematic reviews. Finally, a selection was made for every review.

2.2.2.1 Syndromic surveillance in cattle and small ruminants

The final search terms were:

> ("syndromic surveillance" *OR* "continuous monitor*" *OR* biosurveillance)
>
> *AND* ("animal* health")
>
> *AND* ("farm animal*" *OR* livestock *OR* veterinary* *OR* herd* *OR* cattle *OR* cow* *OR* bovin* *OR* bovid* *OR* sheep *OR* ovin* *OR* ruminant*)

Databases searched (on 26/01/'16) were Scopus, Proquest and Web of Science (WoS).

2.2.2.2 Monitoring and surveillance of endemic animal diseases

The final search terms were:

> Endemic
>
> *AND* (surveillance *OR* monitoring)
>
> *AND* Animal
>
> *AND* (disease* *OR* health)
>
> *AND* epidemiolog*
>
> *AND NOT* Human *AND NOT* Epidemic *AND NOT* Emerging

Databases searched (on 3/03/'16) were Scopus, Proquest and WoS.

2.2.2.3 Surveillance of human health and data collection in low resource environments

The final search terms were:

> Surveillance
>
> *AND* ("data collect*")
>
> *AND* (diseas* *OR* syndrome*)
>
> *AND* Human
>
> *AND* ("develop* countr*" *OR* "limit* resource*" *OR* "low income")
>
> *AND NOT* Animal *AND NOT* Livestock *AND NOT* Farm* *AND NOT* Europe
>
> *AND NOT* Canada *AND NOT* USA

Databases searched (on 29/02/'16 and 1/03/'16) were Embase, Proquest, Scopus and WoS.

2.2.3 Inclusion and exclusion criteria

After the final selection of the search terms and databases for the three reviews, all publications found were imported into EndNote X7 (Clarivate Analytics, 2016). Duplicates were removed. A stepwise protocol was used to assess the compliance of all publications for inclusion in the three systematic reviews. All titles, keywords and abstracts were read and lists of inclusion and exclusion criteria were designed for each of the three reviews to assess what publications should be retained. Flow charts with the specific criteria are presented in the results section of the current chapter (i.e. in paragraphs 2.3.1.1, 2.3.2.1, and 2.3.3.1 respectively). Data could only be extracted from publications where the full paper was accessible. Full papers were read and the final decision whether they should be included in the further review was made.

2.2.4 Data extraction

For each of the three reviews a datasheet was designed in Microsoft Excel (2016; Microsoft Corp., Redmond, WA) to ensure data extraction was structured and transparent. The specific data extracted for the three separate reviews are listed in Table 2-1.

Table 2-1: Data extraction sheet per systematic review

Syndromic surveillance in cattle and small ruminants	Surveillance of endemic animal diseases	Human health surveillance and data collection in low resource environments
'Reference title'	*'Reference title'*	*'Reference title'*
'Year of publication'	*'Year of publication'*	*'Year of publication'*
'Included or excluded?'	*'Included or excluded?'*	*'Included or excluded?'*
'Additional comments'	*'Additional comments'*	*'Additional comments'*
'Subcategory'	*'Subcategory'*	*'Subcategory'*
'Country'	*'Country'*	*'Country'*
'Population coverage'	*'Species'*	*'Data collection system'*
'Surveillance system'	*'Number of animals'*	*'Data type used'*
'Data type used'	*'Methods used'*	*'Methods used'*
'Statistical methods used'	*'Active system described or not?'*	*'Data collected by who?'*
'Collected / Managed by who?'	*'Continuous or one time study?'*	*'Paper or electronic records?'*
'Paper or electronic records?'	*'Disease discussed'*	*'Coding system used?'*
'Coding system used?'	*'Advantages of system'*	*'Statistical software used'*
'Statistical software used'	*'Disadvantages of system'*	*'According to framework or not?'*
'Active system described or not?'	*'Evaluated or not?'*	*'Active system described or not?'*
'General target/aim of study?'	*'Potential relevance'*	*'Time frame/Years of study'*
'Advantages of system'	*'Other remarks'*	*'General target/aim of study?'*
'Disadvantages of system'	*'Date read'*	*'Disease discussed'*
'Evaluated or not?'		*'Advantages of system'*
'Potential relevance'		*'Disadvantages of system'*
'Other remarks'		*'Sustainable or not?'*
'Date read'		*'Evaluated or not?'*
		'Potential relevance'
		'Other remarks'
		'Date read'

2.3 Results and Discussion

2.3.1 Review 1: Syndromic surveillance in cattle and small ruminants

2.3.1.1 The selection of publications: inclusion and exclusion criteria

The focus was on identifying feasibility studies, pilot projects or publications on the methodology, development or implementation of a syndromic surveillance system for cattle and small ruminants (i.e. sheep and goats). After the removal of 20 duplicates a total of 382 unique references were found through the literature search. The publications were assessed for inclusion in the further study based on the criteria in Figure 2-1.

In order to assess the effectiveness of the protocol to capture relevant publications, the literature search was evaluated using 10 previously identified sentinel articles. Nine were detected using protocol as described above. The last sentinel publication was found through assessing the references cited in the 36 publications found previously. By applying the protocol on all the references cited, an additional number of 14 publications were identified. Therefore, the total number of publications included after assessing the title, keywords and abstract was 50.

The full text for all accessible publications was read entirely. Of the 36 references found through the initial search, the full texts for 32 publications were accessible and read. Three publications were excluded after reading the full text because they did not concern syndromic surveillance in cattle or sheep.

Of the 14 references found during the second search, 9 full text publications were retrieved of which 7 were included. Two publications that were excluded were reports funded by the European Commission which did not consider animal health syndromic surveillance specifically. Two of the remaining 5 references were not accessible and for the other three only a citation or abstract was available, and thus were excluded from further analysis. In total, 36 articles were included for the final systematic review on syndromic surveillance in cattle and small ruminants and are presented in Reference list A (Appendix 2-1).

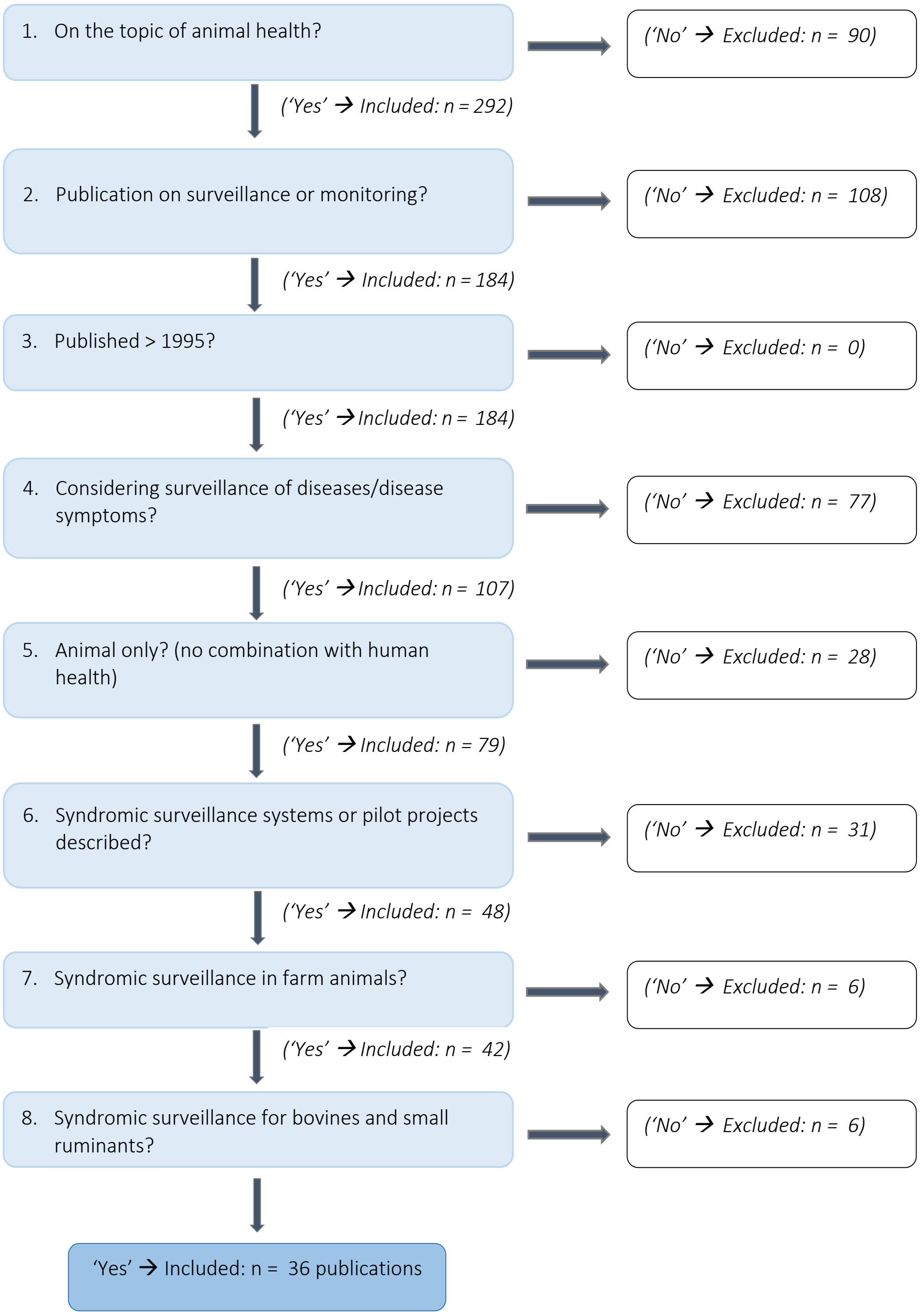


Figure 2-1: Overview of the criteria for inclusion or exclusion of publications in systematic review on syndromic surveillance in cattle and small ruminants based on title, keywords and abstracts only

2.3.1.2 Results for the systematic review on syndromic surveillance in cattle and small ruminants

2.3.1.2.1 The characteristics of syndromic surveillance systems described

The articles originated from 15 countries (Figure 2-2). Most publications found on syndromic surveillance of farm animals revolved around cattle health. Cattle was a species of interest in all 36 publications concerning syndromic surveillance, whereas only a few publications (Van Metre *et al.*, 2009; Vial and Reist, 2014; Sundufu *et al.*, 2015) also specifically mentioned syndromic surveillance of small ruminant health. For example, a paper published by Sundufu *et al*. (2015) investigated the use of syndromic surveillance through case reports of syndromic diagnoses for all livestock diseases in a region in Sierra Leone. However, because of the importance of peste des petits ruminants and the endemicity of the disease in West-Africa, the article placed specific emphasis on this disease.

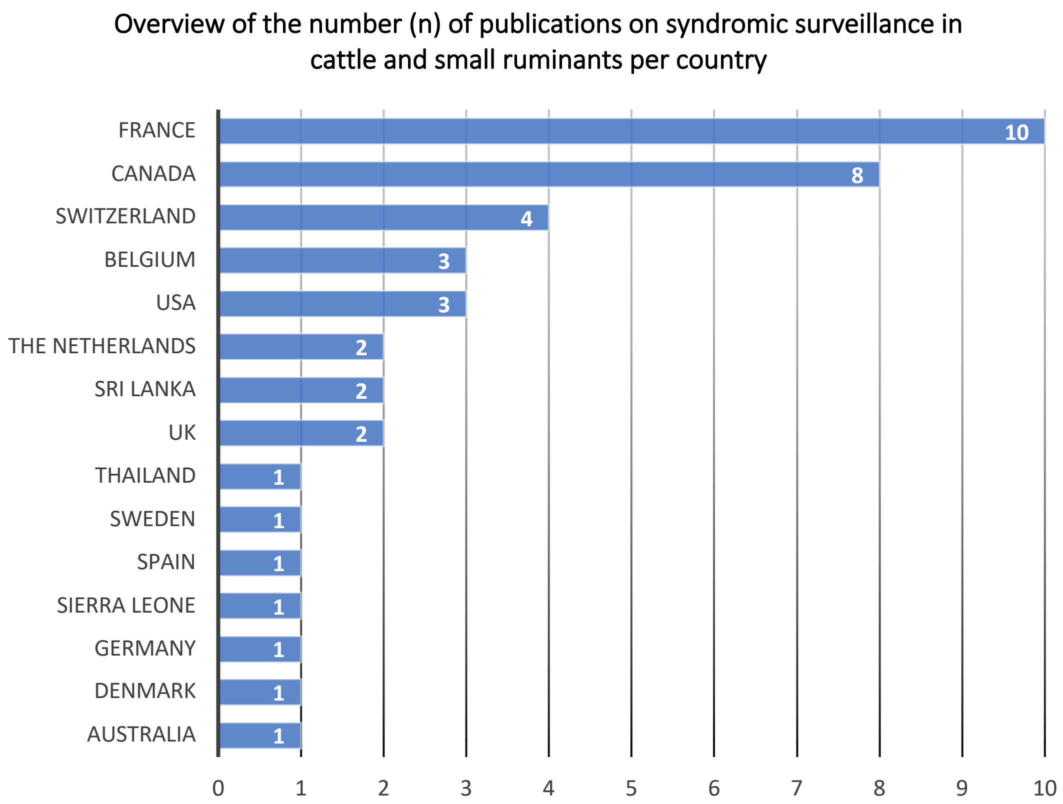


Figure 2-2: Number (n) of publications on syndromic surveillance in cattle and small ruminants per country

The available literature indicated that the use of syndromic surveillance was considered for several purposes, including early warning or detection of new, emerging and/or zoonotic diseases such as Bluetongue virus type 8 (BTV-8) (Madouasse *et al.*, 2013; Marceau *et al.*, 2014; Behaeghel *et al.*, 2015), outbreak detection of all types of disease, including endemic diseases (Dórea *et al*., 2013a), and to help lay observers diagnose livestock diseases and provide them with information and advice such as the Bovine Syndromic Surveillance System (BOSSS) system in Australia (Shephard *et al*., 2006).

2.3.1.2.2 Data sources used for syndromic surveillance and methods used for data analysis

2.3.1.2.2.1 Sources of health data about farm animals

From the 36 publications ultimately included in the review, the types of data most frequently used and assessed for syndromic surveillance originated from (i) demographic data (e.g. cow ID, date of birth, movements), cattle mortality and abortions in 12 (33.3%) publications (e.g. Gates, 2013; Bronner *et al*., 2015; Perrin *et al*., 2015), (ii) abattoir condemnation data in 9 (25.0%) (e.g. Alton *et al*., 2012; Dupuy *et al*., 2015; Vial and Reist, 2015), (iii) clinical signs in 8 (22.2%) (e.g. Shephard *et al*., 2006; Robertson *et al*., 2011; Sundufu *et al*., 2015), (iv) diagnostic laboratories in 7 (19.4%) (e.g. Hyder *et al*., 2011; Dórea *et al*., 2013a) , and (v) reproductive and production data in 5 (13.9%) papers (e.g. Madouasse *et al*., 2013; Marceau *et al*., 2014; Veldhuis *et al*., 2016).

Thirty-four (94.4%) publications described the use of electronic data collection and analysis. For the remaining two publications (i.e. Tulayakul *et al*., 2008; Sundufu *et al*., 2015) it was not specifically described whether paper-based or electronic systems were used.

2.3.1.2.2.2 Statistical analysis and software used for syndromic surveillance

Statistical software packages most frequently used for animal health syndromic surveillance were (i) R, (ii) SaTScan and (iii) ArcGIS (Figure 2-3).

Syndromic surveillance using routinely collected data was often reported in the papers. Since disease surveillance was not the primary purpose of the data collected by e.g. abattoirs or diagnostic laboratories, data had to be arranged in such manner that observations or case counts were coded and sorted adequately through methods such as (i) data mapping, text mining software, or rule based algorithms (Dórea *et al*., 2013b), (ii) hierarchical ascendant classification or HAC (Behaeghel *et al*., 2015), (iii) a naïve Bayes classifier (Shephard *et al*., 2006), or (iv) the FarmFile database for surveillance of diseases, where observations were classified under syndromic groups and additional information could be added (Hyder *et al*., 2011). Thus, the choice of method used to classify the data depended on factors such as data type, format and quality.

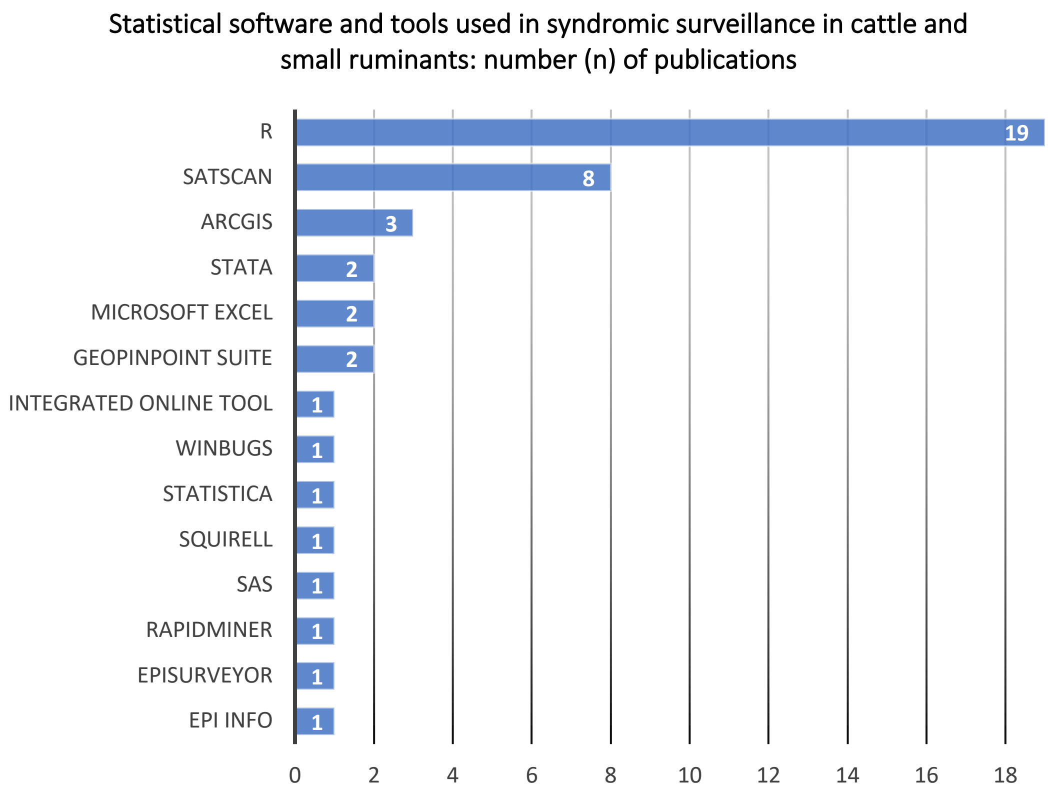


Figure 2-3: Statistical software and tools used in syndromic surveillance for cattle and small ruminants

Although a range of data modelling approaches were described in the publications, generalised linear models such as Poisson and negative binomial models for count data (e.g. Dórea *et al*., 2013a; Bronner *et al*., 2015; Dupuy *et al*., 2015; Pannwitz, 2015; Struchen *et al*., 2015; Vial and Reist, 2015), or binary and multivariate logistic regression (e.g. Dupuy *et al*., 2013b; Gates, 2013; Marceau *et al*., 2013) were frequently reported.

Additionally, the use of various algorithms to detect increases in health indicators or diseases over time was described. Some of the most frequently used algorithms according to the publications found were the statistical process control charts such as Shewhart charts, cumulative sums (CUSUM) and Exponentially Weighted Moving Averages (EWMA) (e.g. Shephard *et al*., 2006; Robertson *et al*., 2010; Dórea *et al*., 2013c; Marceau *et al*., 2013; Veldhuis *et al*., 2016). The use of these algorithms requires pre-processing of the data (e.g. through applying Poisson or negative binomial models) in order to create a stationary time series that serves as an outbreak-free baseline for further statistical analysis. Temporal effects, such as day-of-week effects or seasonality, and trends are thereby modelled and removed (Dórea *et al.*, 2013c; Dórea *et al.*, 2013d). The different control charts detect different types of outbreaks. Whereas Shewhart charts are able to detect sudden increases or 'spikes' in case counts, the CUSUM and EWMA algorithms are able to capture more slowly increasing outbreaks (Dórea *et al.*, 2013c).

However, algorithms also exist that do not require pre-processing and can account for temporal effects themselves. An example of such method that can be used for syndromic surveillance is the Holt-Winters Exponential smoothing algorithm (e.g. Dórea *et al.*, 2013c; Dórea *et al.*, 2013d). The Holt-Winters algorithm is a data-driven method, originally used for forecasting, that takes into account recent temporal events and subsequently incorporates them into the forecasts (Dórea *et al.*, 2013d). In doing so, the Holt-Winters algorithm can be used in combination with process control charts (Dórea *et al.*, 2013c).

2.3.2 Review 2: Surveillance of endemic animal diseases

2.3.2.1 The selection of publications: inclusion and exclusion criteria

After removal of 46 duplicates, a total of 180 unique references were found. Titles, abstracts and key words were read and used to include or exclude articles for further reading according to the criteria specified in Figure 2-4.

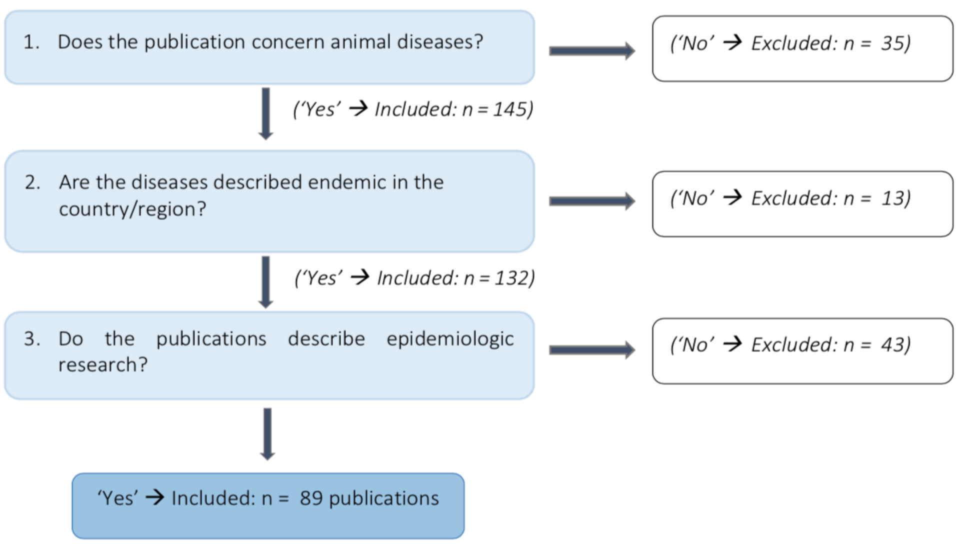


Figure 2-4: Overview of criteria for inclusion or exclusion of publications in the systematic review on the surveillance of endemic animal diseases based on title, keywords and abstracts only

The full texts for thirteen publications could not be retrieved and therefore were excluded. Before reading the full texts for 76 articles, the publications were categorised based on title, keywords and abstracts in those concerning (i) monitoring and surveillance projects of endemic diseases in animals, (ii) other epidemiological studies on endemic animal diseases, (iii) frameworks and recommendations with regard to surveillance of endemic diseases in animals, and (iv) reviews on endemic disease surveillance in animals (Figure 2-5).

Of the 32 articles in the category 'Monitoring/Surveillance projects', two were excluded after reading the entire article, because one only contained data on human disease, while the second paper did not concern an endemic animal disease. Thirty (93.8%) publications were finally included.

Subcategories of included publications on surveillance of endemic animal diseases

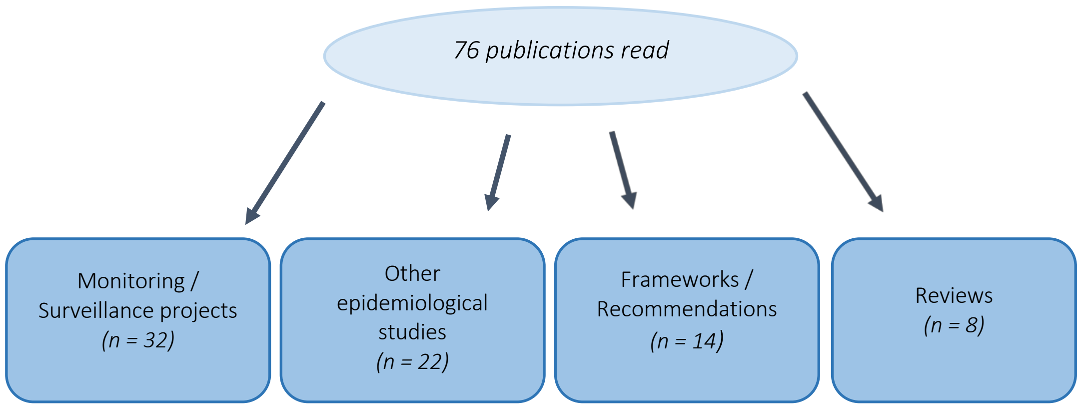


Figure 2-5: Subcategories of publications on endemic disease surveillance in animals after reading the full texts

Of the 14 publications in the category 'Frameworks/Recommendations', one was excluded because it was a description of important goat diseases rather than a paper related to epidemiological research. Thirteen (92.9%) publications were included.

Twenty-two publications were categorised as 'Other epidemiological research' (e.g. one time surveys or prevalence studies) of which three were excluded because one was a case study, one was a study where only simulated models were used, and the third was a publication on the development of a diagnostic test. Nineteen (86.4%) publications were included in the systematic review.

In the category 'Reviews', 8 full text articles were retrieved and read. After reading the publication, two were excluded because they concerned emerging animal diseases rather than endemic diseases.

Reference list B (Appendix 2-2) presents all 68 articles that were included for the final review on endemic diseases in animals.

2.3.2.2 Results for the review on monitoring or surveillance of endemic diseases in animals

Publications on all animal species were included in this review. Cattle, sheep and goats accounted for half (50.4%) of the animal species considered in articles on surveillance of endemic diseases (Figure 2-6).

Thirty-one (45.6%) publications out of 68 originated from high income countries. The number of publications per country or region is presented in Figure 2-7. Many papers on surveillance of endemic animal diseases originated from research carried out in low and middle income countries in Asia, Africa and South America. Explanations for that could be found in the financial impact of livestock diseases (e.g. FMD) and the dependency of the people in those countries on milk or meat production (Nampanya *et al*., 2013; Abbas *et al*., 2014).

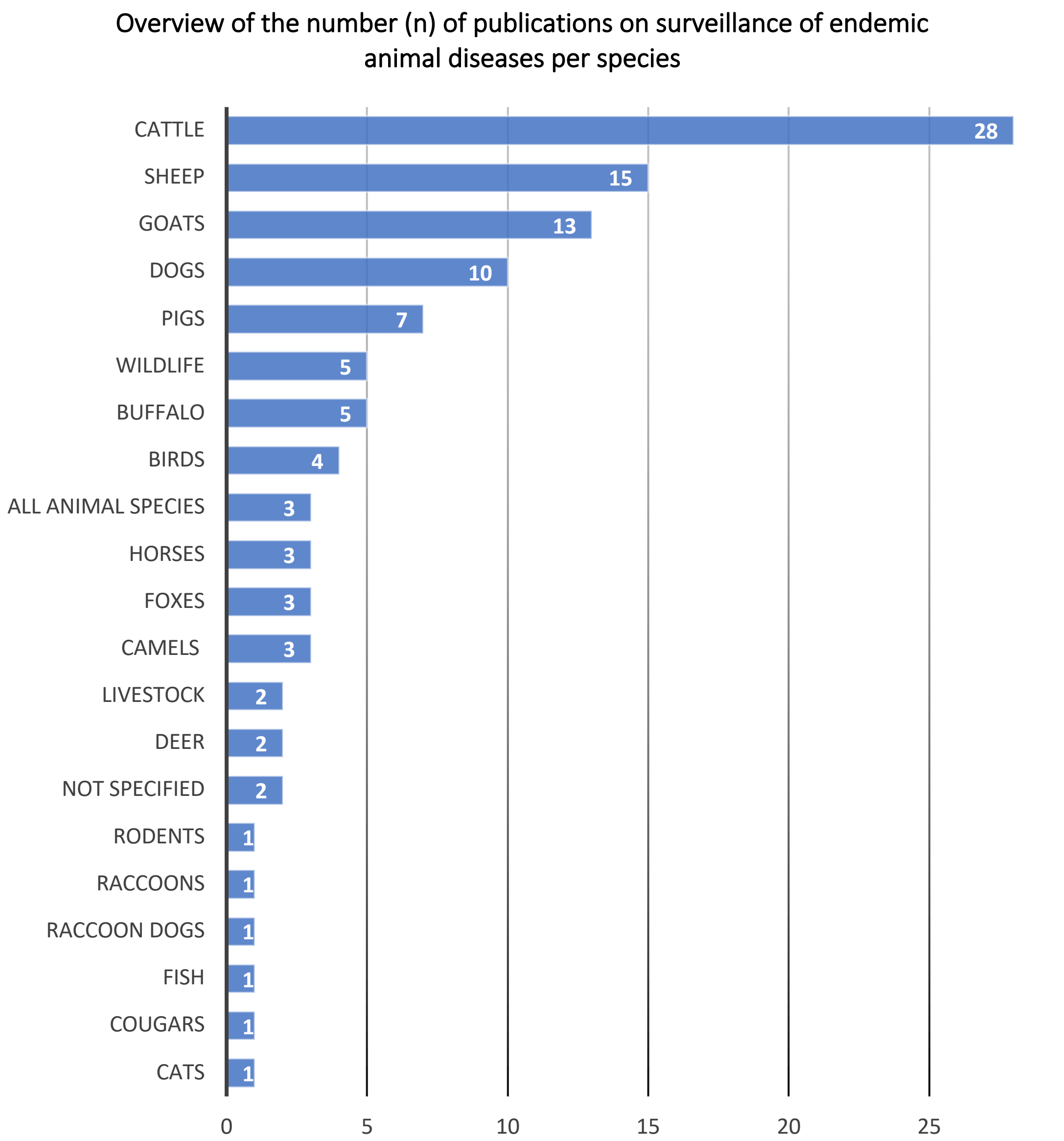


Figure 2-6: Number (n) of publications included in the systematic review on the surveillance of endemic animal diseases per species

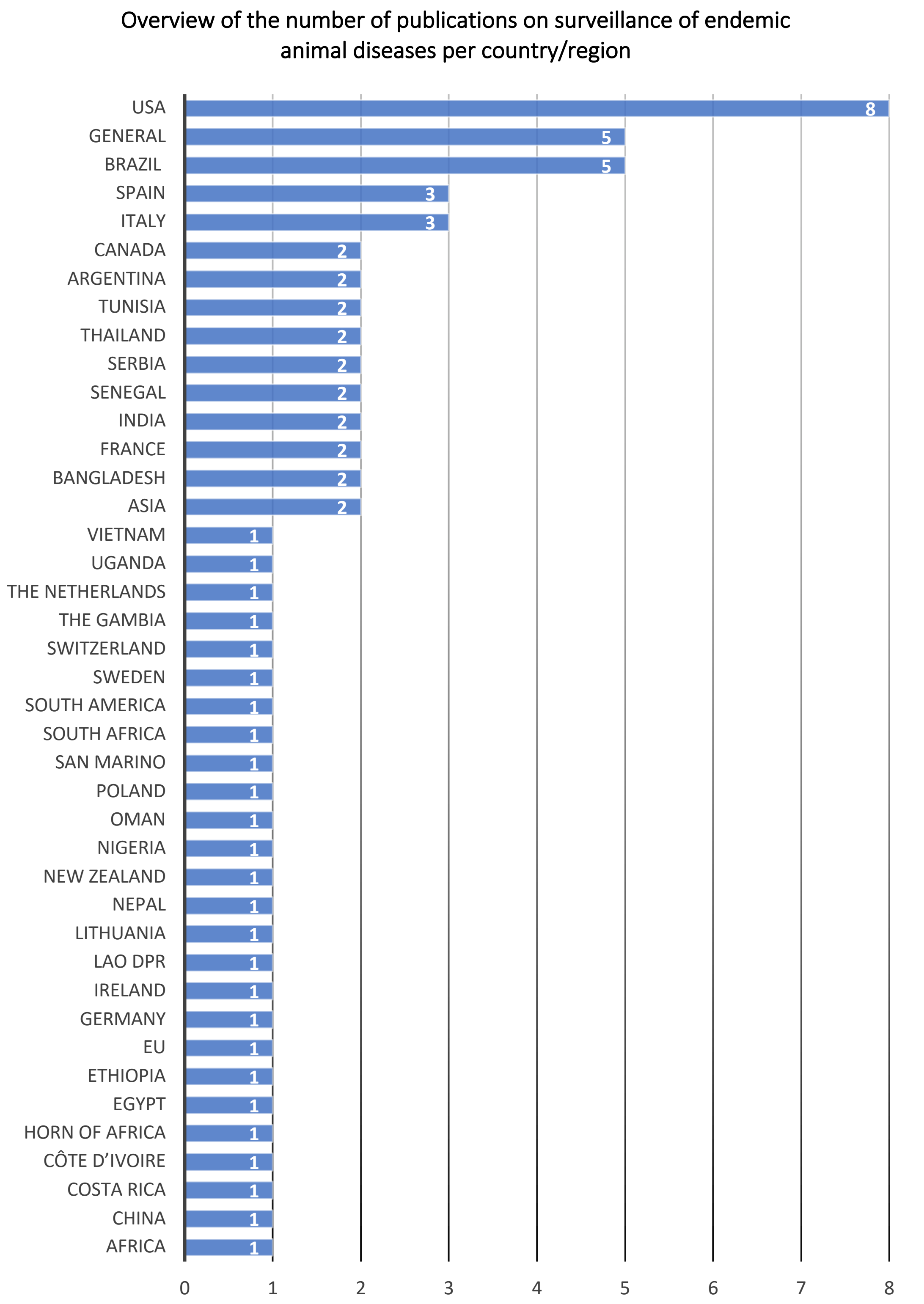


Figure 2-7: Number (n) of publications on the surveillance of endemic animal diseases per country or region

Figure 2-8 shows the number of publications by endemic disease: the most frequently mentioned were (i) FMD (Donaldson and Kihm, 1996; Wentink *et al.*, 2000; Ranabijuli *et al.*, 2010; Loth *et al.*, 2011; King *et al.*, 2012; Nuntawan Na Ayudhya *et al.*, 2012; Nampanya *et al.*, 2013; Mondal and Yamage, 2014; de Carvalho Ferreira *et al*., 2015), (ii) tuberculosis (Wentink *et al*., 2000; Wobeser, 2009; Garba *et al*., 2011; O'Brien *et al*., 2013; Cano-Manuel *et al*., 2014; Buddle *et al*., 2015), (iii) Leishmaniasis (Miró *et al*., 2007; Diouani *et al*., 2008; Cassini *et al*., 2013; Salvatore *et al*., 2013; Braga *et al*., 2014), and (iv) rabies (Gylys *et al*., 1998; Recuenco *et al*., 2008; Mondal and Yamage, 2014; Lopes *et al*., 2015; Oviedo-Pastrana *et al*., 2015). Apart from FMD, all of the diseases listed are endemic as well as zoonotic. However, not all surveillance initiatives had turned out to be effective: some diseases were still endemic regardless of the implementation of a control programme, such as haemorrhagic septicaemia in Asia (Benkirane and De Alwis, 2002) or brucellosis in Egypt (Wareth *et al*., 2014).

2.3.2.3 Data used for the monitoring or surveillance of endemic diseases in animals

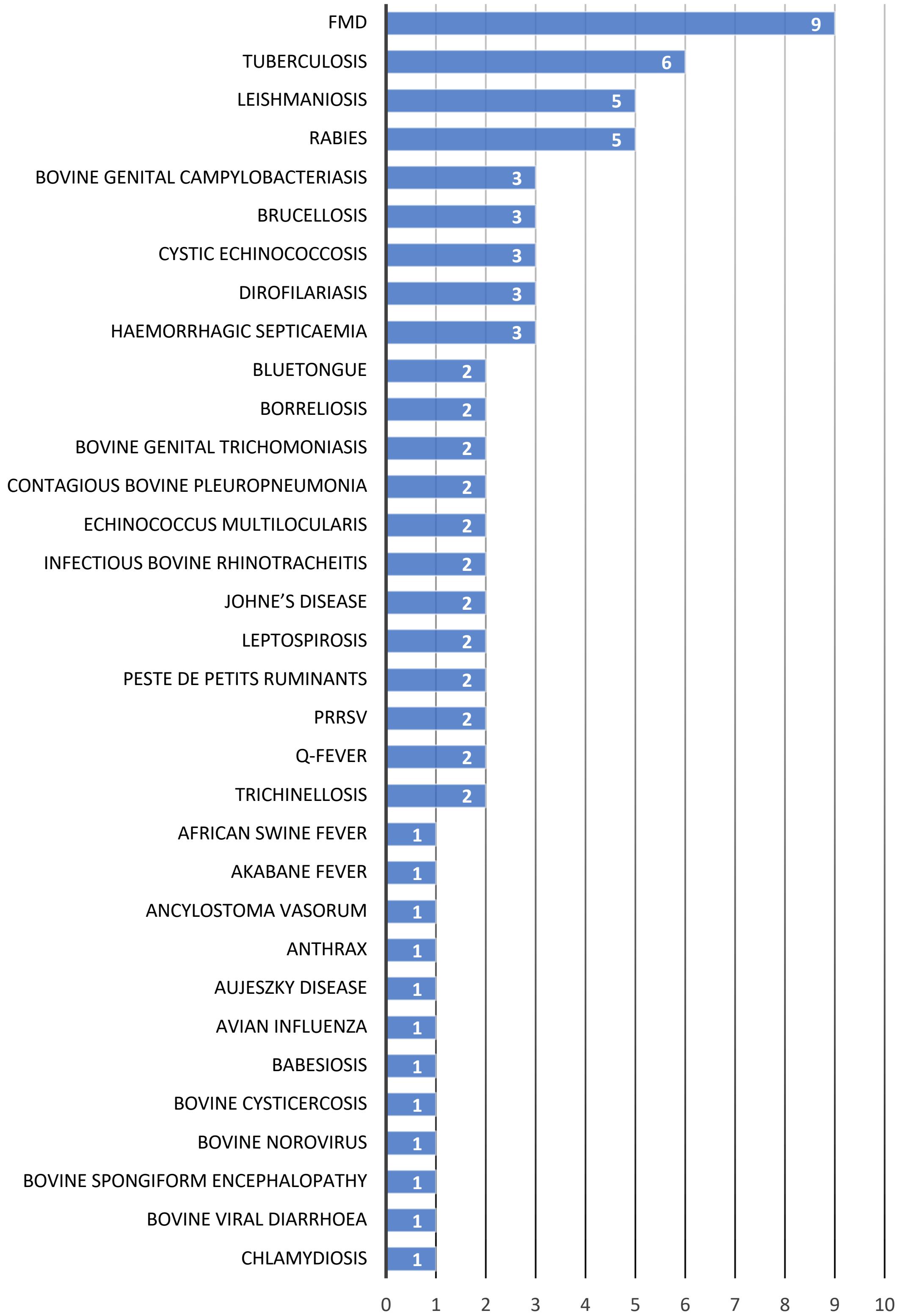
In 59 (86.8%) publications, active data collection or an active surveillance system was described. Passive surveillance was mentioned in 11 (16.2%) articles. However, opinions differed: whereas passive surveillance was considered to be biased by some (Adone and Pasquali, 2013), others claimed that it had an important role to play, particularly in resource limited countries (Mondal and Yamage, 2014).

Most publications reported that data were obtained via diagnostic techniques such as (i) laboratory tests (e.g. serology, cultures, bacterial or viral isolation, and molecular techniques such as PCR) in 53 (77.9%) studies to confirm disease presence in animals (e.g. Cano-Manuel *et al*., 2014; Wareth *et al*., 2014; Alemayehu *et al*., 2015), (ii) in 15 (22.1%) articles clinical diagnoses or signs were used (e.g. Miró *et al*., 2007; Mondal and Yamage, 2014; Lobato *et al*., 2015, and (iii) in 10 (14.7%) publications data from post mortem examinations or abattoir sampling (e.g. Wobeser, 2009; O'Brien *et al*., 2013; Abbas *et al*., 2014).

Accurate records were essential for surveillance of endemic diseases, preferably electronic (Garba *et al*., 2011; Cassini *et al*., 2014). Clinical inspection was an important feature with regard to many diseases such as FMD (Donaldson and Kihm, 1996) and therefore adequate training was needed for the actors in the field (e.g. veterinarians and farmers) (Benkirane and De Alwis, 2002). However, biases such as under-reporting were important to consider when different diseases were defined by similar clinical signs (Ranabijuli *et al*., 2010; Nampanya *et al*., 2013; Mondal and Yamage, 2014; Lobato *et al*., 2015).

To ensure the sustainability of a surveillance system and data collection, incentives were often implemented to keep data providers motivated since human behaviour affects the efficiency of disease surveillance (Dufour and Audigé, 1997; Diouani *et al*., 2008). It was therefore important that the benefits as well as the costs of surveillance for endemic diseases were carefully considered (Gharbi *et al*., 2006; Nedic *et al*., 2011; Häsler *et al*., 2012).

Overview of the number (n) of publications on the surveillance of specific endemic animal diseases (1/2)



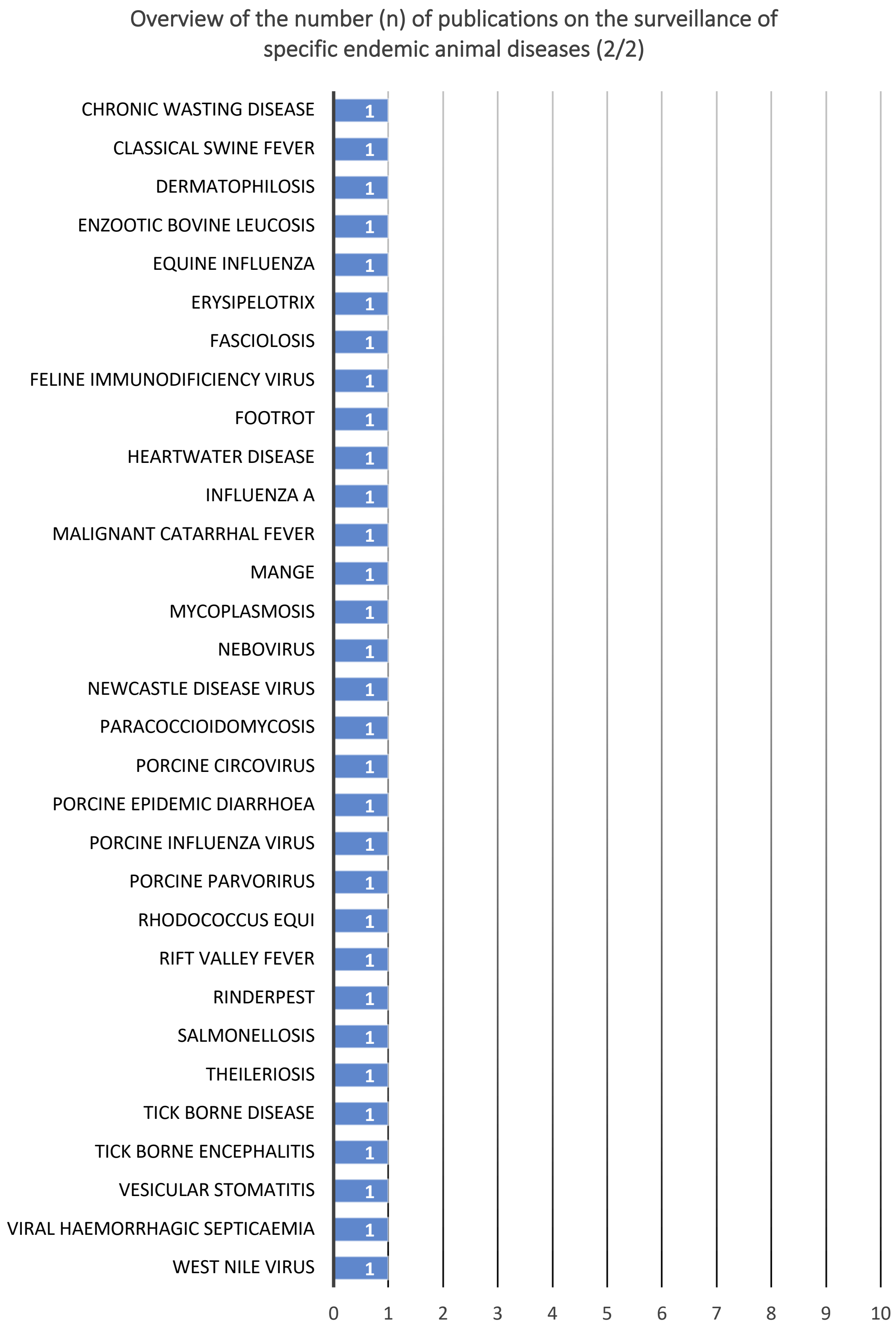


Figure 2-8: Number (n) of publications on the surveillance of specific endemic animal diseases

2.3.3 Review 3: Surveillance of human health and data collection in low resource environments

2.3.3.1 The selection of publications: inclusion and exclusion criteria

After the removal of 34 duplicates, a total of 164 unique references were identified. Titles, abstracts and key words were read and used to include or exclude articles for further reading according to the criteria listed in Figure 2-9.

The full text for seven publications could not be retrieved, therefore these publications were excluded.

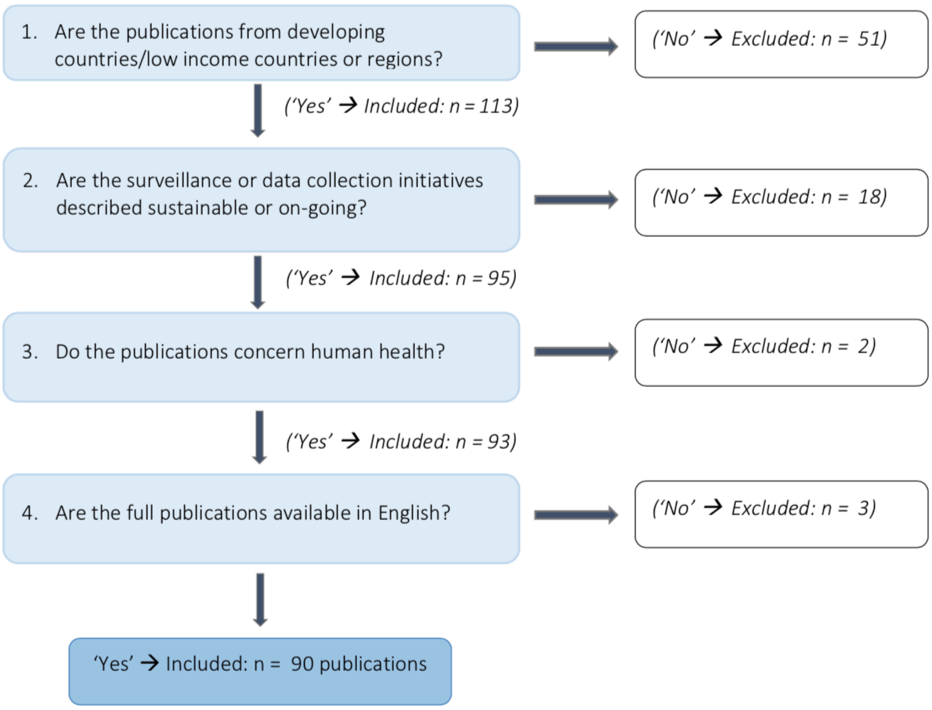


Figure 2-9: Overview of criteria for inclusion or exclusion of publications in systematic review on the surveillance of human health and data collection in low resource environments, based on title, keywords and abstracts only

Before reading the full texts, all articles were divided into subcategories based on title, keywords and abstracts: (i) monitoring and surveillance projects in low resource environments, (ii) other epidemiological studies, and (iii) frameworks or recommendations based on research in low resource environments (Figure 2-10).

In the category of 'Monitoring and/or surveillance projects' all 26 articles were read and included.

Subcategories of included publications on the surveillance of human health and data collection in low resource environments

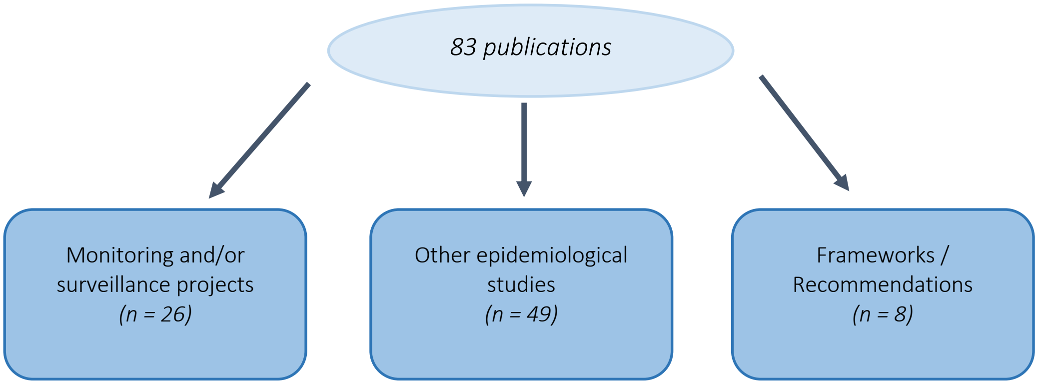


Figure 2-10: Subcategories of publications on the surveillance of human health and data collection in low resource environments after reading the full texts

Forty-nine articles in the category 'Other epidemiological research' were retrieved and read, 11 (22.4%) publications were excluded: two were abstracts only, another two considered molecular research, other reasons for exclusion were the description of viral and atypical causes of a disease rather than epidemiological research, a paper on emerging zoonoses, one paper concerned with AIDS prevention, a publication on validation methods, one paper presented research in the USA instead of low resource countries, a review was excluded, and a dissertation. In total, 38 (77.6%) publications in this category were included.

All 8 publications in the category 'Frameworks/Recommendations' were retrieved and read. Two (25.0%) publications were excluded because they were on vaccinations and they did not concern human diseases and data collection. Six (75.0%) articles were included.

All 70 publications included for the review of human surveillance initiatives and data collection in low resource environments are presented in Reference list C (Appendix 2-3).

2.3.3.2 Results for the systematic review on the surveillance of human health and data collection in low resource environments

The systematic review on surveillance and data collection in low resource environments was carried out because the methods used in these settings could be useful for the development of a syndromic surveillance system for sheep and beef cattle farmers in England as well.

The publications included in this systematic review originated from 39 countries or regions (Figure 2-11). Asian countries were most frequently represented with 50.1%. African and South American countries counted for 36.4% and 11.7% respectively.

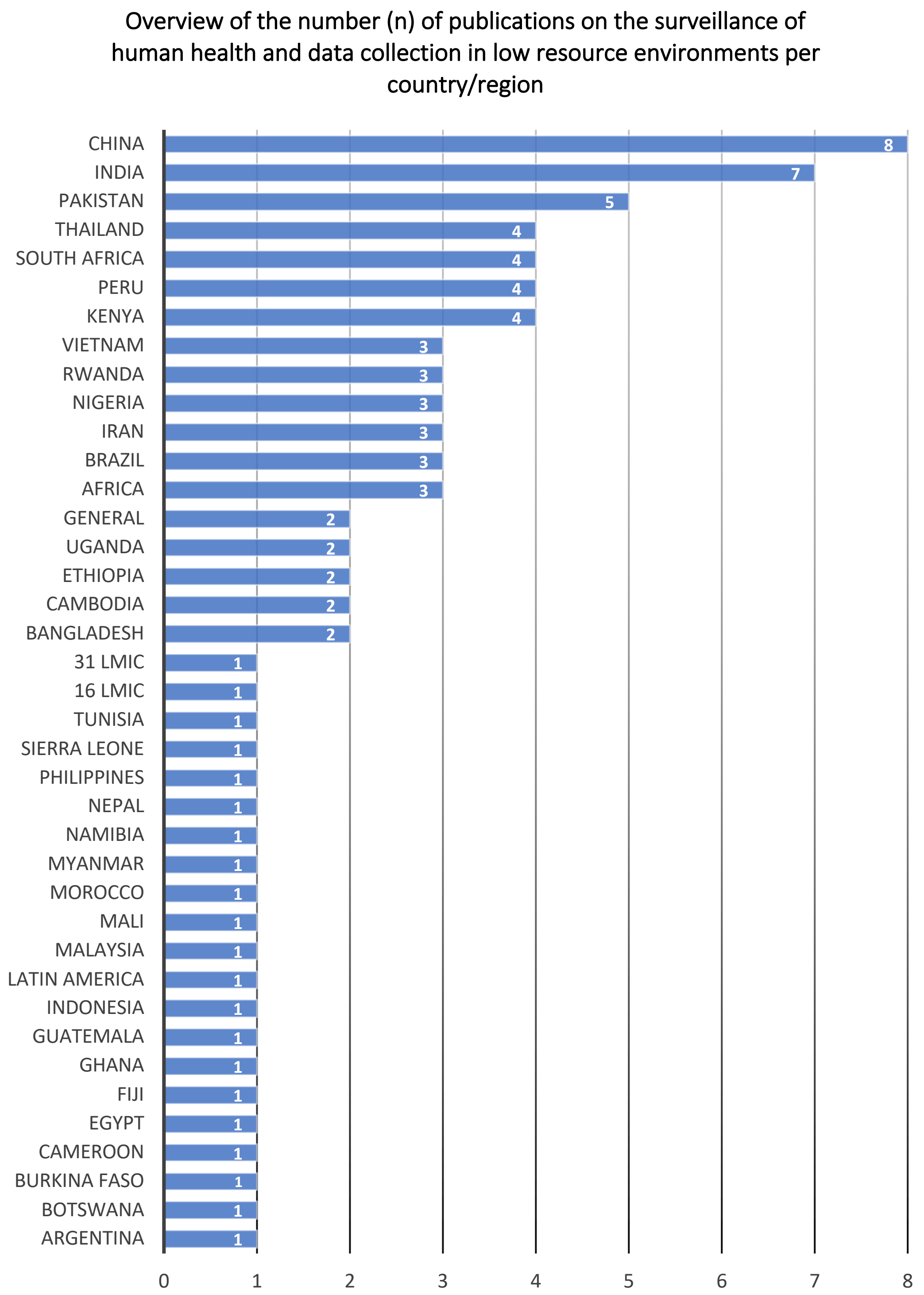


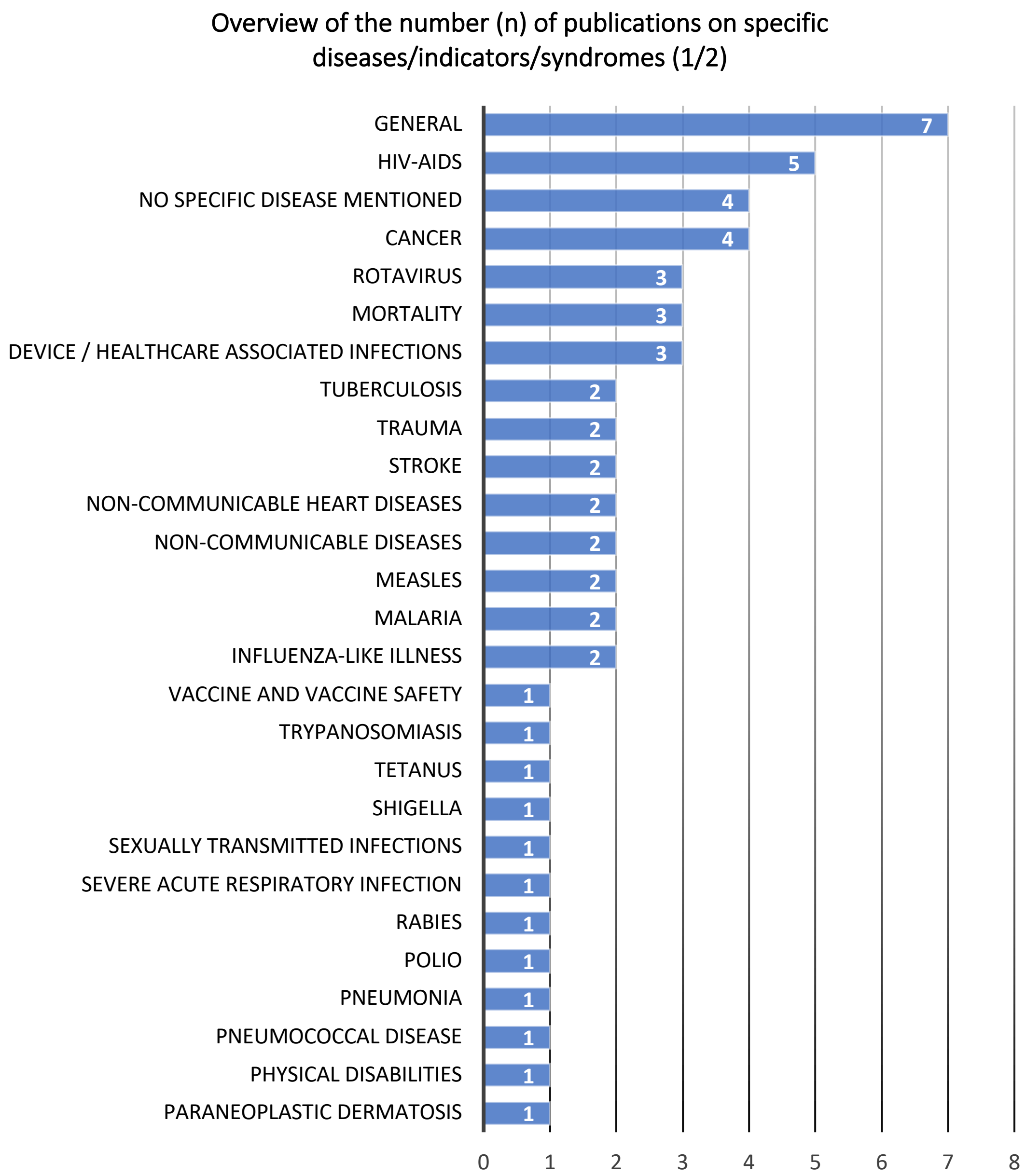
Figure 2-11: Number (n) of publications on the surveillance of human health and data collection in low resource environments per country/region

Functional surveillance systems were reported in 28 (39.4%) of the papers, where the systems were already in place or being developed. In 23 (32.9%) articles there were no functional programmes developed. In the remaining 19 (27.1%) it was not explicitly mentioned whether an active system was implemented or not.

Apart from challenges surrounding data collection and reliability, an additional concern with regard to human health surveillance in resource limited environments were financial costs and funding for both data collection and surveillance (Cecelia *et al*., 2006; Chandy *et al*., 2013; Mehmood *et al*., 2013; Kabuya *et al*., 2014).

2.3.3.3 Monitoring and surveillance of specific diseases

The majority of publications were on epidemiological research for specific diseases (Figure 2-12), but there were also papers describing surveillance systems that depended on the collection of non-specific indicators or syndrome data, such as hypertension (Vathesatogkit *et al*., 2012), occupational injuries (Li *et al*., 2012), birth defects (Mehta *et al*., 2012), mortality (Stevens *et al*., 2014) and trauma (Tyson *et al*., 2015).



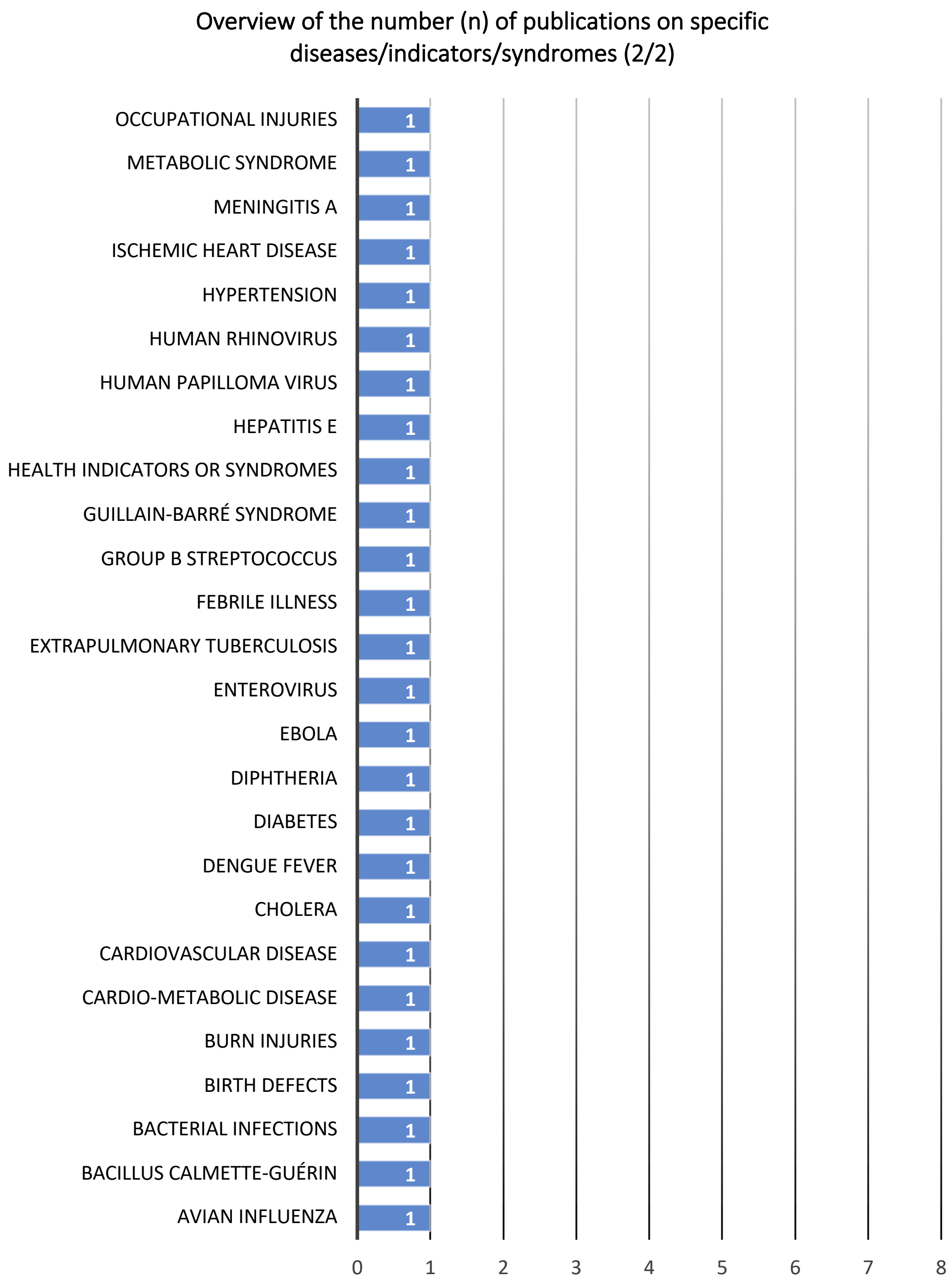


Figure 2-12: Number (n) of publications on the surveillance of human health and data collection in low resource environments for specific diseases, health indicators, or syndromes

2.3.3.4 Data sources, data collection and software used for data analysis

2.3.3.4.1 Data sources reported

Different types of data sources were used, including (i) clinical reports, diagnoses or cases, (ii) interviews, verbal autopsy and questionnaires, and (iii) demographic data (Figure 2-13).

Active sampling or collection of data was described in 39 papers, while passive data collection techniques were described in 17 papers. Surveillance and data collection in resource limited settings were often very basic, through verbal data collection with patients or relatives (e.g. interviews or verbal autopsy). Data was actively collected by e.g. interviewers (Pavan *et al.*, 1999; Nair *et al.*, 2012; Anekwe *et al.*, 2015; Breiman *et al.*, 2015), health care workers and medical staff (Nokes *et al.*, 2008; Esteghamati *et al.*, 2009; Nongkynrih *et al.*, 2010; Mehta *et al.*, 2012; Rosenthal *et al.*, 2012; Ha *et al.*, 2013; Yan *et al.*, 2013; Nicol *et al.*, 2014; Zinszer *et al.*, 2015), and field workers (Aryal *et al.*, 2012; Ibrahim and Bhutta, 2013; Rossier *et al.*, 2014). However, in 41 (58.6%) articles it was not explicitly mentioned who collected or processed the data.

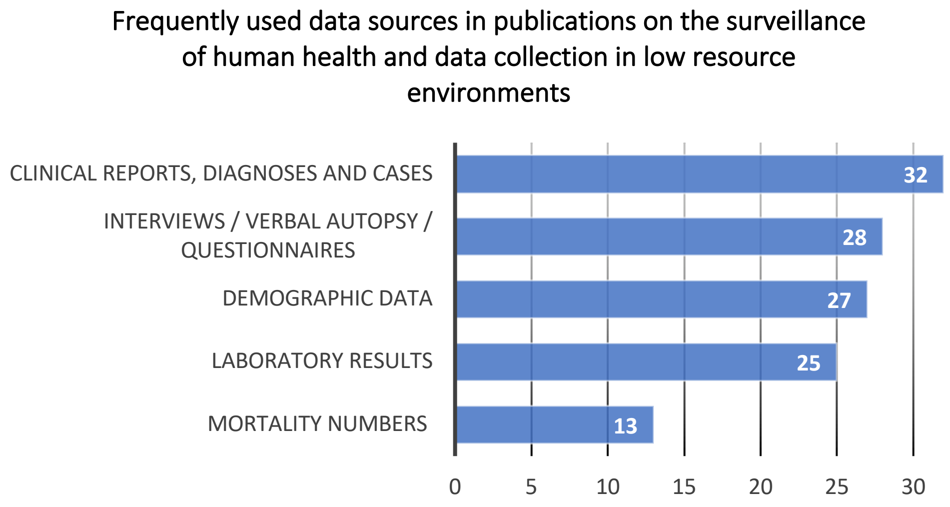


Figure 2-13: Frequently used data in publications on the surveillance of human health and data collection in low resource environments

2.3.3.4.2 Data collection methods and software used for analysis

Twenty-eight (40%) of the 70 publications reported on the use of online tools or computer based electronic systems. Twenty (71.4%) out of 28 articles only discussed electronic methods while 7 (25%) handled research where electronic techniques and paper forms are combined. Only one (3.6%) described the use of only paper records. In 42 (60%) publications it was not explicitly mentioned which methods were used. Eleven (15.7%) of the 70 publications used existing coding systems: nine used the International Classification of Diseases (ICD) while two used an additional coding system (International Classification of Diseases for Oncology and International Classification of the External Causes of Injury – ECECI).

Campbell *et al*. (2012) said that data collection methods depend on the specific local needs, but it should be a minimum burden to data providers. For example, sending SMS messages was described as an easy and feasible application to submit electronic data for the purpose of disease surveillance when resources are limited and therefore pathogen-targeted surveillance is too expensive such as in rural Cambodia (Cheng *et al*., 2013). However, a challenge for the use of electronic data recording methods was that users had to get accustomed to regular submission of data (Campbell *et al*., 2012). Still, Cheng *et al*. (2013) stated that there was increasing automation of data collection, transfer, processing and dissemination. However, the authors also highlighted that the uptake of such system would require efforts from data providers, so should be straightforward and not require too much additional actions.

There were several statistical software packages used for data analysis in resource low environments (Figure 2-14).

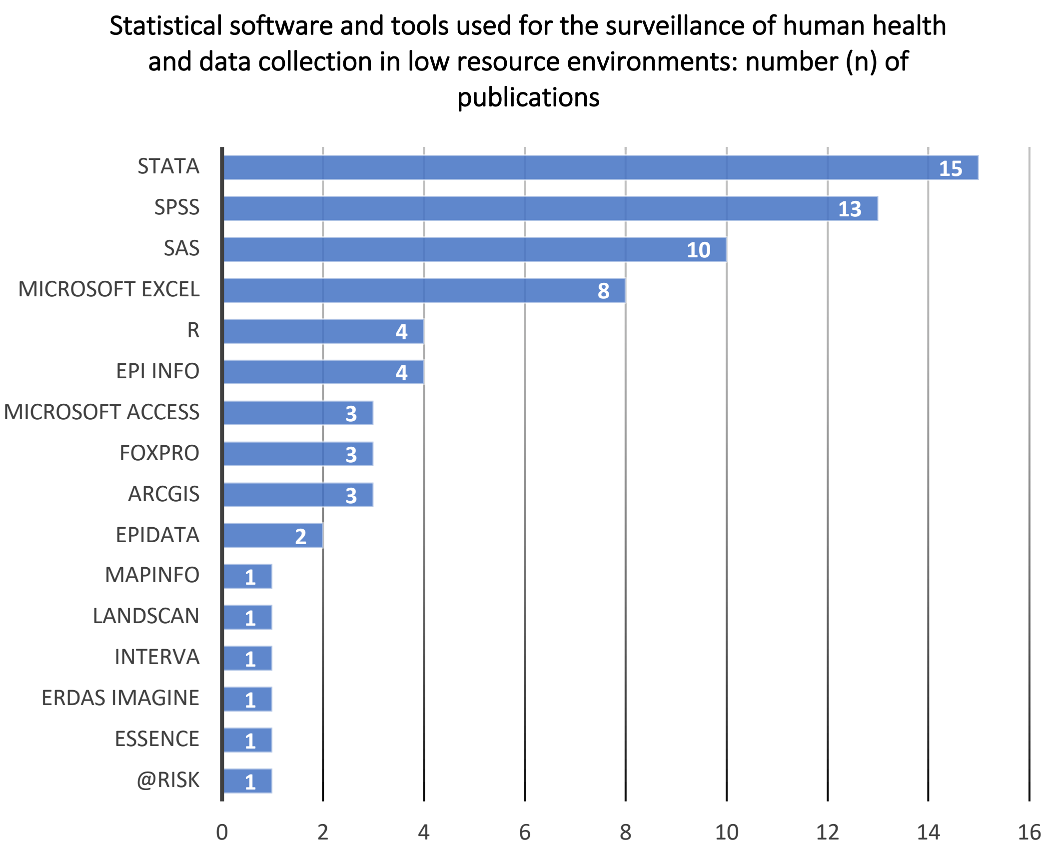


Figure 2-14: Resources and software used for data analysis and surveillance in low resource environments

2.3.3.4.3 Important limitations with regard to data collection

A limitation described by multiple authors was the representativeness of samples drawn from the total population (von Seidlein, 2006; Morris *et al*., 2012; Vathesatogkit *et al*., 2012; Okpechi *et al*., 2013; Wainiqolo *et al*., 2013; Wesson *et al*., 2013; Rafi *et al*., 2015; Tyson *et al*., 2015), e.g. when only individuals who visited a hospital or health care facility were assessed. Different types of bias have been mentioned by authors, such as selection or sample bias (Aryal *et al*., 2012; Mehta *et al*, 2012; Petroze *et al*., 2014; Yang *et al*., 2014; Tyson *et al*., 2015), recall bias (Aryal *et al*., 2012), misclassification bias (Morris *et al*., 2012), measurement bias, or interviewer bias (Aryal *et al*., 2012).

Another important concern with regard to reporting, was reliability: under-reporting or underestimation of the prevalence of diseases had been raised as an issue most frequently (Garcia and Holmes, 2003; von Seidlein, 2006; Si *et al*., 2008; Aryal *et al*., 2012; Bouchbika *et al*., 2013; Joao *et al*., 2013; Laksmaiah *et al*., 2014; Petroze *et al*., 2014; Jia and Mohamed, 2015; Patel *et al*., 2015). Underestimation was linked to passive surveillance (von Seidlein, 2006). However, over-reporting or overestimation was mentioned as well (Garcia and Holmes, 2003; Aryal *et al*., 2012; Craven and Stewart, 2013; Breiman *et al*., 2015).

Poor data quality as well as the presence of incomplete data or loss of study participants were important issues (Cecelia *et al*., 2006; Mehta *et al*., 2012; Chandy *et al*., 2013; Wainiqolo *et al*., 2013; Melaku *et al*., 2014; Nicol *et al*., 2014; Tyson *et al*., 2015). Apart from the quality of data, data sharing (Yan *et al*., 2013) and the type of records posed challenges: electronic data collection might require more effort than paper records, but various authors have reported on the advantages of electronic records, such as improved timeliness (Campbell *et al*., 2012; Cheng *et al*., 2013; Ha *et al*., 2013; Yan *et al*., 2013; Joshi *et al*., 2014; Kabuya *et al*., 2014).

2.4 Conclusions, important implications and challenges for the current project

Although syndromic surveillance is useful for animal health surveillance, not many publications on active and sustainable syndromic surveillance initiatives were available. Moreover, results from the systematic review on syndromic surveillance in cattle and small ruminants indicated that it was very difficult to maintain a system that depended on active reporting. Looking at how surveillance of endemic animal diseases was done worldwide, a similar conclusion could be drawn: only a relatively small number of surveillance initiatives relied on the reporting of clinical observations without diagnostic confirmation.

Syndromic surveillance relying on active farmer reporting of non-specific, clinical health indicators was difficult to achieve. Subsequently, surveillance of specific endemic diseases (rather than clinical signs) mostly relied on diagnostic confirmation, most often by laboratories. Therefore, it would need to be considered whether surveillance of endemic diseases would require farmer input at all. Apart from the feasibility of recording and reporting by farmers, it was therefore also assessed in the current project what other sources could provide useful and interesting diagnostic data according to farmers. Laboratory records, abattoir data, demographic data (e.g. mortality, births), and animal production data could be valid alternatives to consider in a disease surveillance system for beef cattle and sheep health.

Where efforts were required from data providers or producers to submit data into a surveillance system, incentives such as (i) financial benefits, (ii) useful information that would allow for benchmarking, (iii) expert advice, and (iv) additional training were required to increase sustainability and the level of engagement from data providers and producers (Dórea *et al*., 2011; Dupuy *et al*., 2013a).

Using existing or routinely collected data played an important role in human surveillance, specifically when only limited financial resources were available. This type of passive surveillance was useful in resource limited countries (Mondal and Yamage, 2014) and it might also be useful in the context of the current project on surveillance for livestock farmers, where the costs of surveillance for the participants should be reduced as much as possible.

Thus, the following challenges to consider in this project included (i) investigating whether voluntary reporting and co-operation from sheep and beef cattle farmers would be feasible and sustainable within a surveillance system, (ii) identifying and targeting priority areas for surveillance by farmers (e.g. syndromic surveillance of clinical signs versus disease surveillance), (iii) assessing the availability and quality of the data provided for disease surveillance, and (iv) potential incentivising of voluntary reporting.

Chapter 3

FARMERS' OPINIONS AND BEHAVIOUR TOWARDS SURVEILLANCE OF SHEEP AND BEEF CATTLE HEALTH: A QUALITATIVE STUDY

3.1 Introduction

Qualitative research methods allow for the capture of a wide range of data and opinions from participants (Morgan, 1996; Ritchie, 2003; Krueger and Casey, 2009). Qualitative data for this study were collected by means of six focus group discussions with sheep and/or beef cattle farmers in the North, Midlands and South West of England. Focus groups and thematic analysis allow more insight into the behaviour of participants through the dynamics of the discussion and to discover patterns of factors across the different groups that influence behaviour (Braun and Clarke, 2006; May, 2018). The discussions were run until the stage of saturation was reached and no new opinions were raised (Krueger and Casey, 2009).

The aim of this study was to investigate whether a surveillance system where farmers would be required to record data on their own livestock could be useful to aid with decision-making on-farm, and what useful data (e.g. clinical signs or specific diseases present on-farm) could be collected on-farm for this purpose. Additionally, it was assessed how participants preferred data to be submitted and how feedback from a system could be disseminated. Knowledge gained from conducting three systematic reviews (Chapter 2) was also used for designing of the focus group discussions.

3.2 Methods

3.2.1 Ethical approval

An application for ethical approval (reference number REGO-2016-1792) was submitted to the University of Warwick's Biomedical and Scientific Research Ethics Committee (BSREC) on 26th April 2016 covering a detailed outline of the approach, aims and objectives of the study. Conditional approval was granted on 19th May 2016. The revised version with adaptations was submitted to BSREC on 20th May 2016. Full approval for the study was awarded on 23rd May 2016.

3.2.2 Locations for the focus group discussions

Locations for the focus group discussions with sheep and beef cattle farmers were selected in Escrick (North Yorkshire), North Petherton (Somerset) and Oakham (Rutland). Focus groups discussions were conducted in the North, Midlands and Southwest of England to ensure geographical coverage of the whole country. Two separate focus group discussions were held per location with sheep and beef cattle farmers.

3.2.3 Farmer selection

A total of 300 farmers (150 sheep and 150 beef cattle) were contacted by AHDB to participate in the study. The e-mail invite also provided introductory information to the purpose of the study. Interested farmers completed a short online questionnaire with basic questions on their business and flock/herd. Additionally, information on farmers' age and gender was requested. Participants were then selected based on their responses.

Focus group participants can be diverse, however, some homogeneity (e.g. participants of the same gender) is positive for participants who feel safer in an environment with people who are similar to some extent because this is important for the dynamics of the discussion and encourages them to speak freely (Morgan, 1996; Ritchie *et al.*, 2003a). Apart from differences between farmers, also the background of the researchers can affect the dynamics of a focus group discussion. Social desirability bias can be introduced in the study if participants do not feel comfortable contradicting perceived researchers' opinion (Hewitt, 2007).

Ultimately, only male farmers were selected for the study to improve similarity between participants (Morgan, 1996). Where possible, attempts were made to include participants from all age categories, i.e. < 25, 26-35, 36-50, and > 50 years of age.

3.2.4 Study design: focus group discussions with sheep and beef cattle farmers

3.2.4.1 Focus group discussions: course of the meetings and semi-structured guidelines

All participants were provided with relevant documentation covering introductory information to the study and confidentiality, and signed consent forms (Appendix 3-1), prior to the start of the discussions.

The facilitators for the focus groups were Laura Green (Escrick and North Petherton) and Rachel Clifton (Oakham) who followed semi-structured guidelines (Appendix 3-2) with key questions to ensure all relevant topics were touched on during the group meetings. Before the discussions were concluded, the facilitator summarised the meeting in order to give participants an opportunity to address other topics they considered important that were not covered during the meeting.

Key questions that were discussed revolved around three major sections: (i) the identification of the use and scope of a syndromic surveillance programme, (ii) the practical and technological realisation of data recording, and (iii) the dissemination of feedback from a system and incentives for farmers.

3.2.4.1.1 The identification of the use and scope of a syndromic surveillance programme

The first section of the discussion focused on how the outputs of a surveillance system could be useful to farmers and on what level they would use the outputs to their benefit. The key questions considered for the first section were:

(i) 'How can a continuous on-farm monitoring system be valuable to farmers?'

(ii) 'What data is already being recorded and how is it currently used?'

(iii) 'Which clinical signs or diseases need to be monitored through syndromic surveillance?' (e.g. endemic, exotic, new and emerging diseases, zoonoses and/or notifiable diseases)

3.2.4.1.2 Practical and technological realisation of data recording

Possible methods to record and store information on clinical signs or disease numbers were defined and discussed. Keeping adequate records demanded a strong commitment (Chapter 1), so the possibility that farmers responded negatively to this idea was considered.

The key questions for this section were:

(i) 'How realistic is the active on-farm monitoring of diseases?'

(ii) 'Which useful additional sources should be linked within a syndromic surveillance system?'

This section considered whether active recording by farmers on their farm is feasible and which methods would be best to record clinical information (e.g. SMS texts, standardised electronic forms, online questionnaires or mobile phone applications). Sheep farmers were also asked about their use of EID. In addition to clinical signs, farmers were questioned about other data sources they thought were useful for a surveillance system.

3.2.4.1.3 The dissemination of feedback from a system and incentives for farmers

The implementation of incentives could be an important aspect to improve the long-term sustainability of a surveillance system (Chapter 2). Possible incentives for farmers to participate in a surveillance system were identified.

Key questions on this topic were:

(i) 'How would feedback from the system need to be disseminated?'

(ii) 'What would be important incentives to ensure the efficiency and sustainability of a syndromic surveillance programme?'

Knowledge can be disseminated in various ways, according to the needs and wishes of the interested parties. Different possibilities were considered. Because it is challenging to engage people in a surveillance project where they have to record observations (Chapter 2), incentives necessary to ensure the efficiency and sustainability of a surveillance programme were identified together with how and when participants would like to receive feedback from the system.

3.2.4.2 Transcription, coding of the discussions and thematic analysis

The length of the focus group meetings varied between 60 and 110 minutes and were fully audio-recorded. The recorders were switched off when the participants had nothing more to add. To enable the tracking of participants' voices, farmers stated their names, type and flock/herd sizes. Answers from participants were anonymised.

Audio-recordings were transcribed verbatim. The final transcripts were re-read and additional notes were written up. All discussions were coded and re-coded using NVivo 11.0 (QSR International, 2017) to increase robustness. Further thematic analysis was carried out manually using the Framework Approach (Ritchie *et al.*, 2003b). A matrix was created to reduce the amount of data, to visualise relationships in the data, and identify all relevant themes.

3.3 Results

3.3.1 Sheep farmers

3.3.1.1 Participants' profiles

A total of 44/150 (29.3%) sheep farmers expressed an interest in the study by filling in the short, online questionnaire. Five (11.4%) of them completed the survey, but did not provide contact details and were therefore excluded. Further selection of farmers by gender, age and flock size resulted in the invitation of 24 sheep farmers (Table 3-1). Five (20.8%) did not respond when provided with more details about the location and practical information for the focus group interviews, while another five (20.8%) farmers confirmed their presence but cancelled before the meeting. Fourteen of the 24 sheep farmers invited took part in the focus group discussions.

Table 3-1: Selection of sheep farmers for focus group discussions

Sheep farmers	North Yorkshire	Rutland	Somerset
Responded online (n)	14	9	21
Invited after selection (n)	7	7	10
Participants (n)	5	3	6
Flock size (range n)	40 - 600	50 - 950	70 - 1300
Flock size (median n)	220	500	750
Age of participants (n):			
26 - 35 yr	1	0	1
36 - 50 yr	2	0	1
> 50 yr	2	3	4

At the start of the focus group meetings, farmers introduced themselves and the business they were running. Two farmers attended both a sheep and a beef cattle discussion. There was variety in the farm types represented, associated with characteristics such as breed, lambing time and housing at lambing. Indoor as well as outdoor lambing was practised. In general, most flocks lambed between January and May. Some farmers split their ewes into lambing groups by due date. One of the participating farmers started lambing a first group as early as November, a second in March and a third group lambed in June. For some participants, farming livestock was not the only or the primary occupation, which also affected lambing season.

F: 'I work off the farm, so it's important for me to go to lamb outside in May.'

Businesses with solely commercial finishing sheep, breeding units, milking sheep, or combinations of livestock and arable farming were examples of the type of farms from participants. What information they considered to be useful depended on the business type, flock plans, and the interests of the individual farmers. Most participants considered themselves to be progressive farmers and said they already did as much as they could to keep their animals healthy.

F: 'Well…You've got the progressive people 'round [the table] here, haven't you?'

Nine (64.3%) participants were over 50 years old. While some of them explained they were trying to keep up with new technologies and e.g. implemented more sophisticated weighing systems for their sheep, the general belief was that the younger generation of farmers would be more willing and able to implement novel technologies and contribute to a new surveillance system for sheep health.

> *F: 'Well, I sound enthusiastic, but unless you've got the next generation in place, you're gonna be on a loser...'*

When asked what period would be easiest for farmers to record and submit data for surveillance, they indicated that the key periods of the year when they go through their flocks would be the best times.

> *F: 'I think in the autumn, when you sort of have sorted out [your flock], everything else, and [you are] getting ready for the next year, you do have a bit more time or you're glad to take more time to put the data in.'*

Farmers expressed contradictory opinions on recording data: according to some it was of interest to record health indicators, clinical signs and/or sheep diseases, but others stated that while the outputs of a surveillance system could be of added value, they were concerned that it would not be taken up easily if a system would rely on farmers recording data themselves.

> *F: 'I think part of the problem is in the data collection, 'cause it costs the farmer to get the data and I think the costs are too high.'*

> *F: 'You're gonna have a core nucleus of people that are interested in and want to try [it] and do something for themselves and possibly the industry as well, but then there are always the people that are gonna live off the back of what somebody has told them, you know.'*

Participants believed that recording data would not be something most farmers would like to do voluntarily. It would require time they could otherwise be able to spend on different, more relevant matters for their business.

> *F: 'Every farmer that I know resents filling out forms.'*

> *F: 'If you get a month of dry weather, there won't be a farmer near a computer until after harvest.'*

> *F: 'I have to say on my own farm, where we've only got the hundred and fifty ewes, everything's put in a book and when I've got a wet day I go and enter it all up on the computer.'*

A source for data collected on-farm could be EID records and farm management software programmes where flock/herd information is recorded and saved electronically. This data could possibly be used for animal health surveillance if farmers were willing to grant access to their data. However, many different software programmes are used, and collecting, collating and analysing the data from different programmes and in different formats would be a challenging task.

> *F: 'If […] you slip in a consent form so the data can go on to a national database, which you update centrally, then that's fine. I think people would issue the consent, but fundamentally it has to help them and if it doesn't help them, they won't do it.'*

3.3.1.2 Flock management and the monitoring of sheep health

3.3.1.2.1 Flock management and decision-making

> *F: 'My ideal is a sheep that doesn't go wrong, that doesn't get diseases and then can drop dead at ten. But that doesn't happen…'*

The sheep farmers believed that many farmers would be interested to know more about sheep health providing the information would benefit them personally and the health of their own flock.

> *F: 'See, I think you're on the wrong track as you're thinking that farmers will willingly contribute to a national database [for the purpose of monitoring animal health]. I don't think that that's their thinking. They will willingly contribute to something which might help them personally.'*

The sheep farmers considered useful feedback would allow them to evaluate and improve decision-making on their farms.

> *F: 'There's a benefit to knowing what's going on in your own place. Most people haven't got the basics.'*
>
> *F: 'Well, I think the primary incentive is to make sure that you get rid of diseases which lead to economic loss in your flock.'*
>
> *F: 'We only started blood testing last year and I didn't realise I had a problem until I blood tested, but when I found that about sixteen percent of my ewes had got Johne's, I had to make a decision.'*

Participants said that access to more information could influence decision-making and when necessary initiate a change in policy. The farmers considered historic information and results on their own farm to be most important, but they also thought it was useful to receive reports on the spread of diseases in the area.

> *F: 'It makes you feel a little bit better if everybody else is suffering the same thing. […] If all people are having the same problems at least you think "Well, it's not just me that's doing something wrong"'.*

However, the farmers admitted that the costs and benefits of management strategies also influenced their decision-making, and that they made different decisions for pedigree and commercial flocks.

> *F: 'Pedigree boys might be a little bit more on the ball because they're Maedi-Visna accredited or whatever, but for a commercial flock to test all your ewes for certain endemic diseases isn't cost-effective.'*

> *F: 'My Suffolk [flock]'s Maedi-Visna accredited. I did my first test for that, but my commercial flock isn't and it's just, you know, I don't know if it is, I could obviously test for it, but it's three pounds a head for testing so it's like well, I'll just follow the rules and keep them separate and you've got to do the best you can and to do annual testing.'*

3.3.1.2.2 Sheep health recording

3.3.1.2.2.1 Recording health indicators and sheep diseases by farmers

When asked what data were valuable for surveillance according to the participants, reliable diagnostic results were more useful than basic clinical signs collected by farmers. Important diseases discussed by focus group participants are presented in Table 3-2. In general, sheep farmers considered the recording of clinical signs to be 'too basic' since these could have a multitude of causes, including sheep diseases, but also nutrition and environmental factors. The example of diarrhoea was used to demonstrate their view.

> *F: 'The thing is, just because it's dirty backend, doesn't mean necessarily it's got worms or [coccidiosis].'*

Whether they believed reports on clinical signs such as mastitis and lameness would be useful or not depended on the interests of the individual farmers. For some participants, these were the first health indicators they would like to benchmark, while others did not think it would be useful because of e.g. the delay between the time they report a clinical sign and the moment they would receive feedback from a monitoring system. Participants believed that by the time feedback on clinical signs would be provided, often they would have already dealt with the problem.

Some participants believed that a surveillance system that relied on farmers reporting confirmed or suspected cases of a disease would not be very accurate since they feared farmers might not always correctly recognise a specific disease. This might lead to incorrect estimates of disease presence.

> *F: 'You could be getting misinformation, couldn't you? If you don't diagnose it correctly which might be a problem with your [recording].'*

Table 3-2: Sheep diseases discussed in farmer focus groups

Diseases of interest	Diseases participants have had on-farm
Bluetongue virus (BTV)	Abortion (EAE and toxoplasmic)
Border disease (BDv)	Border disease (BDv)
Bovine tuberculosis (bTB)	Caseous lymphadenitis (CLA)
Caseous lymphadenitis (CLA)	Contagious ovine digital dermatitis (CODD)
Coccidiosis	Cysticercus tenuicollis
Enzootic abortion (EAE)	Eye diseases
Fluke and other liver diseases	Flystrike
Flystrike	Footrot
Footrot and other causes of lameness	Haemonchus contortus
Johne's disease	Johne's disease
Lyme disease and other tick-borne diseases	Pneumonia
Maedi-Visna	Pulpy kidney
Mastitis	Schmallenberg virus
Nematodirus and other worm infections	Trace element deficiencies (selenium and cobalt)
Ovine pulmonary adenomatosis (OPA)	Watery mouth
Pneumonia and other lung dieases	
Schmallenberg virus	
Sheep scab	
Toxoplasmic abortion	
Trace element deficiencies	

3.3.1.2.2.2 Other diagnostic data sources

According to the participants, useful diagnostic data could come from a variety of sources, such as veterinarians, laboratories and post mortem examiners.

> *F: 'I just feel personally that the real benefit of this stuff is actually the data, the valuable data actually isn't held by us, it's held by abattoirs and potentially vets.'*

However, most farmers said that they did not receive much diagnostic feedback. Some participants who had commercial flocks said they received some feedback from abattoirs, while the pedigree farmers usually did not.

> *F: 'That's certainly very useful you know if they've got liver damage or anything like that, getting the results back from the abattoir, but obviously when you're selling liveweight, you don't get that feedback unless the buyer says "Well I'm not buying your lambs because they're full of fluke" or something like that.'*

Pedigree farmers in particular were most interested in diagnostic feedback since many sheep diseases can have a devastating effect on the breeding flock. Participants tended to be particularly concerned about iceberg diseases such as Maedi-Visna and Johne's disease.

> *F: 'They call them the iceberg diseases [in a way that] you only hear about the tip and the rest of it's [there] in the industry… And I think that's one of the biggest threats for the industry at the moment I think.'*

> *F: 'I think that some of the ones that are more important to learn about really, the Iceberg diseases and the ones that less people talk about, you know, CLA, Johne's, Maedi-Visna.'*

The farmers said that if anonymised diagnostic data from laboratories, post-mortem examinations or abattoir rejections were used for the purpose of monitoring disease incidence, they would be likely to provide or grant access to their data.

> *F: 'I would go further than ['Could data from laboratories be used?'], I would say should, but it's getting confidence that it is being fully anonymized.'*

3.3.1.3 The spread of sheep diseases

Biosecurity with regard to the introduction of diseases on their own farms was an important topic for the sheep farmers. However, some participants admitted they did retain diseased sheep for economic reasons.

F: 'When culls are worth fifty quid and replacements are one fifty you think twice, won't you?'

3.3.1.3.1 Diseases in the farmers' own flocks

According to the participants, severe diseases were usually only picked up when they noticed a number of sheep suffering similar symptoms. By that time, they often believed it was already too late to treat since diseases can spread quickly and they said they would have already undertaken action, in some cases going as far as culling the affected sheep.

F: 'I don't think it has any value to us, by the time we get those results back, it's probably too late for us to do something about it, we've already acted.

F: 'Well most of these diseases go right across the whole flock anyway.'

Another limitation for participants to getting confirmation of the presence of a sheep disease on-farm was the cost associated with a diagnosis from e.g. a veterinarian or post-mortem examiner.

F: 'There's always a reason why something dies, it's just how much it costs to find out.'

3.3.1.3.2 Buying in diseased sheep

Markets were considered to be a health risk because of diseased animals being sold as healthy sheep. This also contributed to the decision of some sheep farmers to change to a closed flock.

F: 'There's always gonna be […] fifty, sixty, seventy percent who wouldn't bother [looking at the health status of an animal], they'll just buy the cheapest thing on four legs to give them a lamb and I'm afraid that's been the attitude for so long.'

F: '[Our] commercial flock's mainly mule-based but we are moving towards a closed flock 'cause I'm actually somewhat scared of disease risk.'

3.3.1.4 Raising awareness and improving understanding of sheep diseases

The participants believed that information on disease characteristics would increase general knowledge and understanding amongst farmers. Quantitative results from an evidence-based system and disease specific characteristics such as transmission pattern or geographic spread of disease were of interest for this purpose.

F: 'I think it's [important] understanding how they [i.e. diseases] are transmitted as much as anything.'

However, some of the farmers admitted that they did not look for information or reports on health threats.

> *F: 'Yeah I don't read, I've never really looked into the understanding of [sheep diseases].'*

The pedigree farmers felt very strongly about raising awareness and targeting information on the consequences of introducing iceberg diseases (e.g. Johne's disease, Maedi-Visna) into their flock. Commercial farmers were believed to be not as concerned since the impact of these diseases is not as severe as for breeding units. Breeding or pedigree ewes were more valuable and it was difficult to eradicate iceberg diseases from the flock without having to cull a large percentage of the ewes.

> *F: 'But that, Maedi-Visna and Jaagsiekte and these sorts of diseases that are a big problem for people selling breeding sheep. You know there must be a lot of people out there who got those diseases and maybe just aren't even aware of it.'*

> *F: 'For anybody who's selling breeding sheep, [Johne's disease] is an absolute real problem because it's almost impossible to eradicate as I understand it without clearing [their] farm of sheep for two years.'*

3.3.1.5 Feedback, reports from a surveillance programme and other incentives

3.3.1.5.1 Feedback and reports from a surveillance programme for sheep health

The farmers would be interested in a flexible, informative platform where they could access information relevant to the purpose of their business in a timely manner. They said information should be collected and distributed electronically (e.g. via a webpage, mobile app or EID reader).

> *F: 'Do I want a piece of paper? No, I'd rather get it via email. What do I do if I lose that piece of paper? I want to be able to get it in a central [online] database and download it.'*

Participants thought the EID reader could be useful to monitor animal health and inform on decisions. However, the farmers often experienced difficulties with the EID reader, and the complexity and compatibility of the EID software.

> *F: 'Well, my opinion for that, buying an EID reader, was that you know I have information there, on hand, I scan that ewe, oh yeah, she prolapsed, you know that's why I'll cull…' / F: 'But you can't get that information from the previous year, it's all*

wiped… It needs to be there in front of you, you don't wanna go to your computer, you just want it to be there.'

In addition to farmers receiving direct feedback from a surveillance system, industry organisations could also play an important role in the dissemination of outputs from surveillance. The industry using the outputs from a surveillance system to inform farmers on sheep health and for raising awareness on health issues was considered useful by the participants. In general, they agreed that industry organisations such as AHDB provided useful and interesting resources and workshops. However, some experienced difficulties deciding how to implement new strategies or ideas on their own farms.

> *F: 'AHDB, they're running lots of programmes where [you're provided] with the information how to do it, but then it's up to you to take up, you know. […] I was like "Yeah, I can do it…Right…Where do I start?" […] You know what you should do, but actually being able to do it, it's the harder thing to get to.'*

3.3.1.5.2 Financial return

If the participants were to see a financial return from a surveillance system, they said they could be persuaded to contribute. Most of the participants admitted that they would like to record more information, but were not able to because it was time consuming and did not offer a financial benefit.

> *F: 'I think that's the biggest drawback […] I would like to record a lot more from what I do, but it's time and what it costs.'*

> *F: 'Nobody has put the money into sheep to do the same sort of research and work in sheep as they have done in cattle.'*

3.3.1.5.3 Benchmarking of sheep diseases

The individual participants preferred specific diagnostic feedback on their livestock over reports on clinical signs to improve their management strategies. They believed that a farmer-driven system would be picked up more readily if farmers were granted access to their own historic results and some participants would find it useful if they could benchmark their enterprises with similar businesses.

3.3.1.5.4 Accreditation and certification for sheep producers

Participants stated that contribution to a surveillance system could be incentivised with accreditation and certification for their produce. If farmers would be able to e.g. demonstrate high quality produce or freedom from disease, they believed they would want to contribute.

> *F: 'I don't think you need to worry about it's gonna be long-term, of course it's gonna be long-term but an increasing number of people will start to only buy in the accredited stock and then it'll gather pace and it'll gather pace quite quickly.'*

3.3.1.5.5 A tool to help farmers with the diagnosis of sheep diseases

Most sheep farmers said they did not have frequent contact with their veterinarians, so they would be interested in a diagnostic tool to be able to diagnose sheep diseases themselves. An electronic system where farmers had access to a simple and straightforward platform, or where they could record data, take photographs of diseased sheep and diagnose conditions was considered valuable and useful.

3.3.1.5.6 Early warning system and forecasting of sheep diseases

According to the participants, an early warning system could enhance decision-making and raise awareness amongst other farmers. The participants said they would like to be notified about the presence and spread of disease threats before the disease enters their flock. They believed that an early warning system or forecasts which generate timely reports could enable them to implement preventive measures and reduce economic losses.

> *F: 'You know all of a sudden you start to try and solve [a problem], but what we're looking at is having the triggers before you have that problem… the early warning system.'*
>
> *F: 'You know, it's that monitoring and tracking things and hot spots for me that would be very useful… from other farmers and you feed into that.'*
>
> *F: 'It would be good to see regional reports and then think "Hang on a minute, we need to start recording."'*

Since some diseases are airborne or vector-borne, participants thought it would be interesting to be provided with environmental forecasts related to the spread of animal diseases as well. According to the sheep farmers, such forecasts could provide more pathogen-specific information, advise them on preventive measures, and warn farmers about new and emerging diseases coming into the country.

3.3.1.6 Trust issues concerning other organisations and people

From the focus group discussions, it became clear that sheep farmers were wary of advice and opinions from external sources, whether this be other farmers, veterinarians or government agencies.

3.3.1.6.1 Sheep farmers' relationships with veterinarians

Many participants expressed the opinion that they believed veterinarians, through their profession and dealing with diseased animals on a daily basis, would be a useful source to acquire diagnostic data from. However, the farmers contradicted themselves when asked about their relationships with their own veterinarian (paragraph 3.3.1.5.5). Most of the sheep farmers said they only called their vet when they were confronted with problems they were not familiar with or when losses were higher than expected. The participants believed they knew their flocks better than the vets.

> *F: 'In my head I know more or less what is happening, I hope and that sounds pretty old fashioned, but that's how it is.'*
>
> *F: 'You only really tend to call [the vets] if it's something you're not sure about, so if it is footrot or mastitis or something that you are aware of what it is you deal with it yourself.'*
>
> *F: 'But, you do have to pick your vets, 'cause I think most of us would say if, a lot of vet practices we probably know more than the vets know.'*

Another issue the participants raised with regard to veterinarians was the cost for a sheep consult. Some farmers said they rather had the animal culled.

> *F: 'I think [the] problem we have is that if you go to the cattle industry, you've got an animal which is worth between eight hundred and twelve hundred pounds, and so therefore it's got a value and so you are going to call the vet in and you are going to do something about it.'*
>
> *F: 'Well I have a basic rule, don't call the vet for a sheep because the sheep's not worth enough.'*

Some of the farmers were suspicious of the intentions of vets and pharmaceutical companies, who according to some participants could be working together to sell products.

F: 'I'm deeply sceptical about this Bluetongue data. I think it's a conspiracy by the veterinary profession and the drug companies to [flog] high priced drugs. I'm deeply suspicious of it…'

F: 'I think you need to keep drug companies and vets well clear of this system. I just think everyone's after your cash…'

F: 'Your knackerman will be honest. Your vets want to take your cash.'

3.3.1.6.2 Sheep farmers' attitudes towards government

Participants expressed their concern about the motives of the government.

Participants said they were not keen on having government agencies or government funded organisations involved in a surveillance system since they believed a lack of efficiency from the government and veterinary authorities to be present.

F: 'There's a very simple solution, don't let government anywhere near this. Government cannot run things efficiently.'

Furthermore, they felt as if they were being watched and were afraid of the economic consequences if a notifiable disease was reported.

F: 'I would strongly advise you not to use this word surveillance…' / F: 'I'd agree with that. Surveillance has a sort of Defra feel about it. You know, it's a diagnosis, isn't it? This is diagnostic help for the farmer and you need to think in those kind of terms.'

3.3.1.6.3 Sheep farmers' relationships with other farmers

Participants were not only wary about advice from their veterinarian, but also from other farmers. All farmers agreed they wanted to know the health status of neighbouring flocks, but at the same time not all participants were willing to share that diagnostic information themselves. They also feared not every farmer would be honest about diseases present in their flocks.

F: 'That's why a lot of pedigree farmers would shy away from that, because they wouldn't want the tag of having dirty sheep.' / F: 'It's like trying to move an immovable object…'

There was a general feeling amongst the farmers that more transparency and honesty were needed on the presence and spread of infectious diseases that cause large economic losses in their flocks.

F: 'But certainly something like enzootic, then obviously if your neighbouring farmer has it, it'll be very nice to know.' / F: 'So you can be prepared for it or trying to implement extra biosecurity to try and eliminate it.'

F: 'There's no shame in having [a disease], there's only shame if you don't treat it.'

Participants acknowledged it was a consolation if they knew that other farmers in their area were dealing with the same health issues. Some farmers said they did alert their neighbours in the case of a disease outbreak on their farm.

3.3.1.7 Summarising key results in the context of the current project: sheep farmers

Most participants preferred surveillance of specific (endemic) diseases over syndromic surveillance of clinical signs. Therefore, a pilot surveillance initiative would need to be focused on collecting data on specific diseases. Anonymity and confidentiality are key factors to consider in such a system. If a surveillance system would require input from farmers, they would need to see a clear benefit for themselves, and the additional effort of recording data must be kept to a minimum.

Diseases of interest to participants were mostly endemic diseases, and included EAE and Iceberg diseases (e.g. Johne's disease, Maedi-Visna, CLA, Border disease).

The most prominent sources farmers considered to have useful data on sheep health and diseases included veterinarians, diagnostic laboratories, abattoirs and post-mortem examiners. However, since many sheep farmers did not regularly consult their veterinarian, developing a diagnostic tool to help them recognise diseases in their own flock was considered a useful aim for a surveillance system.

Apart from these external data sources, data recorded with farm management software could also be of interest to analyse for surveillance purposes. Participants believed that most sheep farmers would consent to sharing data collected through such software programmes if data were to be treated confidentially. Using this data would not require any additional effort and time from farmers and might therefore be interesting for the purpose of animal health surveillance.

F: '[Farmers] certainly won't want to pay, but they'd all like to know the health map of their flock.'

3.3.1.8 Results from a workshop at the SHAWG Conference

A 30-minute workshop on the topic of surveillance of sheep health and diseases was run at the 2018 SHAWG Conference (21st November 2018). The aim of the workshop was to validate the results of the focus group discussions with sheep farmers and identify additional opinions or beliefs of importance.

A short presentation was given to introduce the PhD project for the attendants of the conference. Subsequently, two short brainstorm sessions were held where the attendants answered six questions in small groups:

(i) 'What are the advantages and pitfalls of a farmer-driven surveillance system in general?'
(ii) 'What would you as a farmer expect from a surveillance system?'
(iii) 'What is needed for farmer engagement?'
(iv) 'What method would be easiest for data collection?'
(v) 'How would you like to receive feedback?'
(vi) 'What are other data sources (for surveillance)?'

Answers were written on post-it notes, collected and concisely summarised for the farmers during the conference. Afterwards, it was assessed whether attendants of the workshop raised additional topics to the focus group participants.

In general, the answers provided through the workshop were very similar to the beliefs and opinions identified in the focus group meetings. The sheep farmers said a farmer-driven system should be (i) easy to use (e.g. when submitting data), (ii) visually attractive, (iii) aimed at farmers, and (iv) should provide accurate and useful feedback which farmers could use to their advantage (e.g. regional results). In addition, the outputs need to be used in a wider context than just the individual farmers, for example for the sheep industry (e.g. knowledge exchange).

Electronic methods were considered best for data collection by farmers, such as via EID readers, mobile applications, online questionnaires and social media. All of these channels apart from social media were raised during the focus group discussions as well. Similar to data collection, also the dissemination of feedback would best be done electronically, through emails, text messages, mobile applications, webpages, farming press or social media. However, some participants also would prefer paper newsletters.

Advantages of a surveillance system related to (i) providing access to more sheep health information for farmers (e.g. on the spread, prevalence and incidence of sheep diseases) and the potential to use information to guide decision-making on-farm (e.g. forecasting for diseases), (ii) raising awareness, (iii) the potential for benchmarking, and (iv) the use of available data and its perceived lower cost.

Pitfalls identified mostly concerned (i) data quality, availability and confidentiality, (ii) honesty, compliance and willingness of farmers to contribute data, (iii) farmer characteristics (e.g. age and knowledge on technological advancements), (iv) time required to collect and submit data, and (v) unclear cost-benefits of such a system.

Apart from data collected and submitted by farmers, other useful data sources for sheep health surveillance included veterinarians, post-mortem examiners, abattoirs, assurance schemes, universities, farm software programmes, as well as industry groups and representatives such as AHDB, SHAWG, NSA, NFU, flock health clubs, livestock information service, electronic medicine book and social media.

In conclusion, the results from the workshop confirmed the validity and completeness of the data collected on sheep health surveillance through the focus group discussions.

3.3.2 Beef cattle farmers

3.3.2.1 Participants' profiles

Twenty-four out of 150 (16%) beef farmers responded by filling in the online questionnaire. One did not provide contact details and was therefore not selected for the further study. Farmers were selected for the focus groups based on gender, age and herd size (Table 3-3). In total, 19 male farmers were invited; 10 (52.6%) were present at the meetings.

Table 3-3: Selection of beef cattle farmers for focus group discussions

Beef farmers	North Yorkshire	Rutland	Somerset
Responded online (n)	7	6	11
Invited after selection (n)	6	5	8
Participants (n)	3	2	5
Herd size (range n)	50 - 650	250 - 400	130 - 340
Herd size (median n)	300	325	200
Age of participants (n):			
26 - 35 yr	0	0	1
36 - 50 yr	0	0	1
> 50 yr	3	2	3

There was a variety in farming systems among the participants: farmers with pedigree herds, breeding herds and finishing cattle attended the meetings. Apart from beef cattle, additional activities such as arable and sheep farming, contracting, and engineering were reported.

Eight (80%) participants were aged over 50. The beef farmers expressed their concern about both the age and attitude of the average farmer.

> *F: 'I'm over seventy you see and there are so many people like me who, I've have sort of semi let go of the reins to my son, but you know, he's only forty-six and he really hasn't quite got enough experience yet [<laughter>]. […] We aren't keeping up with the technology in the same way as these young lads like this […] and I think we have to appeal to our next generation.'*

> *F: 'Things on the web are all very well but a lot of farmers are of an age where they don't have access to a teenager who understands how to work the thing.'*

Most participants considered themselves progressive farmers and indicated they were careful when buying in livestock, especially through markets and dealers. Because of these concerns, some farmers were in the process of changing their business to a closed cattle herd or were becoming high herd health scheme members where they record and blood test their animals.

> *F: 'We have problems with scours from bought in calf heifers and cows so that's why we're going closed herd.'*

3.3.2.2 Herd management and the monitoring of cattle health

3.3.2.2.1 Herd management and decision-making

The participants said a national database where farmers could access their own herd data summarised from different sources (e.g. diagnostic tests, abattoir, health schemes) would provide a valuable tool to aid with decision-making. The beef farmers could use feedback on health status, historic information and key performance indicators from individual animals as valuable knowledge for the selection of replacements.

Many participants already vaccinated their cattle and/or calves. Vaccination against respiratory conditions, e.g. infectious bovine rhinotracheitis (IBR), rotavirus in calves and leptospirosis were mentioned.

> *F: '[We] vaccinate for BVD, lepto[spirosis], IBR, the lot basically and rotavirus due to the scours and calving inside.'*

F: 'I think you got to keep [vaccinating] because even though we're a closed herd, it can be passed over the fence sort of thing.'

Pedigree and crossbred suckler farmers vaccinated because most diseases could have a devastating impact on their breeding herds. Some finishers explained that their cattle were often not vaccinated since they were only on the farm for a short period before being sent to the abattoir.

Similar to vaccination programmes, health schemes were more often taken up by participants with sucklers compared to finishing cattle. Compliance with a health scheme was considered to be proof of good practice by the participants. In addition, they thought that veterinarians should better promote health schemes by convincing farmers of the value as well as increasing the awareness about the presence of diseases and limiting the economic losses.

3.3.2.2.2 Cattle health recording

3.3.2.2.2.1 Recording health indicators and cattle diseases by farmers

The beef farmers said they already recorded information they considered to be important or that was compulsory to comply with a health or assurance scheme. The value of keeping records of clinical signs such as abortion and mastitis differed depending on the farmer. Some participants considered it important to record every case of abortion and subsequently sampled farm dogs to exclude diseases such as neosporosis.

F: 'I blood test for [Neospora]. So the minute I see Neospora, the cow is up the road, […] because you're reducing risk all the time.'

Some farmers already engaged in diagnostic testing for diseases they considered to be of interest (e.g. BVD, Johne's disease) or if they needed proof of freedom from disease, e.g. in order to comply with their health or assurance scheme or to sell stock at market.

F: 'It's a marketing tool for me to sell bulls, basically…'

However, other producers only started recording abortions and contacted their veterinarian when they noticed a high percentage of diseased animals or a drop in productivity on-farm.

The participants preferred surveillance of diagnostic results over non-specific indicators collected by farmers such as lameness or diarrhoea because it was considered too common a sign (Table 3-4).

F: 'We all get lameness, but then getting the offcuts of the dairy industry, they're bred for things other than good feet.'

F: 'It can't just be a couple of calves got scours and upload that onto the database 'cause that could be any number of reasons for a calf scouring. [...] It needs to be diagnosed through a lab.'

However, key performance indicators (KPI's) could also be of interest for surveillance according to the participants because these factors were used for the selection of replacements or buying bulls.

Table 3-4: Cattle diseases discussed in farmer focus groups

Diseases of interest	Diseases participants have had on-farm
Bluetongue virus (BTV)	Bovine viral diarrhoea (BVD)
Bovine tuberculosis (bTB)	Cryptosporidiosis
Bovine viral diarrhoea (BVD)	Fluke and other liver diseases
Johne's disease	Foot problems and lameness
Leptospirosis	Johne's disease
Liver fluke or fasciolosis	Respiratory diseases (e.g. pneumonia, IBR)
Neosporosis	Scours
Respiratory diseases (e.g. pneumonia, IBR)	Trace element deficiencies

One farmer admitted to having taken part in a scheme where his cattle were tested for leptospirosis and iceberg diseases via blood testing. However, he dropped out because he perceived the scheme as being too time consuming and expensive.

F: 'Well I did take, take part in a scheme a few years ago. That was a blood test, but that was quite time consuming and quite expensive, the vets time and collecting the blood and everything, so I dropped out of it.'

A new recording system would need to be very simple and basic according to the farmers.

F: 'We haven't got an issue at the moment, but like I said if you can do [surveillance] that's very simple and could be cost-effective, we would probably look at it…yeah, certainly…'

3.3.2.2.2.2 Other diagnostic data sources

Diagnostic laboratories, abattoirs, veterinarians and post-mortem examiners were identified by farmers as important data sources.

> *F: 'It's getting the farmers involved in these things so that they can see the value of getting a post mortem so next time when there isn't a subsidy on it they say 'well I might just get that one post mortemed or I might start vaccinating.'*

Additionally, participants considered data from dairy cattle (e.g. milk testing) to be valuable as well. Johne's disease was identified as an important cause of economic losses. This disease can be detected through the testing of milk samples. Beef farmers also believed that because of the more intensive nature of dairy farming, dairy producers already recorded more cattle health data and were more accustomed to using recent technological advances in farming. Therefore, the beef farmers considered that the national dairy herd could serve as a sentinel population.

> *F: 'But you can't do this in isolation with just beef producers, it's got to be done in conjunction with the dairy people.'*

> *F: 'The dairy boys who know they've got Johne's do know what minimisation steps to take, but I don't think the beef boys necessarily know what the dairy boys do.'*

> *F: 'I think the dairy herds are moving with technology very, very fast and moving forward very, very fast and you're more likely to get that type of cooperation with the dairy herds.'*

Following the success of the BVD eradication scheme in Scotland, the participants were aware of the implications of this disease and the need to eliminate it from the national herd.

> *F: 'We've just started using BVD tags in the past year we're BVD clear. I want to keep my herd as clear as possible.'*

The aim of the BVDFree England scheme (BVDFree England, 2019), to eradicate the disease by 2022, was known by most and was mentioned in all group discussions.

> *F: 'But I think fundamentally, you got to get into farmer behaviour and people have got to begin to understand what the economic losses might be. There is absolutely no reason why this country should not be BVD free.'*

3.3.2.3 The spread of cattle diseases

3.3.2.3.1 Diseases in the farmers' own herds

The participants indicated they already based management decisions on information they had on their cattle herd. However, farmers said they would like more reliable reports on diseases present in the area or in neighbouring herds. Participants would like to receive more robust information about the history of both farms and individual animals.

> *F: 'Well the most important information to me if you think about it is what's happening in my neighbour's [herd].'*

> *F: 'Well to be honest the biggest disease I worry about is TB and whether it's getting into my herd or whether it's getting into a neighbour's herd.'*

> *F: 'I'd like to know how my neighbours are doing in case they ever get in with ours. We double fence to keep them away but whereas we're a closed herd, they're going buying from markets and bringing cows and calves in next doors, so we have to keep vaccinating because they could be bringing something that gets to ours, as they're naïve to it.'*

Because of these concerns, some farmers were in the process of changing their business to closed herds and were joining herd health schemes where they needed to record health indicators and blood test their animals.

3.3.2.3.2 Buying in diseased cattle

The participants were divided: although most agreed that reports on the health status of other herds would enable them to implement targeted preventive strategies where necessary such as when buying in replacements, not everyone was as concerned about introducing diseases on their farm. While most participants said that they only buy in proven disease-free cattle, another farmer admitted that as he bought animals no other farmer would purchase, he had probably introduced multiple diseases due to this management policy.

> *F: 'At the moment I need to know: is it something where I can satisfactorily fatten it and get it to something suitable for human consumption or am I going to pour food into this and watch it go downhill.'*

Another participant explained he had suffered large economic losses due to problems with the presence of bTB on his farm. To ensure the survival of his business, he saw no other option than to buy in cheap grazing cattle in the Spring to ensure some of the financial losses could be recovered. By October the animals had gained enough weight to send them to the abattoir and they were sold deadweight.

> *F: 'We just got rid of ninety-two um…blonde cows plus their calves due to TB'ing in the area and I needed some money after ten years of being shut down. […] I don't care*

what I buy at market, as long as can see it's big boned, big frame, it's gonna make money, three hundred quid, you know, in no time at all. I don't care who buys it, I just want that money.'

However, in general participants said they wanted to prevent introducing diseases from nearby farms into their herd by reducing the risk of animal contact with stock from farmers they feared were not equally as considerate when buying in cattle, especially if bought through markets or private dealers. Those farmers wanted more certainty about the health status of the animals they bought in and the history of the farm of origin.

In recent years, some participants became more aware of the consequences of impulsively purchasing animals without investigating the health status of the individual animal or the farm of origin.

> *F: 'Well the most important things for me is when I'm buying stock in that's not coming through the markets, coming direct from farm, I'm always checking as much as I can the health status or where it's coming from, particularly TB. I'm always scanning on the ibTB programme before I buy anything.'*

> *F: '[Testing individual animals] doesn't tell you the history, 'cause everything's got to be [TB] tested to be sold, it doesn't tell you the history about that farm.'*

3.3.2.4 Raising awareness and improving understanding of cattle diseases

> *F: 'I think it's a general awareness problem. […] Well it is a today's problem but it's a tomorrow's impact.'*

Raising awareness amongst farmers and targeting information around buying in diseased cattle would be valuable according to the participants.

> *F: 'I think that's key: raising awareness.'*

> *F: 'If we're doing the right thing and we're very pleased then we've got to encourage everyone […] to be doing the right thing, but there's an awful lot of "I'm not telling you what we're doing, I'm telling you what you want to hear" goes on…But it's now very much the case where you've got to increase people's awareness about what these diseases can cause.'*

> *F: 'People [need to be] aware of the financial costs of ignoring some of these diseases, but you can't work with somebody who doesn't want to listen.'*

Some of the participants actively searched for recent updates on the presence and spread of (endemic) cattle diseases, while others admitted their knowledge about these topics was very limited. However, the focus group discussions also resulted in participants saying it encouraged them to educate themselves better in the future.

> *F: 'To be fair, I don't know a lot about TB. I don't know if deer can give it to the cows, I don't know if there's TB in the badger population. I don't really know a lot about TB and I probably wouldn't, until I got it…'*

The participants thought by raising awareness and improving understanding of the characteristics and spread of livestock diseases more farmers might be encouraged to take part in a new system when anonymous reports on the health status of the stock of compliant and non-compliant farmers would be made public. The beef farmers wanted more disease specific information such as spread and transmission patterns.

> *F: 'If it gave farmers an idea of how widespread these diseases were and then that made them stop and think well actually I may well have this disease on my farm and it's costing me this much, […] maybe I should look at it and do something about it.'*

The participants from the South West of England were dealing with bTB and its devastating effects since the disease was present in the wider area. The participants from the North of England said they did fear bTB, but since they did not have the disease in their area, they felt bTB was less of a priority compared to the BVD eradication programme.

> *F: 'There's a lot more interest in this part of the world (i.e. North of England) in doing [the BVD eradication programme], down the South West where they have another disease that really takes up all their time BVD is very much on the back burner and anything that lives is a profit so long as it doesn't react to a skin test. That's the problem with TB…'*

3.3.2.5 Feedback, reports from a surveillance programme and other incentives

3.3.2.5.1 Feedback and reports from a surveillance programme for cattle health

> *F: 'Well I think all information is useful, but some's more useful than others, I suppose…'*

One reason why participants were hesitant to take in advice is that they felt there was a lot of information available, but often they did not know if the information was reliable. Therefore, farmers were careful with feedback to improve the health of their herd. A platform where valuable, anonymous information from different databases is accessible and can be consulted by all farmers would be of interest to the participants.

> *F: 'To different people, different bits of information are relevant. We need to signpost where we can access this information 'cause it's pointless sending it to everybody, but in this modern communication age it would highlight where it's available and point people in the right direction.'*

> *F: 'There's a huge problem with databanks, I mean I don't finish anything but I would like to know how they finish and what they're like on the hook 'cause that would be an immense value to me, but I can't get it because of data protection. That is a real barrier.'*

The participants felt that the feedback from third party data sources needed to be improved. Abattoir reports could be an invaluable source of information, but farmers doubted the reliability of the feedback. Additionally, finishers received more information than breeders. However, participants said the economic consequences of most cattle diseases had more of a devastating effect on the breeding herd and they feared finishers would be less interested in monitoring and preventing cattle diseases.

> *F: 'The fattening side of the beef industry is the terminal end of things. They are living with the health issues and they've learnt to live with them.'*

> *F: 'I think the real problem with a lot of these diseases is that the people who suffer are the breeding units, the people who should be paying are the finishing units, but the finishers ain't interested because most of these diseases will [cull] the animal before they get in the hands of the finishers.'*

3.3.2.5.2 Financial return

Farmers said they would be willing to provide information if a surveillance system were to provide participants with either a financial return or valuable information to increase productivity.

> *F: 'It's money... Farmers will follow the money.'*

However, the questions of who would launch and fund this recording system were raised. According to the participants it would be necessary that an independent organisation completed the task of linking all databases together and generating useful information for farmers in the form of reports. If farmers could see the value of such a programme, they could be persuaded to provide information they recorded on their own farm, which would be useful for the industry and for AHDB when targeting courses and workshops.

3.3.2.5.3 Benchmarking of cattle diseases

Most farmers wanted to be able to consult historic information on their own herd and local area to benchmark their results and keep up to date with information on disease spread and transmission.

> *F: 'I think we need to get some national records to be able to set other things against, we do need to be able to know where we are on either a national, a regional or a sector base.'*

Although the farmers appreciated the value of benchmarking with regard to the beef cattle industry in general, they believed that the individual producer preferred specific feedback from diagnostic laboratories, post-mortem examinations, veterinarians and abattoirs condemnation reports.

> *F: 'From an industry point of view it really needs to be wider than individual farmers, 'cause individual farmers would have individual problems. We need a wider screening measure to look at the whole industry but the individual farmer needs to be able to look at his own side and perhaps you need to be able to compare the results you're getting, why yours are going, against a sector an industry benchmark.'*

> *F: 'I believe in benchmarking but I don't think it's very popular among the farmers farming stock and I agree, would be very difficult to be totally honest with my neighbours.'*

3.3.2.5.4 Accreditation and certification

Farmers addressed the value of demonstrating the health status of their cattle on a national and international level.

> *F: 'It's adding a value to be able to give an animal health assurance; it is being tested and at the time of test was proven clear.'*

> *F: 'The benefits [of monitoring the health status of cattle] are felt at the micro level, not on the macro level, unless […] certain overseas markets start to demand additional certification and maybe the domestic market would start to demand additional certification.'*

The concerns about the future role of the UK on international trade and the uncertainty about how Brexit will affect UK farmers' positions on the European and worldwide market urged farmers to consider how the livelihood of their livestock businesses should be secured.

3.3.2.5.5 Early warning system and forecasting of cattle diseases

In recent years, new diseases have emerged in the cattle population (e.g. BTV and Schmallenberg virus). Although BTV had not been diagnosed in the herds of participants in the North of England, they said they should stay vigilant since the disease is transmitted by midges.

> *F: 'It would be very useful to have accurate briefings circulated widely when new diseases do come in to the area.'*

> *F: 'A single snapshot's no good, you just got to look at long term 'Oh, is this disease increasing in prevalence?', if it is, can we reasonably easily make people aware of it and its economic consequences and turn around that increase?'*

The farmers feared that the movement of infected cattle and midges during transport could quickly introduce the disease in Northern herds. Therefore, the farmers said that the integration of environmental data in forecasts and reports on prevalence and disease spread would be valuable.

The outbreak of BTV is an example where farmer priorities differed since the virus has not been detected as high as North Yorkshire, but Northern farmers expressed their interest in receiving forecasts about the spread of BTV in the country.

3.3.2.6 Trust issues concerning other organisations and people

Similar to the sheep farmer discussions, the beef cattle participants were not convinced other farmers and veterinarians were always honest and trustworthy.

3.3.2.6.1 Beef cattle farmers' relationships with veterinarians

Most cattle farmers had regular contact with their veterinarian, although the participants believed their veterinarians could be more helpful for e.g. health planning.

> *F: 'The vets ought to be better at explaining the value of a periodic health planning meeting and the farmer's mind should be more open and receptive to having that kind of thing, rather than just saying 'It's another two hundred and fifty quid or whatever on your bill.'*

3.3.2.6.2 Beef cattle farmers' attitudes towards government

Farmers said they were hesitant to send samples to APHA laboratories out of fear of positive test results and the respective consequences. Participants had seen the damage a positive bTB result on farms in the region had caused in the past. Some had experienced this situation themselves and were aware of the devastating effects caused by positive test results. However, several farmers thought useful information is generated by Defra with regard to bTB.

> *F: 'That's one of the few useful things Defra has done recently. It's mapped for England and Wales the incidence of TB.'*

Government agencies were considered to closely watch farmers. One farmer described the government as "Big Brother". Moreover, some participants viewed government agencies as the bearers of bad news. Participants indicated that their veterinarians are provided with test results and government laboratories will not report back to the farmer.

> *F: 'I won't use State Veterinary because they won't talk to the farmer.'*

Additionally, in recent years several governmental laboratories shut down. All these factors, the lack of communication, laboratories closing down and the fear of notifiable diseases being detected in the herd, widened the distance between farmers and government bodies.

3.3.2.6.3 Beef cattle farmers' relationships with other farmers

> *F: 'Ooh… I wouldn't trust a farmer…<laughter>'*

The above quote demonstrated a rather general consensus from the beef participants about other farmers' trustworthiness and attitudes towards animal health.

> *F: 'I think there's too many farmers that have the attitude that an animal's first wish is to die.'*

Because the farmers feared not all producers were being honest about the disease status and history of an animal, they found it useful if it should be made compulsory to advertise the testing history of cattle sold through market.

> *F: 'I have a blood test and ninety-nine percent of my animals show that I'm clear of Johne's, and I've got one reactor… I can't sell that to any more of the pedigree people, so you shift it through market and for somebody, I don't actually because I wouldn't do that, but there are many unscrupulous people who will shift it through market…'*

Thereby, the farmers believed that non-compliant producers who sell cattle through livestock markets should be urged to improve their management strategies and disclose the health status of their stock.

> *F: 'Farmers will always tend to pretend things are getting slightly better than they are unless they're grumbling how bad a time they've had with something.'*

3.3.2.7 Summarising key results in the context of the current project: beef cattle farmers

As for sheep farmers, the beef cattle farmers preferred information on specific cattle diseases rather than syndromic surveillance of clinical signs. Diseases of interest for surveillance included Johne's disease, bTB, leptospirosis, BVD and fasciolosis. Raising awareness of such livestock diseases was considered important as well.

Beef cattle farmers also predominantly identified the same important data sources as sheep farmers: veterinarians, diagnostic laboratories and abattoirs.

Although sheep farmers were interested in a diagnostic tool to aid them with recognising sheep diseases, cattle farmers did not raise a similar need. Beef farmers would see more benefit to a (national) database as an output of disease surveillance where they could consult the health status or test results from other herds, e.g. with regard to buying proven disease-free cattle at markets or as part of an accreditation scheme by which farmers could demonstrate their cattle were free from certain specific diseases.

3.4 Discussion

3.4.1 The usefulness of a surveillance system for sheep and beef cattle health

Farmers preferred a surveillance system for specific diseases over syndromic surveillance of general clinical signs such as lameness or mastitis. The diseases of importance identified in this study were very similar across the different group discussions. Noteworthy was that of the conditions listed by sheep and beef cattle farmers, most were endemic diseases. Currently, early warning, introduction and spread of new and emerging livestock diseases are priorities in many existing surveillance initiatives (Kosmider *et al*., 2011; Carslake *et al*., 2011; Rodríguez-Prieto *et al.*, 2015). Therefore, it very well could be that farmers rather feared the spread or introduction of endemic diseases in their flock/herd than new or emerging diseases and thus prioritised the surveillance of endemic diseases.

Some of the most important endemic diseases for sheep producers were iceberg diseases (e.g. Johne's disease and Maedi-Visna) that cause severe losses and were often linked with buying in rams or replacement ewes. The confirmed cases of these diseases are only 'the tip of the iceberg', with many cases remaining undiagnosed and/or causing sub-clinical infections. By the time animals begin to express clinical signs, they will already have started spreading the disease and so the chance of other individuals already being infected is high (Barratt *et al.*, 2018; Ogden *et al.*, 2019). For example, the incubation period for animals infected with *Mycobacterium avium* subspecies *paratuberculosis* (MAP) can last for several years during which clinical signs of Johne's disease are not yet expressed (Hadorn and Stärk, 2008; Benjamin *et al.*, 2010). This means that it is difficult to generate accurate estimates of their prevalence and incidence, such as for Johne's disease, Maedi-Visna, CLA, Border disease, and ovine pulmonary adenocarcinoma (Robinson *et al.*, 2019). Therefore, syndromic surveillance of clinical signs would not be useful for decision-making on-farm as it would not generate results in time to prevent further spread of the diseases.

Similarly, for beef cattle farmers, diseases of the highest importance included bTB, BVD, and Johne's disease. The prevalence of bTB is highest in Wales and the South West of England where participants suffered most from the disease and bTB was considered the highest priority. Farmers who were previously confronted with severe disease issues on their farm sometimes saw no other option than to buy in cheap animals without knowing their disease status in order to reduce some of the economic losses they experienced due to devastating livestock diseases such as bTB. In the North of England, where bTB levels were not as high, farmers appeared more concerned or aware about BVD and referred to the way the control of BVD was carried out in Scotland where an eradication scheme for BVD was launched in 2010 (gov.scot, 2019). Following the Scottish example, the BVDFree England scheme was launched on 1st July 2016, where participating farmers could submit a tissue sample taken during ear tagging and test for BVD (Anonymous, 2019).

The different characteristics of farms need to be considered in the development of a surveillance system, since their needs differed. The spectrum of sheep and beef enterprise types in England was a case in point. Overall, sheep and beef breeders had a different view on the effect of livestock diseases on their farm than commercial sheep farmers or beef finishers. Breeding stock spends a longer time on the farm than finishing or rearing cattle. Pedigree sheep farmers and beef breeders were more likely to implement preventive control measures such as keeping closed flocks/herds, routine vaccination or engage in diagnostic testing schemes than the commercial and finishing farmers. Infectious diseases in breeding flocks/herds are likely to have larger economic consequences because of the value of a breeding ewe or cow compared to commercial finishing sheep or cattle. Additionally, other farm-specific features such as outdoor or indoor housing, the scale of the enterprise, the number of livestock, and intensive versus extensive farming systems all required their own management policies. Keeping in mind all of these factors, it would be challenging to develop a surveillance system that generated information that was useful for every farmer.

3.4.2 The feasibility of surveillance based on data recorded by livestock farmers

In order to explain farmers' behaviour with regard to decision-making and their willingness or unwillingness to contribute to a surveillance system for sheep and beef cattle health, the Theory of Planned Behaviour (TPB) can be used (Ajzen, 1991). Originating from the field of health psychology, the TPB has served as a basis to explain farmer behaviour and decision-making with regard to e.g. (i) the adoption of preventive and control policies for cattle diseases (Brennan *et al.*, 2016), (ii) the intention of dairy cattle farmers to implement measures for the diagnosis of gastro-intestinal parasites (Vande Velde *et al.*, 2018), (iii) barriers for the implementation of best practice for the treatment of footrot in sheep (O'Kane *et al.*, 2017), (iv) the use of preventive measures to improve dairy herd health (Jones *et al.*, 2016), and (v) the association between membership of herd health schemes and management of mastitis on dairy farms (Lind *et al.*, 2012).

Behavioural intention is determined by (i) 'attitude' or whether a person perceives the outcome of a certain behaviour is favourable or unfavourable, (ii) 'subjective norm' or how thoughts and opinions of others about a certain behaviour are perceived, and (iii) 'perceived behavioural control' or how a person considers their own ability to act (Ajzen, 1991; Brennan *et al*., 2016; Gilbert and Rushton, 2018). Those three concepts of the TPB are closely connected and therefore affect each other. Farmers who believe a surveillance system would provide them with information they could then use for their own benefit might therefore be more willing to contribute data on their livestock ('attitude'). Relevant behavioural intentions as well as perceived behavioural control are predictors which directly influence behaviour and therefore decision-making by farmers and their willingness to actively contribute to animal health surveillance (Ajzen, 1991; Gilbert and Rushton, 2018).

Prior experience and knowledge about endemic diseases on-farm, or an increased awareness of the introduction of a new disease can improve the willingness of farmers to report disease data. Disease awareness has been known to affect reporting of diseases, for example when Bluetongue virus (BTV) was first detected in Switzerland in 2007 and the reporting of suspected BTV cases increased after launching information campaigns on the disease (Hadorn *et al.*, 2008).

Farmer reporting would best be done electronically. However, the adoption of novel technologies such as electronic recording of health data, could be complicated by the average age of the English farmer. Older farmers who were not familiar with using e.g. computers or EID readers admitted they were less likely to invest their time and money in the implementation of new electronic equipment or software. The focus group participants believed the next generation of farmers would be more likely to contribute to disease surveillance. However, McKillop *et al.* (2018) emphasised it should not just be assumed that all young farmers would automatically implement innovative technology, since not every farmer focuses on the same aspects of livestock farming. Some farmers keep up with novel technology because it is an integral part in their management policy or the equipment they use improves operations on their farms. However, this varies between farmers. Therefore, caution is warranted with the general assumption that the younger generation of farmers is more likely to use more innovative approaches for the recording of animal health information as well as the contribution to a surveillance system for sheep and beef cattle health.

Not all farmers were interested in contributing to surveillance, but some factors might affect their willingness to participate. Sheep and beef farmers who are already recording animal health data are probably more willing to use the feedback of information to their advantage. This hypothesis will be further investigated via the questionnaire described in Chapter 5.

Thus, recording by sheep and beef cattle farmers would need to be simple in order to be sustainable. Active recording and submission of health data into a surveillance system requires additional time and money. Therefore, farmers would need to be able to record and submit data at a convenient time. Key periods in the year, such as lambing/calving time, tupping or worming, would be the best time since these are the times when farmers spend more time on the individual animals.

3.4.3 The feasibility of surveillance based on data from other sources

Apart from recording by farmers, other organisations collect and/or hold animal health data. Useful data for surveillance could be provided by e.g. (i) veterinarians or veterinary practices, (ii) diagnostic laboratories, (iii) post mortem examiners, and (iv) abattoirs.

A gap in the communication between farmers and other data sources such as veterinarians, abattoirs, and laboratories was apparent. Although veterinarians were considered an important source for health data on livestock, not every farmer trusted the motives of their veterinarian. Sheep farmers in particular felt they had to rely on themselves, their own experience and knowledge, rather than on their veterinarian's. Moreover, because of the steady growth of corporate veterinary practices, farmers did tend to see different veterinarians (Lowe, 2009; Kaler and Green, 2013). Therefore, it was difficult to build a trusted relationship between vet and sheep farmer.

The cattle farmers saw their vets more frequently than most sheep farmers. It was already reported in previous research that both sheep farmers and veterinarians are aware that the economic value of an individual animal is an important factor in this regard (Kaler and Green, 2013; Bellet *et al.*, 2015). This implies that in relation to the value of the individual animal, a visit from the vet for a sheep is more expensive than for a cow. However, some sheep farmers contradicted themselves when they said that veterinarians would be able to provide more useful data on their sheep than they could themselves. Farmers with both sheep and cattle were therefore more likely to ask the vet for advice on their sheep when they were already on the farm to attend to the cattle.

However, many cattle farmers also expressed their concerns about the role and trustworthiness of veterinarians. The vaccination of livestock against Bluetongue was used as an example to demonstrate trust issues and difficulties in communication between farmers and veterinarians. The first warnings about the risk of Bluetongue virus type 8 (BTV-8) spreading from continental Europe in 2007 resulted in a mass vaccination in England (Hateley, 2009). However, these preventive measures did not have a sufficient effect. Apart from the spread of BTV-8 in other countries such as France, other serotypes were identified as well. Since the applied vaccine was not effective for all BTV serotypes, the results from the vaccination campaigns were not optimal (Hateley, 2009). This might have led to participants being more careful and inquisitive when given advice by their veterinarian on vaccination as a preventive strategy because many of them could not see an improvement.

An additional source for on-farm data could be found in records electronically submitted via farm management software programmes. This data could be used for animal health surveillance if farmers would be willing to grant access to their data. Since 2010, all adult sheep in England must carry at least one unique electronic identifier (GOV.UK, 2014). In practice, the use of the EID reader and software to record data was perceived as cumbersome because of the variety of software packages available and the use of handheld readers which were considered not practical by many sheep farmers. Many different software packages are used, so collecting, collating and analysing data from different programmes in different formats would be a challenging task. Legislation and the accompanying pressure sheep farmers experience to adopt EID technology on-farm (Lima *et al*., 2018), together with the practical issues discussed and farmers' willingness to invest time and effort into adopting technological tools might influence the uptake of EID as a tool to aid with decision-making on-farm.

Although data on sheep and cattle health is currently being collected by different people and in different formats, useful outputs could be generated in a surveillance system and benefit farmers. However, the investigation and potential implementation of these additional data sources was beyond the scope of the current project.

3.4.4 Feedback from a surveillance system and other incentives for farmers

Because of the risk of diseases spreading, farmers wanted robust and relevant information, but it was often not clear to them which information was reliable. The trust in a surveillance system would increase if information was produced that allowed the farmer to take action which results in a clear benefit or improvement. The improvement of the health of their livestock was a priority for farmers. Contributors would need to see a return of useful information that could aid them with decision-making on-farm, with the ultimate goals to increase the price of their produce or reduce production losses. Outputs generated from a surveillance system could also be used to raise awareness about diseases and educate farmers that are not familiar with their effects and how they should best be managed.

A surveillance system based on active input by farmers would need to generate useful feedback in return for the time and effort required to collect and submit data. Feedback could therefore be used as an incentive to encourage participation. Other incentives included benchmarking, early warning forecasts, or diagnostic help for the sheep farmers in particular. The trust issues with regard to their veterinarians could explain why sheep farmers more than cattle farmers considered a surveillance system to be a useful aid to recognise diseases themselves. However, there is a possibility that such a diagnostic tool for sheep farmers might lead them to consult their vets less, since most farmers indicated they only call the vet when they encounter an unknown disease or losses are higher than expected.

In the context of Brexit, a surveillance system that were to provide proof of quality produce (e.g. as part of international certification) might therefore be an incentive for farmers to contribute. The UK has the largest sheep population in the EU and is the biggest exporter in Europe (Colby, 2015). New trade agreements need to be negotiated by the time the UK leaves the EU which will impact on the export of beef and sheep produce. The focus group discussions were conducted in June and July 2016, around the time of the referendum (on 23rd June 2016) on whether the UK should exit the EU. The information and uncertainty about a potential Brexit affecting agriculture and livestock farming might therefore have increased farmers' concern about accreditation and certification with regard to export of their produce to EU countries.

3.4.5 Aims for disease surveillance: differences between sheep and beef cattle farmers

A diagnostic tool could be valuable if it would allow sheep farmers to help diagnose diseases themselves based on e.g. differential diagnoses in accordance with clinical signs, or by providing them with pictures of lesions as seen in specific sheep diseases. Veterinarians are entitled to officially diagnose animal diseases, whilst farmers are not authorised to do so. However, in recent years there has been a shift towards sheep farmers recognising diseases themselves, e.g. with regard to foot lesions (Kaler and Green, 2008; Kaler and Green, 2013).

Beef cattle farmers did not particularly express an interest in a diagnostic tool as such. However, they indicated that disease information on cattle would be useful when historic herd information and individual animal test results could be disclosed, e.g. at livestock markets.

An important consideration with regard to disease surveillance is the economic value of the individual animal (Kaler and Green, 2013). The cost of a veterinary consult relative to the value of a sheep versus the value of a cow might explain why beef cattle farmers consulted their veterinarian more often than sheep farmers, either on a regular basis (e.g. as part of a herd plan) or when they encountered diseases in their herd.

Disease surveillance was preferred over syndromic surveillance by both sheep and beef cattle farmers. Although, as reported, the opinions of sheep and beef cattle farmers differed on some levels (e.g. the need for a diagnostic tool), there were important similarities identified, such as the need to raise disease awareness, or the general concern about not knowing what diseases were present in neighbouring flocks/herds, so participants feared infectious pathogens might be blown in over the fence or transmitted in case of mixing livestock. Most farmers expressed their interest in reliable information on the spread and incidence of endemic diseases in their area and believed surveillance of sheep and cattle diseases would be useful for individual farmers as well as the sheep and beef cattle industry.

3.4.6 Impact and implications of the study for livestock farmers and the industry

The scope and aim of a farmer-driven surveillance system need to be defined together with the identification of the diseases or syndromes of interest to farmers. Researchers often tend to have a different view on problems than the population they are targeting, which might lead to the development of solutions that are of no effective use to the people who should benefit from them the most (Krueger and Casey, 2009). Thus, to increase understanding of farmer behaviour with regard to animal health surveillance and to capture relevant statements and opinions from primary beneficiaries (i.e. farmers), qualitative methods such as focus group discussions were used for the collection of a range of different perceptions.

The development of an efficient and sustainable surveillance system for livestock farmers requires cooperation from farmers, stakeholders and data providers. Different actors are interested in monitoring different health indicators. Governments are generally more concerned about targeting diseases that affect trade and public health (zoonoses and new or exotic animal diseases), while the livestock industry is affected by a broader range of endemic diseases that influence the productivity of the animal population and have a significant economic impact (Carslake *et al*., 2011).

Surveillance of important endemic cattle and sheep diseases will provide both farmers and the industry with more detailed information on the levels of economically important livestock diseases and the animal health status in general. Individual farmers could use outputs for decision-making on-farm, while organisations such as AHDB would be able to target research, farmer workshops and funding according to important health issues arising at a given moment in the future.

3.5 Conclusions

Although syndromic surveillance of clinical signs might offer some benefits, the surveillance of specific sheep and cattle diseases would be preferred by farmers. Such a surveillance system should provide participants with relevant feedback on the health status of their own livestock, and with national and regional information and reports on the presence and spread of diseases. Through the focus group discussions three important areas were identified where outputs from a surveillance system would be useful for producers: (i) flock/herd management and decision-making (e.g. buying in rams), (ii) monitoring of spread and early warning of introduction of diseases in the area (e.g. spread of bTB to the North of England), and (iii) raising awareness about important livestock diseases (e.g. the effects and costs of iceberg diseases in sheep).

Based on the results of the focus group discussions, two studies were designed to capture quantitative data from farmers on (i) the presence of sheep/cattle diseases on their farm in 2017 and 2018 (Chapter 4), and on (ii) farmers opinions and behaviour towards surveillance of animal health and production (Chapter 5).

A feature that needs to be considered when developing a surveillance system where farmers actively have to submit data they have collected on-farm is the user-friendliness. Such a system needs to be electronic, simple, quick to access and cheap for the farmers. Based on these findings, a pilot survey was designed to collect disease data from farmers (Chapter 4).

The results presented in Chapter 3 suggest that not every farmer has the same needs with regard to feedback from disease surveillance. For different farmers, different information is useful. Factors such as (i) species farmed, (ii) enterprise type (e.g. pedigree flock versus commercial flock), (iii) location (e.g. region), (iv) flock/herd size, (v) whether or not farmers are members of a flock/herd health scheme, and (vi) whether they already recorded data on their animals (e.g. production data, clinical signs and/or diseases) could possibly affect farmers' opinions and behaviour towards surveillance of sheep and beef cattle health. In Chapter 5, it is investigated if any of the factors listed are significant predictors for the willingness of farmers to contribute data for surveillance.

Apart from farmer recording, data for animal health surveillance can also originate from other parties such as abattoirs, diagnostic laboratories, veterinarians and government organisations. Access to information from these sources is often limited for farmers and often, little feedback is provided to producers. Further on in Chapter 5, the participants' perceived usefulness of data from these third parties will be assessed in order to establish whether animal health surveillance based on data from these other sources could be of added value to sheep and beef cattle farmers.

Chapter 4

SURVEILLANCE OF ENDEMIC SHEEP AND BEEF CATTLE DISEASES IN ENGLAND: DEVELOPMENT AND RESULTS FROM A PILOT SYSTEM

4.1 Introduction

In the study presented in the current chapter the feasibility of recording and reporting disease data by sheep and beef cattle farmers was assessed in order to address the surveillance gap in endemic livestock diseases (FAWC, 2012). The main aim of this study was to test if farmers would provide data via a very short, straightforward and online survey rather than collecting data to estimate the prevalence of the selected diseases in England. Since robust information on the prevalence of endemic diseases is often lacking, farmers can play an important role if they are willing to collect and contribute data for surveillance. They are placed in a unique position where they could provide data on sheep and beef cattle health, such as clinical signs seen in their livestock, but also diseases that were confirmed (e.g. by diagnostic laboratory test or post mortem examination) or that they suspected and recognised themselves.

The prevalence of endemic livestock diseases for which no surveillance initiatives are in place are often unknown and very difficult to estimate because farmers are not always able to recognise or diagnose specific diseases themselves. Focus group participants believed many farmers have learnt to live with the production losses or are unaware of the presence of a disease in their flock or herd (Chapter 3). Sheep farmers in particular consider themselves to be experts on their flocks and therefore do not always believe a third person could provide them useful and relevant information (Kaler and Green, 2013; Tongue *et al.,* 2017). This might contribute to the knowledge gap regarding the prevalence of endemic sheep and beef cattle diseases.

The results from the focus group discussions conducted in June and July 2016 indicated that a simple, electronic tool for recording the presence of important endemic sheep and beef diseases would be of interest to farmers. From the results presented in Chapter 3 it was clear that most farmers considered surveillance of specific (endemic) livestock diseases to be more useful than non-specific clinical signs. Therefore, a questionnaire was developed to assess if farmers would indeed record and contribute data for a pilot system. Five sheep and five cattle diseases that were identified as important diseases of interest according to the focus group participants (Chapter 3) were selected. The five endemic sheep diseases included in this study were (i) Johne's disease, (ii) Maedi-Visna, (iii) CLA, (iv) EAE, and (v) sheep scab. Endemic cattle diseases selected were (i) Johne's disease, (ii) bTB, (iii) leptospirosis, (iv) BVD, and (v) fasciolosis. In general, not much robust information is available on the prevalence of these diseases.

Johne's disease is a chronic disease caused by *Mycobacterium avium* subspecies *paratuberculosis* that undergoes a long incubation period in the animal and subsequently causes excessive weight loss and a decrease in the body condition score in both sheep and cattle. Johne's disease costs the industry £13 million every year (Caldow and Gunn, 2009). Especially in sheep, the disease is often very difficult to confirm, since diagnostic tests for Johne's disease in sheep have a low sensitivity, some only around 25% (Sergeant, 2001). This makes it difficult to diagnose the disease in an early stage and therefore prevent its spread across the flock or herd.

Maedi-Visna is a slowly progressive viral disease that is clinically expressed via different presentations: pneumonia (Maedi) and chronic wasting disease (Visna) (Minguijón *et al.*, 2015). Transmission mostly occurs via respiratory secretions, vertical transmission from ewe to lamb via the milk, or via semen (Zachary, 2007). The annual cost of Maedi-Visna has been estimated at £3.4 million (Bennett and Ijpelaar, 2005).

Infection with *Corynebacterium pseudotuberculosis* leads to the chronic disease caseous lymphadenitis (CLA), in the UK often characterised by abscesses in the head and neck region of small ruminants (Fry and McGavin, 2007; Fontaine and Baird, 2008). Although first diagnosed in the UK in 1989 and currently an endemic disease in the country, no estimates of costs have been published (Fontaine and Baird, 2008; SHAWG, 2016).

Enzootic abortion (EAE) in sheep is caused by a bacterial infection with *Chlamydophila abortus* that results in late-term abortion in ewes infected within the first six weeks of gestation (Foster, 2007). The annual costs due to EAE in sheep have been estimated at £23.8 million (Bennett and Ijpelaar, 2005).

Sheep scab, caused by *Psoroptes ovis*, induces hypersensitivity, irritation and an allergic dermatitis in sheep that leads to expanding lesions of the wool and skin (Hargis and Ginn, 2007; Busin, 2018). Sheep scab has been estimated to cost £8.3 million annually (Nieuwhof and Bishop, 2005).

Infection with *Mycobacterium bovis* causes bTB, which is also a zoonotic disease. Common routes of infection in cattle include inhalation as well as transmission via milk (López, 2007).

The Bovine TB Strategy review (Defra, 2018) reports that the control of the disease costs the tax payer in general £70 million per annum and an additional £50 million to the livestock industry.

Leptospirosis causes haemolytic anaemia, as well as abortion in cattle (by *Leptospira interrogans* Hardjo) (Foster, 2007; Fry and McGavin, 2007) and is estimated to cost £11 million per year (Bennett and Ijpelaar, 2005).

Bovine viral diarrhoea (BVD) can present itself in the form of a clinical disease or a persistent infection in cattle. Apart from diarrhoea, BVD can cause respiratory problems, reductions in milk production as well as fertility, and abortion (McGowan *et al*., 1993; Brülisauer *et al*., 2010; Yarnall and Thrusfield, 2017). BVD has been estimated to cost £39.3 million annually (Bennett and Ijpelaar, 2005).

Fasciola hepatica uses a snail as its intermediate host and is found worldwide, predominantly in wet environments. The parasite migrates through the intestinal wall and via the liver into the bile ducts where it causes cholangitis, obstruction of the bile ducts and eventually chronic fasciolosis (Cullen, 2007). Fasciolosis costs £23 million each year in total (Bennett and Ijpelaar, 2005), of which an estimated £13-15 million is attributed to the sheep and beef cattle industry (Wright, 2012).

The pilot study described in this chapter was designed based on the needs of livestock farmers as identified in Chapter 3: (i) specific diseases were targeted rather than recording clinical signs, (ii) the questionnaire was developed online and distributed via email to meet the requirement that data collection preferably should be electronic, and (iii) the questionnaire was kept as straightforward and concise as possible to ensure it would be easy to complete and take up a minimal amount of time.

4.2 Materials and Methods

4.2.1 The development of an online questionnaire to capture disease data

An online questionnaire was designed as a pilot surveillance system to collect data from sheep and beef cattle farmers. The survey included questions on farm specifics and on sheep and cattle diseases encountered on-farm (Appendix 4-1). Farmers provided information on the species of livestock they farmed (sheep, beef cattle, dairy cattle, pigs, poultry or horses), the type of enterprise (e.g. pedigree, commercial and/or store lambs for sheep farmers), flock/herd size, and the county where the farm was located.

Tick box questions were used to capture data on disease presence in a clear and standardised manner. Respondents who farmed sheep were asked to indicate whether they had seen (i) Johne's disease, (ii) Maedi-Visna, (iii) CLA, (iv) EAE or (v) sheep scab in their sheep flock in 2017 and 2018. Cattle farmers were asked if they had encountered (i) Johne's disease, (ii) bTB, (iii) leptospirosis, (iv) BVD or (v) fasciolosis in their cattle herd in 2017 and 2018. The answer options were (i) 'yes' in case the disease was diagnosed and confirmed, (ii) 'suspected' if the diagnosis was not confirmed or the farmer was not confident about a (diagnostic) result, (iii) 'no' in case the disease had not been present in the flock/herd, and (iv) 'I do not know' if no other answer applied.

Since the questionnaire was designed online and not administered on paper, it was possible to include rules and survey logic to ensure participants completed all relevant questions without skipping any. For example, if the respondent indicated a certain disease was present on their farm, an additional tick box question was shown on who identified the condition. Answer options to this question for all sheep and four cattle diseases were (i) 'me' (i.e. the farmer), (ii) 'my veterinarian', (iii) 'samples sent to a diagnostic laboratory', (iv) 'post-mortem examiner', (v) 'reports from an abattoir', and (vi) 'other'. Only for bTB other options were shown: (i) 'compulsory TB testing', (ii) 'pre- or post-movement TB testing', (iii) 'abattoir findings', and (iv) 'other'.

The questionnaire contained only closed and tick box questions, and took around five minutes to complete. Partial data was saved to allow farmers to complete the questionnaire at a later convenient time if necessary. Respondents who were interested in the results of the study were able to submit their name and email address in order to receive a summary of the results after completion of the study. It was clearly stated that this personal information would only be used for the purpose of providing them with results and no personal identifiers were used during any stage of the data analysis.

Pre-testing or pilot testing prior to the start of the study was done to evaluate the structure of the questionnaire and to assess the time it took to complete the survey (Martin *et al.*, 1987); Dean, 2015). The questionnaire was pre-tested by members of the research group at the University of Warwick to assess the flow, structure and content as well as to ensure all relevant issues were covered. Subsequently, the questionnaire was piloted for 22 farmers who had participated in the focus groups discussions and said they would be willing to test a pilot system in the research project. Ten farmers completed the survey, corresponding with a response percentage of 45.5%. No alterations were suggested by the pilot farmers, therefore no changes were made to the questionnaire.

4.2.2 Selection of participants, consent and confidentiality

Participants were selected by AHDB out of approximately 8300 farmers who kept sheep and/or beef cattle and for whom email addresses were known to AHDB. Based on the total number of 8300 participants, the recommended minimum sample size was 368, with a 95% confidence interval and 5% error margin (Raosoft, 2004). A sample size of 2000 was selected with the margin of error estimated at 1.91%. Stratified random sampling reduces the sampling error compared to random sampling and was used to ensure optimal geographic coverage by inviting a proportional number of farmers per county to participate in the study (Thrusfield, 2007d; Dohoo *et al.*, 2009c).

Response burden, confidentiality and anonymity, and the clarity of the questions were considered in the development of the online questionnaire. The selected farmers were sent an introductory email (Appendix 4-2) where the purpose of the study was explained, and information on confidentiality and consent was provided. The online link to the survey was included in the email invite. Participants who clicked on the link were taken through to the webpage where the same information on the purpose of the study and confidentiality were displayed on the first page prior to starting the survey. By filling in the questionnaire, farmers consented to their data being used in the study. Farmers who wished to remain anonymous and were not interested in receiving a summary with results from the study were able to do so.

Disease data were requested for two consecutive years from January to December 2017 for the first and from January to December 2018 for the second year. The first questionnaire on disease presence in 2017 was distributed on 23rd May 2018. A reminder email (Appendix 4-3) was sent on 20th June 2018. The link to the online survey was closed on 1st July 2018. The survey to collect disease data for 2018 went out to the same sample of 2000 farmers on 30th January 2019. A reminder for the survey was sent on 25th February 2019. As indicated by participants in the focus group discussions (Chapter 3), an incentive to persuade farmers to participate in a surveillance system was to provide them with feedback. Therefore, when the farmers were invited to complete the questionnaire on disease presence in 2018, they were advised that a short summary with results from 2017 would be provided after they completed the questionnaire (Appendix 4-4). The online questionnaire on disease presence in 2018 was closed on 7th March 2019.

4.2.3 Data management

The questionnaire was developed using Qualtrics® (Qualtrics, 2005). After closing the online link to the survey, data were extracted and saved in an Excel spreadsheet (2016; Microsoft Corp., Redmond, WA). Since the survey consisted of tick box questions, multiple choice questions and closed questions where participants only needed to fill in the number of livestock they farmed, no additional coding was necessary before the analysis could be carried out.

4.2.4 Statistical analysis: the presence of sheep and cattle diseases in 2017 and 2018

Frequency distributions were used to summarise the percentages of each farming system, the median and range of flock/herd sizes. Because of the low response percentage, numbers of diseases both diagnosed and suspected were aggregated to calculate the estimated prevalence of a disease. Respondents who indicated they did not know whether the disease had been present in their flock/herd were considered not to have had the disease. Throughout Chapter 4, disease prevalence is reported as a percentage. The exact Clopper-Pearson method (Clopper and Pearson, 1934; Wallis, 2013) was used to calculate 95% confidence intervals for the disease proportions for both years separately. Pearson Chi-square and Fisher's Exact tests were then used to compare the proportions of the specific diseases reported for 2017 and 2018.

All analyses were carried out in R/RStudio (R Core Team, 2019; RStudio Team, 2018) and SPSS 24.0 (IBM Corp, 2016).

4.3 Results

4.3.1 Respondents to the questionnaire on disease presence on-farm

For the questionnaire on disease presence in 2017, 241/2000 (12.1%) farmers responded to the survey but only 208 fully completed the questionnaire. The usable response percentage was 10.4%. There were 68 (32.7%) sheep farms, 48 (23.1%) cattle farms, and 92 (44.2%) with both sheep and cattle. In total, 181/2000 (9.1%) participants responded to the questionnaire on diseases present in 2018, however only 159 questionnaires were fully completed. The usable response percentage was 8.0%. Out of 159 farms, 47 (29.6%) were sheep farms, 34 (21.4%) were cattle farms, and 78 (49.1%) with both sheep and cattle. Thirty-nine (24.7%) respondents recalled having completed the questionnaire on disease presence in 2017 as well, 37 (23.4%) participants had not responded previously, 81 (51.3%) did not know, and one farmer did not want to say. One participant did not answer the question.

Since individual response percentages for most counties were low, they were grouped into five regions (Figure 4-1). The number of respondents and response percentages per region are shown in Table 4-1.

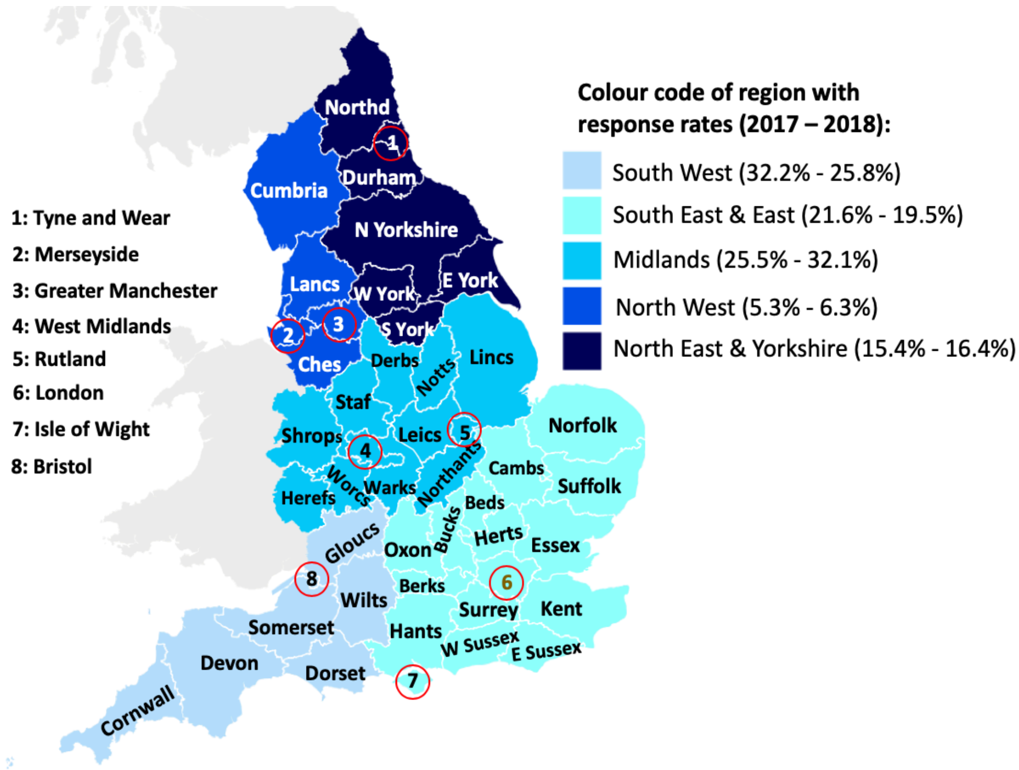


Figure 4-1: English counties were grouped in five regions: South West (SW – Bristol, Cornwall, Devon, Dorset, Gloucestershire, Somerset, Wiltshire), South East and East (SE&E – Berkshire, East Sussex, Essex, Hamptonshire, Hertfordshire, Isle of Wight, Kent, London, Norfolk, Suffolk, Surrey, West Sussex), Midlands (MID – Bedfordshire, Buckinghamshire, Cambridgeshire, Cheshire, Derbyshire, Herefordshire, Leicestershire, Lincolnshire, Northamptonshire, Nottinghamshire, Oxfordshire, Rutland, Shropshire, Staffordshire, Warwickshire, West Midlands, Worcestershire), North West (NW – Cumbria, Greater Manchester, Lancashire, Merseyside) and North East (NE – Durham, Northumberland, East Riding of Yorkshire, North Yorkshire, South Yorkshire, Tyne and Wear, West Yorkshire) (the map was constructed using datawrapper.de, accessed May 2019)

Table 4-1: Distribution of sheep and beef cattle farmers in England and percentage of responses on disease presence in 2017 and 2018 by region

Regions	Number of farmers selected		Respondents 2017		Respondents 2018	
	n	%	n	%	n	%
North East (NE)	361	18.1	32	15.4	26	16.3
North West (NW)	152	7.6	11	5.3	10	6.3
Midlands (MID)	634	31.7	53	25.5	51	32.0
South East & East (SE&E)	334	16.7	45	21.6	31	19.5
South West (SW)	519	26.0	67	32.2	41	25.8
Total	*2000*	*100.0*	*208*	*100.0*	*159*	*100.0*

4.3.1.1 Characteristics of sheep flocks

The median ewe flock size in 2017 and 2018 was 150 and 160 respectively, while the median number of lambs was 295 and 270 respectively (Table 4-2).

Table 4-2: Sheep flock size in 2017 and 2018 as reported by sheep farmers

Farm specifics	Flock size in 2017		Flock size in 2018	
	Ewes (n)	Lambs (n)	Ewes (n)	Lambs (n)
Number of farms	157	152	124	119
Median flock size	150	295	160	270
Range	3 - 2200	10 - 4000	4 - 2500	8 - 5000

Sheep flocks were kept on 160 (77%) farms in 2017 and on 125 (78.6%) in 2018. There were often multiple types of enterprise run on the same farm. Of the three types, commercial flocks were most often reported by sheep farmers both in 2017 and 2018 (Table 4-3).

Table 4-3: Frequency of sheep enterprise types reported for 2017 and 2018

Type of enterprise	Frequency reported by 160 farmers (2017)		Frequency reported by 125 farmers (2018)	
	n	%	n	%
Pedigree	54	33.8	38	30.4
Commercial	125	78.1	96	76.8
Store lambs	37	23.1	26	20.8

4.3.1.2 Characteristics of cattle herds

The median size of adult cattle herds in 2017 and 2018 was 60 and 50 respectively. For calves, the median number of animals was 55 in 2017 and 40 in 2018 (Table 4-4).

Table 4-4: Herd size in 2017 and 2018 as reported by cattle farmers

Farm specifics	Herd size in 2017		Herd size in 2018	
	Adult cattle (n)	Calves (n)	Adult cattle (n)	Calves (n)
Number of farms	138	125	108	101
Median herd size	60	55	50	40
Range	3 - 660	2 - 1000	2 - 500	1 - 995

Cattle herds were kept on 140 (67.3%) and 112 (70.4%) farms in 2017 and 2018 respectively. Often more than one enterprise type was reported. Table 4-5 shows the breakdown of the frequency of the separate cattle enterprises. Crossbred and pedigree suckler herds were the enterprise types most frequently reported by participants in both years. Although the questionnaire was aimed at beef farmers, 7 (5%) respondents also farmed dairy cattle in 2017 and 2 (1.8%) did in 2018.

Table 4-5: Frequency of cattle enterprise types reported for 2017 and 2018

Type of enterprise	Frequency reported by 140 farmers (2017)		Frequency reported by 112 farmers (2018)	
	n	%	n	%
Pedigree suckler	56	40.0	49	43.8
Crossbred suckler	71	50.7	53	47.3
Finishing cattle	56	40.0	41	36.6
Rearing cattle	55	39.3	35	31.3
Calves	34	24.3	32	28.6
Dairy	7	5.0	2	1.8

4.3.2 The presence of the five sheep diseases on English farms in 2017 and 2018

4.3.2.1 Estimated prevalence of sheep diseases in 2017 and 2018

The frequency number, prevalence and exact 95% C.I. for each of the five sheep diseases are summarised in Table 4-6. Disease prevalence for any of the five sheep and cattle diseases is described as the proportion (in percentage) of positive farms to the total number of participating farms.

In 2017 and 2018, EAE was the disease with the highest prevalence in sheep flocks (15.0% and 13.6%), followed by sheep scab (8.1% and 12.8%), and CLA (9.4% and 6.4%). The prevalence for both Johne's disease (3.1% and 2.4%) and Maedi-Visna (0.6% and 0.8%) was very low for both years. Fisher's Exact test was used to compare the prevalence of the diseases in 2017 and 2018. The test showed there were no significant differences found between the prevalence in 2017 or 2018 for any of the five sheep diseases. Apart from Maedi-Visna and sheep scab (in 2017), sheep farmers were most likely to diagnose diseases themselves (Table 4-6). The breakdown of the numbers of diseases diagnosed by others than sheep farmers is presented in Table 4-7. Other than the respondents, veterinarians most frequently diagnosed sheep diseases, followed by diagnostic laboratories.

Table 4-6: The estimated prevalence of sheep diseases in 2017 and 2018

Sheep diseases in 2017 (on 160 flocks)	Frequency n	Prevalence %	(95% C.I.)	Identified by Farmers n (%)	Identified by Others[a] n (%)
Johne's disease	5	3.1	(1.0 -7.1)	4 (80.0)	1 (20.0)
Maedi-Visna	1	0.6	(0.0 -3.4)	.	1 (100.0)
CLA	15	9.4	(5.3 -15.0)	9 (60.0)	6 (40.0)
EAE	24	15.0	(9.9 -21.5)	13 (54.2)	11 (45.8)
Sheep scab	13	8.1	(4.4 -13.5)	4 (30.8)	9 (69.2)
Sheep diseases in 2018 (on 125 flocks)	**Frequency n**	**Prevalence %**	**(95% C.I.)**	**Identified by Farmers n (%)**	**Identified by Others[a] n (%)**
Johne's disease	3	2.4	(0.5 -6.9)	2 (66.7)	1 (33.3)
Maedi-Visna	1	0.8	(0.0 -4.4)	.	1 (100.0)
CLA	8	6.4	(2.8 -12.2)	5 (62.5)	3 (37.5)
EAE	17	13.6	(8.1 -20.9)	9 (52.9)	8 (47.1)
Sheep scab	16	12.8	(7.5 -20.0)	10 (62.5)	6 (37.5)

[a]: Farmers indicated who identified the diseases they encountered in their herd: (i) the veterinarian, (ii) a diagnostic laboratory, (iii) an abattoir, (iv) a post-mortem examiner, or (v) another method not listed

Table 4-7: Sheep diseases identified by others than sheep farmers in 2017 and 2018

Sheep disease in 2017	Identified in sheep by: Veterinarian n (%)	Diagnostic lab n (%)	Abattoir n (%)	PM[a] n (%)	Other n (%)
Johne's disease	.	1 (100.0)	.	.	.
Maedi-Visna	1 (50.0)	1 (50.0)	.	.	.
CLA	4 (57.1)	2 (28.6)	.	.	1 (14.3)
EAE	10 (66.7)	2 (13.3)	.	3 (20.0)	.
Sheep scab	7 (77.8)	.	1 (11.1)	.	1 (11.1)
Sheep disease in 2018	**Identified in sheep by: Veterinarian n (%)**	**Diagnostic lab n (%)**	**Abattoir n (%)**	**PM[a] n (%)**	**Other n (%)**
Johne's disease	1 (100.0)	.	.	.	.
Maedi-Visna	1 (50.0)	1 (50.0)	.	.	.
CLA	1 (33.3)	1 (33.3)	.	.	1 (33.3)
EAE	7 (63.6)	4 (36.4)	.	.	.
Sheep scab	5 (83.3)	1 (16.7)	.	.	.

[a]: PM = post-mortem examiner

4.3.2.2 Investigation of associations for the presence of sheep diseases

Fisher's Exact test was used to investigate associations between the presence of sheep diseases on the one hand, and (i) species of livestock (i.e. 'sheep' versus 'sheep and cattle') farmed and (ii) the type of enterprises (i.e. 'pedigree flock' versus 'no pedigree flock') on the other hand. A significant association was found for sheep scab and the animal species farmed. All 13 respondents who saw sheep scab in 2017 kept both sheep and cattle ($\chi^2 = 10.458$, df = 1, $p < 0.01$). A significant association was discovered for 2018 ($\chi^2 = 4.927$, df = 1, $p = 0.026$): out of 16 farmers who had sheep scab on-farm, 14 (87.5%) kept both sheep and cattle, while only two (12.5%) respondents only farmed sheep. Farms where both species are present were therefore 4.92 times as likely to have encountered sheep scab in 2018 than farms with only sheep (OR = 4.92, 95% C.I. = 1.07 – 22.73). When the case counts of sheep scab for the years 2017 and 2018 were aggregated, it was found that farmers who farmed both sheep and cattle were 10.67 times more likely to report sheep scab than respondents who only kept sheep (OR = 10.67, 95% C.I. = 2.48 - 45.81). No significant associations were found between any of the five sheep diseases and the enterprise type.

4.3.3 The presence of five cattle diseases on English farms in 2017 and 2018

4.3.3.1 Estimated prevalence of cattle diseases in 2017 and 2018

The frequency number, prevalence and exact 95% C.I. for each of the five cattle diseases included in the questionnaire are presented in Table 4-8. Both in 2017 and 2018, fasciolosis was the disease most frequently reported on cattle farms (37.1% and 33.0%), followed by bTB (14.3% and 16.1%), Johne's disease (10.0% and 14.3%), and BVD (10.0% and 8.0%). The estimated prevalence for leptospirosis was the lowest for both years: 2.1% in 2017 and 1.8% in 2018. Fisher's Exact test was used to compare the prevalence of the diseases in 2017 and 2018. There were no significant differences found between the year and disease prevalence for any of the five selected cattle diseases.

Contrary to the findings for sheep farmers, beef cattle farmers were not very likely to have diagnosed cattle diseases themselves (Table 4-8). The breakdown of the numbers of diseases diagnosed by others than cattle farmers are presented in Table 4-9 for Johne's disease, leptospirosis, BVD and fasciolosis, and in Table 4-10 for bTB. For fasciolosis, abattoirs diagnosed most cases in both years. Respondents indicated that Johne's disease, leptospirosis and BVD were most often diagnosed through diagnostic testing at laboratories, followed by veterinarians.

Table 4-8: The estimated prevalence of cattle diseases in 2017 and 2018

Cattle diseases in 2017 (on 140 herds)	Frequency n	Prevalence %	(95% C.I.)	Identified by Farmers n (%)	Identified by Others[a] n (%)
Johne's disease	14	10.0	(5.6 - 16.2)	3 (21.4)	11 (78.6)
bTB	20	14.3	(8.9 - 21.2)	.	20 (100.0)[b]
Leptospirosis	3	2.1	(0.4 - 6.1)	.	3 (100.0)
BVD	14	10.0	(5.6 - 16.2)	1 (7.1)	13 (92.9)
Fasciolosis	52	37.1	(29.1 - 45.7)	18 (34.6)	34 (65.4)

Cattle diseases in 2018 (on 112 herds)	Frequency n	Prevalence %	(95% C.I.)	Identified by Farmers n (%)	Identified by Others[a] n (%)
Johne's disease	16	14.3	(8.4 - 22.2)	4 (25.0)	12 (75.0)
bTB	18	16.1	(9.8 - 24.2)	.	18 (100.0)[b]
Leptospirosis	2	1.8	(0.2 - 6.3)	.	2 (100.0)
BVD	9	8.0	(3.7 - 14.7)	1 (11.1)	8 (88.9)
Fasciolosis	37	33.0	(24.4 - 42.6)	9 (24.3)	28 (75.7)

[a]: Farmers indicated who identified the diseases they encountered in their herd: (i) the veterinarian, (ii) a diagnostic laboratory, (iii) an abattoir, (iv) a post-mortem examiner, or (v) another method not listed; [b]: Farmers indicated who identified bTB in their herd: (i) compulsory bTB testing in their area, (ii) an abattoir, (iii) pre- or post-movement bTB testing, or (iv) another method not listed

Table 4-9: Cattle diseases identified by others than cattle farmers in 2017 and 2018

Cattle disease in 2017	Identified in cattle by: Veterinarian n (%)	Diagnostic lab n (%)	Abattoir n (%)	PM[a] n (%)	Other n (%)
Johne's disease	4 (28.6)	7 (50.0)	1 (7.1)	.	2 (14.3)
Leptospirosis	1 (25.0)	2 (50.0)	.	.	1 (25.0)
BVD	5 (29.4)	10 (58.8)	.	1 (5.9)	1 (5.9)
Fasciolosis	3 (8.3)	6 (16.7)	26 (72.2)	1 (2.8)	.

Cattle disease in 2018	Identified in cattle by: Veterinarian n (%)	Diagnostic lab n (%)	Abattoir n (%)	PM[a] n (%)	Other n (%)
Johne's disease	5 (38.5)	7 (53.8)	.	.	1 (7.7)
Leptospirosis	.	2 (100.0)	.	.	.
BVD	5 (55.6)	4 (44.4)	.	.	.
Fasciolosis	2 (6.9)	2 (6.9)	25 (86.2)	.	.

[a]: PM = post-mortem examiner

Bovine tuberculosis was most frequently confirmed through compulsory bTB testing in the area of the farm, followed by diagnosis during inspection at the abattoir.

Table 4-10: Bovine tuberculosis identified by others than cattle farmers in 2017 and 2018

bTB	Identified in cattle by			
	Compulsory testing	Abattoir	Pre-/post-movement testing	Other
	n (%)	n (%)	n (%)	n (%)
2017	18 (75.0)	6 (25.0)	.	.
2018	14 (73.7)	3 (15.8)	1 (5.3)	1 (5.3)

4.3.3.2 Investigation of associations for the presence of cattle diseases

Fisher's Exact test was used to investigate associations between the presence of cattle diseases on the one hand and (i) species of livestock farmed (i.e. 'cattle only' versus 'cattle and sheep') and (ii) the type of enterprise on-farm (i.e. 'suckler herd' versus 'no suckler herd') on the other hand. No significant associations with species farmed or enterprise type were found for any of the five cattle diseases.

4.4 Discussion

4.4.1 Comparing data on sheep and cattle diseases from farmers and other sources

Because the response percentage for both years and the prevalence of most of the diseases reported were low, the results were externally validated by comparing the difference of the estimated prevalence of the five sheep and five cattle diseases obtained through our survey for 2017 and 2018 with the difference in data for both years from diagnostic laboratories from APHA and SRUC (Surveillance Intelligence Unit, 2020), and abattoir records, from the Food Standards Agency's (FSA) open data source (data.gov.uk, 2019a; data.gov.uk, 2019b). By evaluating the increases and decreases in the prevalence, it is possible to monitor disease trends even when response percentages are low. Moreover, the monitoring of trends could be informative for the dynamics of diseases in England.

The APHA in collaboration with SRUC launched online Disease Surveillance Dashboards where disease counts, diagnosed through diagnostic laboratory testing or post-mortem examinations by APHA or SRUC, can be consulted per species (i.e. cattle, sheep, pig, poultry), the purpose of the livestock, age category, year (from 2012), month and region (Surveillance Intelligence Unit, 2020). However, it should be noted that no denominator data were available to investigate the proportion of positive cases or whether there were significant increases or decreases of submissions for diagnostic testing in 2017 and 2018. Also, the dashboards only contains data from the APHA and SRUC laboratories. Results from private laboratories are not included.

Another data source of interest for sheep and cattle health is the Collection and Communication of Inspection Results (CCIR) from the FSA. This open data source contains abattoir inspection data such as the number of disease counts, total number of throughput and the number of abattoirs the data originated from (data.gov.uk, 2019a; data.gov.uk, 2019b).

4.4.1.1 Sheep diseases in 2017 and 2018

The dashboard for sheep diseases can be consulted online (Surveillance Intelligence Unit, 2019a) and data for all five sheep diseases in our study were available (Table 4-11). From the CCIR dataset cases on sheep scab recorded at the abattoirs were available (data.gov.uk, 2019b) and the proportion of cases on the total number of throughput was calculated.

Table 4-11: Prevalence of sheep diseases: the comparison between survey results and other data sources (diagnostic laboratory and abattoir data)

Sheep disease	Survey prevalence			Dashboard counts[a]			CCIR prevalence[b]		
	'17	'18	*(diff)*	'17	'18	*(diff)*	'17	'18	*(diff)*
	%	%	*(%)*	n	n	*(n)*	%	%	*(%)*
Johne's disease	3.1	2.4	*(- 0.7)*	35	31	*(- 4)*	.	.	.
Maedi-Visna	0.6	0.8	*(+ 0.2)*	3	11	*(+ 8)*	.	.	.
CLA	9.4	6.4	*(- 3.0)*	9	8	*(- 1)*	.	.	.
EAE	15.0	13.6	*(- 1.4)*	113	93	*(- 20)*	.	.	.
Sheep scab	8.1	12.8	*(+ 4.7)*	10	21	*(+ 11)*	0.003	0.005	*(+ 0.002)*

'diff': difference between observed values for 2017 and observed values for 2018; [a]: Data acquired from sheep dashboard (http://public.tableau.com/profile/siu.apha#!/vizhome/SheepDashboard_/Overview) (accessed May 2019); [b]: Data acquired from http://data.gov.uk/dataset/ac8be1d5-ee8c-4f0e-9124-dbb44cb77962/sheep-goat-conditions (accessed May 2019).

4.4.1.1.1 Johne's disease

From the survey results, the prevalence of Johne's disease was estimated at 3.1% in 2017 and 2.4% in 2018. Similar to the survey findings, dashboard counts of Johne's disease decreased in 2018 compared to 2017. No data on Johne's disease were available through the CCIR dataset.

Similar as for cattle, Johne's disease has a long latent period in infected sheep prior to the expression of clinical signs. Therefore, clinical disease usually does not present itself before the animal is two years old (Sergeant, 2001) and the disease is often only recognised in a later stage when infected animals have already started shedding (Carslake *et al*., 2011; Robinson *et al.*, 2019): this can explain the low prevalence reported by sheep farmers. An additional difficulty is that Johne's disease does not usually cause diarrhoea in sheep contrary to cattle (Robinson *et al*., 2019).

In Canada, where Johne's disease is also an endemic disease in sheep, a study conducted on a sample of 485 culled sheep from two abattoirs found the prevalence of Johne's disease, based on the presence of lesions in the intestines of the sheep, to be 3.0% (Arsenault *et al.*, 2003).

4.4.1.1.2 Maedi-Visna

For both years in our survey, Maedi-Visna was the disease with the lowest prevalence reported by farmers with 0.6% in 2017 and to 0.8% in 2018 respectively. The sheep dashboard also indicated a higher number of Maedi-Visna being diagnosed in 2018 compared to 2017.

Other studies in Europe were conducted and depending on the country the prevalence of Maedi-Visna as an endemic disease varied: a Finnish survey conducted in 1994 reported the prevalence in 545 sheep flocks to be 1.6% (Sihvonen *et al.*, 1999) . The prevalence of Maedi-Visna was higher in e.g. Belgium where Michiels *et al.* (2018) reported that the disease was confirmed in 15/85 (17%) of Belgian sheep flocks under investigation.

4.4.1.1.3 Caseous lymphadenitis

From the cases reported by respondents in the study, the estimated prevalence of CLA decreased from 9.4% in 2017 to 6.4% in 2018. Although the difference was minimal, more cases of CLA were reported through the sheep dashboard for 2017 (n = 9) compared to 2018 (n = 8).

Binns *et al.* (2002) estimated the prevalence of CLA in the UK between 1990 and 1999. Their results showed that 45% of the farmers in their study had noticed abscesses in their sheep flock and 11% of them had received the diagnosis of CLA, which means CLA was confirmed on approximately 5% of the participating farms. However, the prevalence was found higher in 2000 when it was shown that out of a total of 745 flocks sampled, 18% had at least one positive test result confirming CLA (Baird *et al.*, 2004).

In Canada, CLA was found in 21% of a sample of 485 sheep, although the authors believed the true prevalence would probably be higher (Arsenault *et al*., 2003). Similarly, Paton *et al.* (2003) found the prevalence of CLA in Australian sheep flocks in 2002 to be 20%.

4.4.1.1.4 Enzootic abortion

Enzootic abortion was the disease most frequently reported in the online survey with 15.0% in 2017 and 13.6% in 2018. The data from the sheep dashboard also showed lower numbers of EAE detected in 2018 compared to 2017.

Longbottom *et al.* (2013) found that 33.8% of 442 respondents to a questionnaire in the UK had encountered EAE in their flocks. Moreover, the prevalence of EAE was found to be higher in large (i.e. more than 150 sheep) compared to small flocks (i.e. less than 150 sheep): 47.2% versus 9.3% (Longbottom *et al.*, 2013). However, due to the low response percentages for the study on disease presence in 2017 and 2018 presented in this chapter, no differentiations could be made by flock size in the statistical analysis presented.

4.4.1.1.5 Sheep scab

Similar to the findings from our online survey where the prevalence of sheep scab in 2017 was 8.1% versus 12.8% in 2018, the sheep dashboard data showed a higher number of cases for 2018 (n = 21) as opposed to 2017 (n = 10). Sheep scab was also included on the list of conditions assessed during ante mortem inspection at the abattoir and although the proportions of sheep scab were extremely low for both years, more sheep scab was reported in the CCIR for 2018 (0.005%) than 2017 (0.003%). Thus, in all three data sources, the level of sheep scab had increased in 2018 compared to 2017.

Previous research from Rose *et al.* (2009), based on a survey of 700 sheep farmers in Great Britain, reported a prevalence of 8.6% for sheep scab. The results from our study (8.1% and 12.8%) approach the prevalence as reported by Rose *et al*. (2009).

4.4.1.2 Cattle diseases in 2017 and 2018

The cattle dashboard (Surveillance Intelligence Unit, 2019b) only contained data on three of the five selected diseases: Johne's disease, BVD (including persistent infections) and fasciolosis (Table 4-12). Through the CCIR dataset, also cases of bTB and fasciolosis recorded at the abattoirs were available (data.gov.uk, 2019a) and disease prevalence was calculated as the number of cases detected on the total throughput.

Table 4-12: Prevalence of cattle diseases: the comparison between survey results and other data sources (diagnostic laboratory and abattoir data)

Cattle disease	Survey prevalence			Dashboard counts[a]			CCIR prevalence[c]		
	'17	'18	*(diff)*	'17	'18	*(diff)*	'17	'18	*(diff)*
	%	%	*(%)*	n	n	*(n)*	%	%	*(%)*
Johne's disease	10.0	14.3	*(+ 4.3)*	818	538	*(- 280)*	.	.	.
bTB	14.3	16.1	*(+ 1.8)*	4583[b]	3307[b]	*(- 1276)*	0.08	0.07	*(- 0.005)*
Leptospirosis	2.1	1.8	*(- 0.3)*	0	0	*(0)*	.	.	.
BVD	10.0	8.0	*(- 2.0)*	96	55	*(- 41)*	.	.	.
Fasciolosis	37.1	33.0	*(- 4.1)*	83	82	*(- 1)*	7.1	6.9	*(- 0.2)*

'diff': difference between observed values for 2017 and observed values for 2018; [a]: Data acquired from cattle dashboard (http://public.tableau.com/profile/siu.apha#!/vizhome/CattleDashboard/Overview) (accessed Mary 2019); [b]: Data acquired from http://www.ibtb.co.uk (accessed May 2019); [c]: Data acquired from http://data.gov.uk/dataset/d29ae5a8-8971-4af0-9935-91f87a809e5a/cattle-conditions (accessed May 2019)

4.4.1.2.1 Johne's disease

The data from our survey showed an increase in the prevalence of Johne's disease for 2018 (14.3%) compared to 2017 (10.0%). The case counts of Johne's disease from the dashboard data on the other hand were lower in 2018 (538 counts for all cattle) compared to 2017 (818 counts for all cattle).

Historical results on the prevalence of Johne's disease in British cattle herds showed large differences in prevalence. Çetinkaya *et al.* (1998) reported that 17.4% of 2915 English and Welsh dairy cattle farmers surveyed indicated Johne's disease had been present on their farm during some time in the past. Between 1985 and 1994, 4.9% of dairy farmers had encountered Johne's disease in their cattle, but for the years 1993 and 1994 the prevalence decreased to 1.5% and 1.3% respectively (Çetinkaya *et al*., 1998). These numbers might well be an underestimation of the true prevalence, since clinical signs are expressed long after the initial infection with the pathogen, diagnostic tests for the disease have low sensitivity and the disease is under-reported (Daniels *et al*., 2002; Carslake *et al*., 2011). A more recent study found the herd prevalence to be 68.3% (Velasova *et al*., 2017).

More publications are available on the prevalence of Johne's disease in dairy cattle than in beef herds. Good *et al.* (2009) reported Irish dairy herds showed a higher prevalence of Johne's disease than beef herds: 31.5% versus 17.9%. Most of the herds tested were beef cattle herds: 71.7%. Testing for Johne's disease was done on blood samples collected for annual brucellosis testing (Good *et al*., 2009). Most of the respondents (67.4%) in the study of Çetinkaya *et al*. (1998) kept beef cattle, however only 2.9% of them said they had seen Johne's disease in their beef herd. Moreover, 38% also kept sheep, but only 0.8% of respondents had seen Johne's disease in their sheep flock.

4.4.1.2.2 Bovine tuberculosis

The results of the online survey indicated that the prevalence of bTB increased from 14.3% in 2017 to 16.1% in 2018. However, no such increase was found for bTB diagnosed at the abattoirs or presented in the cattle dashboard.

Bovine tuberculosis is endemic in the UK with the highest prevalence of the disease reported in the South West of England and Wales, however, the true prevalence of bTB is probably underestimated by the surveillance currently in place (Defra, 2018). While bTB is still an endemic disease in England, Scotland has been declared free of bTB since 2009 (Bessell *et al.*, 2013). To obtain a disease free status, the Scottish surveillance system consisted of three components: (i) the routine testing of cattle herds for bTB, (ii) post mortem inspection at abattoirs, and (iii) post movement testing of animals coming in from other countries of the UK and Ireland (Gates *et al.*, 2013). In 2014, Defra presented a plan to eradicate bTB from the English cattle herd (Defra, 2014) in which they hoped to eradicate the disease by 2025 in Northern and Eastern parts of England and with the ultimate goal to achieve 'Officially Bovine TB Free' (OTF) status by 2038.

As a zoonotic disease that affects human as well as animal health, bTB is the most politically important cattle disease out of the five selected for the study (Carslake *et al*., 2011). However, though *Mycobacterium bovis* is a zoonotic pathogen, transmission from cattle to humans rarely occurs: only around 1% of human tuberculosis is caused by infection with *M. bovis* (Hardie and Watson, 1992; Jalava *et al.*, 2007; Davidson *et al.*, 2017).

4.4.1.2.3 Leptospirosis

Leptospirosis had the lowest prevalence of the five diseases in both years: 2.1% (in 2017) and 1.8% (in 2018). No cases were reported on the cattle dashboard. However, leptospirosis is often one of the diseases covered in cattle health schemes and testing of blood samples showed a higher prevalence than reported in the online survey: Velasova *et al*. (2017) found the herd prevalence estimates of leptospirosis in dairy cattle was 46.9%. For beef cattle specifically, a study carried out in Ireland showed a prevalence of 91% (Barrett *et al.*, 2018).

4.4.1.2.4 Bovine viral diarrhoea

The estimated prevalence of BVD decreased from 10.0% in 2017 to 8.0% in 2018 as shown in our study. Similarly, the cattle dashboard indicated a decrease in positive cases in 2018. The herd prevalence of BVD in British dairy cattle was 66% (Velasova *et al*., 2017). Brülisauer *et al.* (2010) investigated the prevalence in Scottish beef cattle herds: 16% of the beef cattle herds sampled showed cattle had been infected with BVD, while Barrett *et al*. (2018) found a herd level prevalence of 100% for the 161 Irish beef herds tested in their study.

4.4.1.2.5 Fasciolosis

Fasciolosis was reported by 37.1% of respondents to the online survey in 2017 and by 33.0% in 2018. Although the differences were small, the cattle dashboard and abattoir data also showed a decrease in 2018.

McCann *et al.* (2010) reported a herd prevalence of approximately 76% in dairy cattle, while Velasova *et al*. (2017) later found the herd prevalence of fasciolosis in British dairy cattle had decreased to 55.1%. Byrne *et al.* (2016) found that fasciolosis was associated with dairy herds as opposed to research from Dupuy *et al*. (2013b) that showed an association between fasciolosis and beef cattle. Since the current study only focused on beef cattle farmers, no evidence has been found to endorse these claims from either of the authors cited.

4.4.1.3 The relevance and validation of the results from the online survey

For all five selected sheep diseases as well as BVD and fasciolosis in cattle, the direction (i.e. increase or decrease) between the prevalence in 2017 and 2018 calculated from the online survey coincided with the direction of the case counts (for the dashboard data) and the prevalence at the abattoir. For both Johne's disease and bTB in cattle, the results from the online survey showed that the estimated prevalence had increased in 2018 compared to 2017. However, the case counts from the cattle dashboard and the prevalence of bTB diagnosed at the abattoir decreased in 2018 compared to 2017.

The literature was assessed in search for numbers on disease prevalence in England (and by extension the UK or GB) to demonstrate it is challenging to calculate the prevalence of endemic diseases as well as to interpret and compare results from other studies with those from the online questionnaire. As shown for many of the diseases considered in the current survey, not much prior information was available on the true prevalence. In addition, the prevalence of a disease is due to alter over time and for geographical areas, so the results reported by individual studies need to be interpreted with caution (Brülisauer *et al*., 2010).

However, the outcomes presented in our study add to the current knowledge and understanding, and helps to build a bigger picture on the presence and prevalence of important endemic sheep and beef cattle diseases. If continued data collection from farmers is carried out over time and subsequently compared with results from previous years, this information could then be used to monitor trends in the presence and prevalence of endemic livestock diseases throughout England.

4.4.2 Recording data by farmers and feedback from surveillance

Farmers can play an important role in disease surveillance because of their daily contact with animals and experience they have with diseases previously encountered on their farm (Palmer *et al.*, 2009). Although their opinions were considered when developing the pilot system (Chapter 3), the response percentage was low in 2017 (10.4%).

Feedback of the results was identified as an incentive (Chapter 3) and therefore used in an attempt to increase the response percentage in 2018: a short summary of the results from 2017 was included as an incentive for participants to contribute: farmers were told that after completing the 2018 survey they would be provided with a brief overview of the prevalence of the five sheep and five beef diseases in 2017 (Appendix 4-4).

However, the summary of results offered did not generate an increase in the response percentage. The useable response percentage decreased with 2.4% from 10.4% the first year to 8.0% the second. Moreover, only 24.7% (39/158) of respondents in 2018 recalled completing the questionnaire in 2017. One reason for the fall in response proportion might be the timing of the online questionnaire. Data on diseases in 2017 were collected from the end of May 2018 until the end of June 2018, after the lambing season. The 2018 invite was sent in January 2019 and data collection continued until 7th March 2019, and so included weeks that might overlap with lambing season which is a busy time for farmers (Chapter 3). Completing questionnaires was not considered a priority during busy periods of the year (Chapter 3). However, since data from the complete year 2018 were required, the earliest time the questionnaire could go out to farmers was January 2019 and a potential overlap with lambing season for some participants could therefore not be avoided.

Another explanation for the low response percentages might be the electronic nature of the questionnaire. Low response rates of approximately 5.0% to electronic questionnaires have been reported other than for sheep and cattle farmers, such as for pig farmers (Elbers *et al.*, 2008) and poultry farmers (Elbers *et al.*, 2010).

4.4.3 Identifying or diagnosing sheep and cattle diseases on-farm

In the current study, farmers indicated who identified a disease in their flock or herd. As indicated for sheep diseases in particular, it was often the farmer who diagnosed the condition. This did not come as a surprise, since many of the focus group participants had already addressed that they did not consult their veterinarian regularly (Chapter 3). This could be explained by the farmers considering themselves to be sheep experts and knowing 'what is going on in my flock' better than sheep veterinarians. Sheep farmers often only contacted their veterinarian when they were faced with a problem that was bigger than expected or they were not familiar with (Chapter 3; Kaler and Green, 2013). Farmers were confident in their abilities to recognise diseases and subsequently consider the risks a condition might pose, confirming what has been reported previously by Palmer *et al*. (2009), Garforth *et al.* (2013), and Kaler and Green (2013).

When looking at who diagnosed diseases in beef cattle, the proportion of cattle farmers diagnosing diseases themselves was markedly lower than for sheep farmers. The value of a cow compared to the value of a sheep might play a role in the willingness of farmers to consult their veterinarian or submit samples for diagnostic testing (Chapter 3). However, the cost of a veterinary consult was often a barrier for beef cattle farmers as well (Chapter 3; Kaler and Green, 2013; Tunstall *et al.*, 2019).

The current study was targeted at beef cattle farmers, so it needs to be taken into consideration there might potentially be differences in behaviour between beef and dairy cattle farmers. Dairy farmers might be better at recognising and reporting occurrences of abortion because beef cattle is often being managed in a more extensive way than dairy cattle (Bronner *et al*., 2014).

4.4.4 Farmers' awareness of diseases: the example of Johne's disease

Attitudes vary between farmers according to what they consider important for their own individual situation, but a distinction was also made between farmers who keep different species on their premises. Johne's disease was identified as one of the most important endemic sheep and cattle diseases present in England (Chapter 3) and was therefore included in the online survey for both species.

The results showed that although Johne's disease affects sheep as well as cattle, the disease was reported more frequently by farmers who kept cattle. This finding adds to a belief that was raised in the focus group discussions (Chapter 3): the value of a cow is higher than that of a sheep and therefore more money is spent on a veterinary consult, diagnostic testing and treatment of the disease in cattle. Farmers who keep both species are also likely to discuss issues in their flock during a consult for their cattle (Kaler and Green, 2013). Iceberg diseases in sheep often go unnoticed because the infected animals only start expressing clinical signs approximately two years after the initial infection (Sergeant, 2001). Additionally, diagnostic tests for Johne's disease in sheep often have a low sensitivity, which does further complicate diagnosis of the disease (Daniels *et al*., 2002; Carslake *et al*., 2011).

4.4.5 The design of the questionnaire to capture disease data and data analysis

During the developmental stages of this pilot study, important features regarding a surveillance system identified by livestock farmers (Chapter 3) were kept in mind: simplicity, flexibility and data quality. By designing an online questionnaire it was possible to implement rules into the survey that required respondents to complete all of the questions before continuing to the next page. The logic rules and structure of the electronic survey also ensured respondents were only presented with questions relevant to the specific answers they had provided: respondents who only farmed sheep did not receive any questions specifically aimed at cattle farmers. The survey was short and did not require free text to be filled in.

Multiple choice questions were used to collect data on the presence of the specific diseases in a format where farmers only had to tick the appropriate answer. In case a disease had indeed been diagnosed or suspected, farmers were presented with a follow up tick box question on who identified the disease, thus ensuring that it was a simple and quick survey for farmers to complete.

Optimal clarity of the questions was ensured first by assessment of the questionnaire by members of the research group and later by piloting the survey to a limited number of 22 farmers. Sensitivity, or the true proportion of farms where the disease was present and reported via the survey, is an important attribute for evaluating a surveillance system (Hoinville *et al*., 2013). The study included farmers reporting diseases they had recognised as such themselves. However, since the current study depended on data submitted by farmers without confirmed diagnostic evidence, it was not possible to assess the sensitivity.

Flexibility was accounted for by taking participants' opinions and suggestions into account. Although open ended questions were not used in the questionnaire, farmers were given the opportunity at the end to provide additional comments they were concerned about. If necessary, comments could then be used as a basis to make improvements to a potential next version of the survey. No such suggestions were made to improve the structure of the questionnaire, but some participants suggested that pneumonia in sheep and cattle would be an interesting clinical sign to include in a surveillance system in the future.

4.4.6 Limitations of the study and recommendations

Although the focus group participants believed that farmers would be willing to participate in a surveillance programme when it would provide them with more information on e.g. disease prevalence and spread (Chapter 3), the useable response percentages for the survey on disease presence for both years was low: 10.4% and 8% respectively.

The willingness of farmers to participate in a surveillance programme is a well-known issue (Bronner *et al*., 2014). Even though farmers might say they would contribute to a surveillance system, it is not possible to know for certain that they would report diseases when faced with them (Hopp *et al.*, 2007). Reasons for a lack of interest to participate might include the time required to fill in a survey, or farmers are not concerned about certain health risks at the time of the study and have not witnessed any of the diseases in the previous years. A lack of trust in third parties and the fear of the consequences when a notifiable disease is reported to the government agencies (Mubamba *et al.*, 2018) or veterinarians (Kaler and Green, 2013; Bronner *et al*., 2014) could also explain the behaviour of farmers to not report diseases they have seen in their livestock.

Sentinel surveillance where data is continually being collected from the same pre-defined sample that is representative for the total population could be an alternative approach to capture data, identify baseline levels for diseases of interest and analyse their presence in the population over time, e.g. as investigated by Murray *et al.* (2019) for ovine mortality in Ireland. Sentinel surveillance could also be used as a solution to under-reporting through surveillance that relies on voluntary reporting of diseases (Mubamba *et al*., 2018).

4.5 Conclusions

Based on the frequency of diseases reported for both years, the sheep diseases most frequently encountered on-farm were EAE and sheep scab. The prevalence of the iceberg diseases Johne's disease, Maedi-Visna and CLA was lower, which might relate to the long latent period in affected animals, as well as to the finding that sheep farmers reported they were mostly the ones to diagnose diseases in their flock.

Cattle diseases were more likely to be diagnosed by veterinarians, diagnostic laboratory tests, and inspection at the abattoir. Fasciolosis was the disease with the highest prevalence in 2017 and 2018, and was most frequently diagnosed during inspection at the abattoir.

The low and decreasing response percentages in the pilot survey indicate that a farmer-driven surveillance system for sheep and beef cattle diseases would not be sustainable. Therefore, data sources other than reporting by livestock farmers might provide a good alternative for animal health surveillance.

Chapter 5

FARMERS' OPINIONS AND BEHAVIOUR TOWARDS SURVEILLANCE OF SHEEP AND BEEF CATTLE HEALTH: A QUANTITATIVE STUDY

5.1 Introduction

Within the current project, focus group discussions were conducted to obtain qualitative data from sheep and beef cattle farmers on the potential usefulness and benefits from a surveillance system for endemic diseases in ruminants (Chapter 3). This qualitative research through which an understanding of beliefs or behaviours was gained served as a preliminary step to quantitative methods (Pope and Mays, 1995), i.e. online and postal questionnaires to validate and complement the qualitative results (Chapter 5), as well as the development of a pilot survey to capture disease data from farmers (Chapter 4).

The aims of the study presented in this chapter were (i) to validate the results from the focus groups, (ii) to investigate whether there were clinical signs or diseases that a larger group of farmers considered important additional to those identified in Chapter 3, and (iii) to identify significant predictors for contribution to a surveillance system through logistic regression.

5.2 Methods

Initially, online questionnaires were developed. However, as will be discussed later on, the questionnaires were converted to paper copies because of the low response percentages. Only the results from the postal questionnaires are reported in the current chapter. Tables with descriptive results from the online and postal questionnaires are presented in an appendix.

5.2.1 Design and structure of the questionnaires

Two questionnaires were developed: one for sheep and one for beef cattle producers on farmer recording and surveillance of production and disease (Appendix 5-1, Appendix 5-2). The questionnaires were developed around five main sections: (i) farm specific information, (ii) current recording of data on-farm, (iii) the value of surveillance of clinical signs, (iv) the value of surveillance of specific diseases, and (v) other useful data sources for animal health surveillance.

5.2.1.1 Section 1: Farm specific information

Data were requested on the county, species farmed, enterprises run, livestock numbers, membership of the BRP, and membership of a health scheme.

5.2.1.2 Section 2: Current recording of data on-farm

Farmers were asked to complete questions on whether they had recorded data on their livestock in 2017. If so, they indicated the type of data, when and how it was recorded, and whether farmers used or had shared their data in 2017.

5.2.1.3 Section 3: The value of surveillance of clinical signs

The usefulness of surveillance of clinical signs was assessed by asking participants to indicate their level of agreement with Likert item statements on the usefulness of surveillance, important clinical signs, if either a national or regional benchmark would be most useful, and whether participants could be found willing to contribute and/or pay for such surveillance system.

Respondents were also asked to indicate the extent to which they agreed that syndromic surveillance of the five clinical signs listed would be useful. The clinical signs for sheep were (i) abortion, (ii) lameness, (iii) mastitis, (iv) deaths, and (v) culls. Similarly, for cattle the clinical signs selected were (i) abortion, (ii) pneumonia, (iii) mastitis, (iv) deaths, and (v) culls.

5.2.1.4 Section 4: The value of surveillance of specific diseases

Similar Likert item statements were used to assess whether disease surveillance was believed to be useful. Important sheep diseases considered were (i) Johne's disease, (ii) Maedi-Visna, (iii) CLA, (iv) EAE, and (v) sheep scab. Cattle diseases listed were (i) Johne's disease, (ii) bTB, (iii) leptospirosis, (iv) BVD, and (v) fasciolosis.

5.2.1.5 Section 5: Other useful data sources for animal health surveillance

Whereas the previous sections of the questionnaire were aimed at assessing the feasibility of surveillance by participation from farmers where they would actively collect data on-farm, an additional section contained questions on the usefulness of data from other sources. Data sources considered were (i) abattoirs, (ii) post mortem examiners, (iii) diagnostic laboratories, (iv) health schemes, and (v) veterinarians. Respondents also indicated which of the these had provided useful feedback on their livestock in 2017.

Finally, the farmers were asked to indicate the desirability of (i) an online webpage, (ii) emails, (iii) a mobile app, or (iv) paper leaflets as channels to provide them with feedback.

5.2.2 Type of questions included in the questionnaires

Sections 3 to 5 were comprised of mostly five-point Likert items where participants indicated to what extent they agreed with statements. The Likert items were treated as continuous variables in the statistical analysis, with 'Strongly disagree' coded as '1', 'Disagree' as '2', 'Neither agree nor disagree' as '3', 'Agree' as '4', and 'Strongly agree' as '5'. A 'Not applicable' or 'NA' option was included for respondents who did not consider any answer to accurately represent their opinion.

Four potential channels to provide farmers with feedback (an online webpage, email, mobile app, and paper leaflets) were also assessed through five-point Likert items measuring the desirability: 'Very undesirable' coded as '1', 'Undesirable' as '2', 'Neutral' as '3', 'Desirable' as '4', and 'Very desirable' as '5', with the option 'Not applicable' for participants who felt none of the other answers to fit their opinion.

5.2.3 Pilot testing of the online questionnaires

The questionnaires were pilot tested by research group members to evaluate the content and structure of the questionnaire. Improvements suggested were included before the questionnaires were piloted for five sheep and five beef cattle farmers who previously participated in the focus group discussions. The farmers were able to make suggestions on the content and structure of the questionnaire in case it included unclear features. Three sheep and three beef cattle farmers completed the online test version, but no suggestions for improvements were raised.

5.2.4 Selection of participants

5.2.4.1 Invitations for the online questionnaire

The online questionnaire was developed using Qualtrics® (Qualtrics, Provo, UT, 2018). The recommended sample size with a 95% confidence interval and 5% error margin was 377 (Raosoft, 2018). For both sheep and cattle questionnaires, a sample size of 1000 was selected with the margin of error estimated at 3.02%. Unlike the selection process described in Chapter 4, the sample of farmers for this study was not stratified proportionally to the number of farmers per county.

On 3rd September 2018, a link to the online questionnaire was sent to random samples of 1000 sheep and 1000 beef cattle farmers with email addresses known to AHDB. The email also contained introductory information as well as information on confidentiality and data management (Appendix 5-3, Appendix 5-4). The same information was provided on the start page of the online questionnaire. Before farmers were taken forward to the questionnaire, it was explained that completing the questionnaire meant they consented to their data being used for the study.

Data was directly extracted from the online database to an Excel spreadsheet (2016; Microsoft Corp., Redmond, WA). Because of the low response percentages from both sheep and beef cattle farmers, the questionnaires were converted into a postal version to be sent out to a different sample of 1000 sheep and 1000 beef cattle farmers.

5.2.4.2 Invitations for the postal questionnaire

A different sample of farmers than those selected for the online questionnaires were invited to complete a postal copy. Cover letters with introductory information to the study and information on confidentiality and data protection were included, as well as a pre-paid envelope (Appendix 5-5, Appendix 5-6). Farmer addresses were not shared with the University of Warwick. The questionnaires were sent to imageData, where names and addresses of farmers were printed with a unique reference number (URN). The postal questionnaires were sent out between 19th-23rd November 2018. A spreadsheet was used to track the respondents by URN and this was sent to AHDB to remove the names and addresses from respondents before a second copy of the questionnaire and a pre-paid envelope were sent to non-responders between 21th-25th January 2019.

Data from postal questionnaire responses were manually entered into the questionnaire in Qualtrics® (Qualtrics, Provo, UT, 2018) to ensure the same structure as for the online responses. Double data entry was done to reduce the chance of mistakes being made. Subsequently, data were extracted to an Excel spreadsheet (2016; Microsoft Corp., Redmond, WA) and the reliability of data entry was evaluated by comparing paper versions of a random selection of 20 sheep farmer and 15 beef farmer questionnaires to the data in the spreadsheet.

5.2.5 Data management and analysis

Software used for data entry and management were Qualtrics® (Qualtrics, Provo, UT, 2018) and Excel (2016; Microsoft Corp., Redmond, WA). Statistical analyses were carried out in SPSS 24.0 (IBM Corp, 2016) and R/RStudio (R Core Team, 2019; RStudio Team, 2018). The 'ggplot'-function from the 'ggplot2' package (Wickham, 2009) was used to generate the graphs with distributions of the answers to the Likert item questions.

5.2.5.1 Descriptive statistics and comparing more than two related samples

The Chi-square and Fisher's Exact tests were used to identify associations between categorical variables (Thrusfield, 2007e; Dohoo *et al.*, 2009d). Categories within the data were pooled when there were few respondents and where the pooling did not affect the logic of the interpretation of the results.

The Shapiro-Wilk test was used to assess the distribution from the Likert items: p-values < 0.05 suggested data were not normally distributed. Friedman's Analysis of Variance (ANOVA) was used to investigate statistically significant differences between more than two related samples (Martin and Bridgmon, 2012).

Post hoc tests and pairwise comparisons were carried out using the Related Samples Wilcoxon Signed Rank Test to identify statistically significant differences between pairs of variables. The Bonferroni correction was applied for multiple pairwise testing (Field, 2009a; Martin and Bridgmon, 2012).

5.2.5.2 Principal Component Analysis (PCA)

PCA was used to eliminate multicollinearity from the dataset and as a data reduction technique to improve parsimony, whilst retaining as much of the initial variance from the original dataset as possible (Dohoo *et al.*, 2009e; Tabachnik and Fidell, 2013a). Subsequently, principal components (PCs) were used in the logistic regression analysis. Because the dataset was small, which can reduce the reliability of PCA, missing values from the Likert items were imputed using the Expectation Maximisation (EM) technique (Tabachnik and Fidell, 2013b). Little's test was used to ascertain data was missing completely at random (MCAR) (Little, 1988).

Three methods were used to determine the number of PCs to be retained for further analysis: (i) the Kaiser criterion where PCs with Eigenvalues > 1 are to be retained (Field, 2009b), (ii) parallel analysis was carried out where the number of components to be retained was calculated based on the theory that the Eigenvalues from the original data should be higher than Eigenvalues from randomly generated correlation matrices via Monte Carlo simulation (Vivek *et al.*, 2017), and (iii) a Scree plot where the Eigenvalues are plotted on a two dimensional graph and the optimal number of components is identified as the point of inflexion (Field, 2009b; Tabachnik and Fidell, 2013a). Subsequently, oblique rotation of the components was used to improve interpretability (Field, 2009b; Tabachnik and Fidell, 2013a).

The reliability of the PCA was investigated using Cronbach's alpha and the inter-item correlation (Field, 2009b; Tabachnik and Fidell, 2013a).

5.2.5.3 Binary logistic regression

Logistic regression was applied to evaluate the relationship between explanatory variables or predictors and the binary outcome to the research question if respondents would be willing to contribute to a surveillance system for sheep and/or beef cattle health ('0' = no; '1' = yes/maybe).

The model was formulated as follows (Thrusfield, 2007f; Dohoo *et al.*, 2009f):

$$logit(P(Y)) = \beta_0 + \sum \beta_i X_i$$

with $P(Y)$ as the probability of 'Y = 1' versus 'Y = 0'; β_0 = the intercept; β_i = regression coefficient of the respective predictors X_i.

The goodness of fit of the models was assessed by using three techniques: (i) the Likelihood Ratio Test (LRT), (ii) Hosmer and Lemeshow test, and (iii) the area under the curve (AUC) calculated from receiver operating characteristics (ROC) curves (Field, 2009c).

5.3 Results

5.3.1 Sheep farmers' questionnaire

Results and tables for the online questionnaire are provided in Appendix 5-7.

5.3.1.1 Respondents to the questionnaire and flock characteristics

After the postal questionnaire went out in November 2018, 165/1000 (16.5%) questionnaires were returned. An additional 91 (9.1%) responses were received after the reminder was sent out in January 2019. In total, 256 (25.6%) questionnaires were returned of which 189 (73.8%) were completed to an extent: 6 (3.2%) responses were not included in the final analysis because there was either no information available on the county (66.7%) or the farm selected for the study was not located in England (33.3%). Finally, the total usable response percentage for the postal questionnaire was 18.3% (Figure 5-1).

Out of 183 respondents, 71 (38.8%) farmed sheep as well as cattle. Fifty-three (29.0%) farmers kept pedigree flocks, 152 (83.1%) respondents kept commercial flocks, and 40 (21.9%) kept store lambs. Thirty-six (19.8%) respondents were members of a health scheme in 2017.

Furthermore, 49 (27.4%) farmers were members of the BRP in 2017. Median flock size is presented in Table 5-1.

Table 5-1: Median flock size of 183 respondents to the postal sheep questionnaire

	Ewes (n)	Lambs (n)	Rams (n)	Total (n)
Median	197.5	325	6	506
Range	10 - 2750	4 - 4250	1 - 330	4 - 7065
Respondents n (%)	178 (97.3%)	172 (94.0%)	171 (93.4%)	183 (100%)

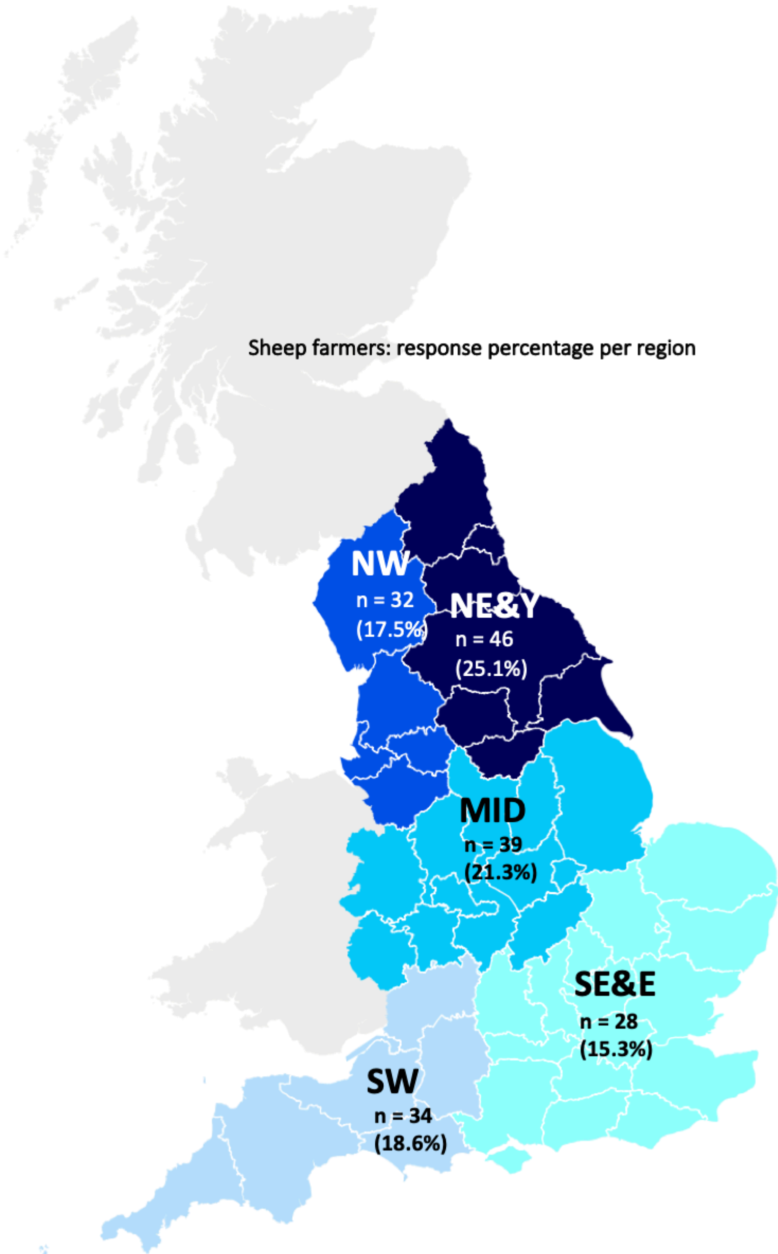


Figure 5-1: The distribution of respondents to the postal version of the sheep questionnaire (with the response percentage per region) (the map was constructed with datawrapper.de, accessed May 2019)

5.3.1.2 Recording of health and production data by sheep farmers

Ninety (49.2%) respondents indicated they had recorded data on their sheep in 2017 (Table 5-2). Thirty (33.3%) farmers had recorded electronically, while 59 (65.6%) had only recorded on paper. Seventy-one (78.9%) farmers had used the data recorded for decision-making on their farm. Thirty (33.3%) farmers who recorded data also had shared data with third parties in 2017.

Table 5-2: Recording of sheep health and production data by 183 respondents to the postal questionnaire

Specifics on data recording in 2017		Respondents	
		n	%
Type of data recorded (total n = 90):			
	Clinical signs	18	20.0
	Diseases diagnosed	24	26.7
	Production data	79	87.8
	Other	2	2.2
Frequency of electronic data recording on-farm (total n = 30):			
	Daily	1	3.3
	Weekly	4	13.3
	Monthly	11	36.7
	Quarterly	7	23.3
	Annually	3	10.0
	Other	2	6.7
Data shared with third parties (total n = 30):			
	Other farmers	10	33.3
	Veterinarian	20	66.7
	AHDB Beef & Lamb	3	10.0
	Breed societies	6	20.0
	Health scheme	3	10.0
	Other	5	16.7

5.3.1.3 Sheep farmers' opinions on the usefulness of surveillance of clinical signs and sheep diseases

Participants indicated to what extent they agreed that surveillance of clinical signs in sheep would be useful for (i) decision-making, (ii) the sheep industry, (iii) comparing data with a regional benchmark, or (iv) comparing with a national benchmark. The distribution of responses to the Likert items regarding the usefulness of surveillance of clinical signs is presented in Figure 5-2.

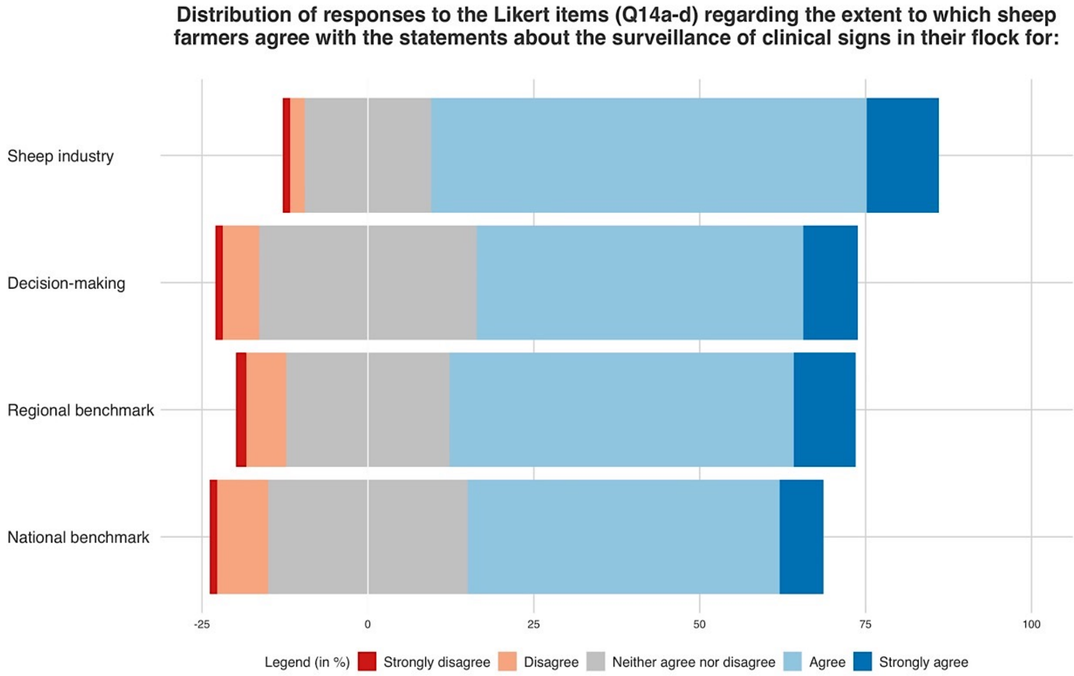


Figure 5-2: Distribution of responses to Likert items: Please indicate the extent to which you agree with the following statements about the surveillance of clinical signs in your flock: 'I believe a summary of clinical signs from a national surveillance system would help me with decision-making on my farm'; 'I believe a summary of clinical signs from a national surveillance system would be useful for the sheep industry.'; 'I believe comparing my own flock average with a regional average would be useful for me.'; 'I believe comparing my own flock average with a national average would be useful for me.' (Q14a-d)

Considering surveillance of clinical signs, 76.5% of respondents (strongly) agreed it would be useful for the sheep industry, 61.2% for comparing data with a regional benchmark, 57.4% for decision-making, and 53.6% for comparison with a national benchmark.

When comparing the four Likert items on the usefulness of surveillance of clinical signs, sheep industry scored significantly higher than decision-making ($p < 0.01$) and national benchmarking ($p < 0.01$) (Table 5-3).

With regard to sheep diseases, 74.3% of respondents (strongly) agreed that surveillance of sheep diseases would be useful for the sheep industry, 63.4% and 54.1% for regional and national benchmarking respectively, and 50.8% of respondents (strongly) agreed surveillance of sheep diseases would be useful for decision-making on their farm. The distribution of answers from sheep farmers is presented in Figure 5-3.

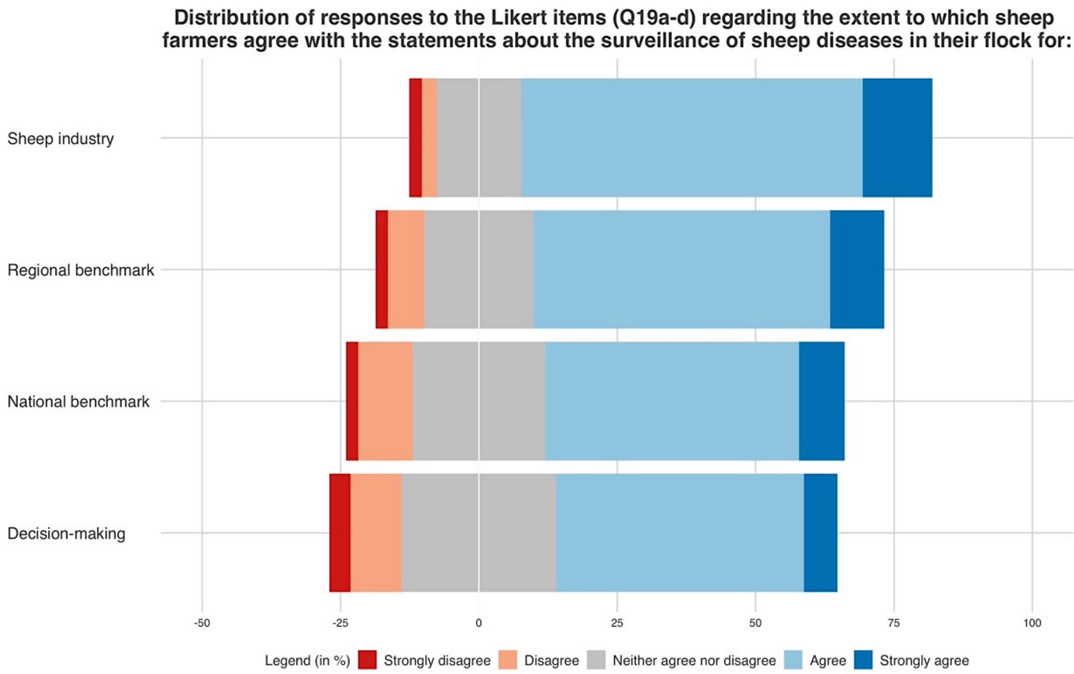


Figure 5-3: Distribution of responses to Likert items: Please indicate the extent to which you agree with the following statements about the surveillance of sheep diseases diagnosed in your flock: 'I believe a summary of sheep diseases from a national surveillance system would help me with decision-making on my farm'; 'I believe a summary of sheep diseases from a national surveillance system would be useful for the sheep industry.'; 'I believe comparing my own flock average with a regional average would be useful for me.'; 'I believe comparing my own flock average with a national average would be useful for me.' (Q19a-d)

For the statements on surveillance of sheep diseases, sheep industry scored higher than decision-making ($p < 0.01$) and national benchmark ($p < 0.01$). The scores from the Likert items on surveillance of clinical signs versus specific diseases were compared pairwise. Respondents scored the usefulness of clinical signs significantly higher than sheep diseases for decision-making on-farm (Table 5-3).

Table 5-3: Mean ranks for the four Likert items on the usefulness of surveillance of clinical signs and diseases in sheep

Usefulness for	Mean ranks for clinical signs[a]	Mean ranks for sheep diseases[b]	Differences between clinical signs and diseases mean rank ($p < 0.05$)
Sheep industry	2.84	2.86	.
Regional benchmark	2.51	2.58	.
Decision-making	2.37	2.21	$Z = -2.855, p < 0.01$
National benchmark	2.29	2.35	.

[a]: Friedman test indicated significant differences ($\chi^2 = 44.9$, df = 3, $p < 0.01$); [b]: Friedman test indicated significant differences ($\chi^2 = 63.424$, df = 3, $p < 0.01$)

5.3.1.4 On-farm monitoring of clinical signs in sheep

Five clinical signs were scored on a five-point Likert scale: (i) abortion, (ii) lameness, (iii) mastitis, (iv) deaths on-farm, and (v) culls for national and regional benchmarking (Figure 5-4 and Figure 5-5).

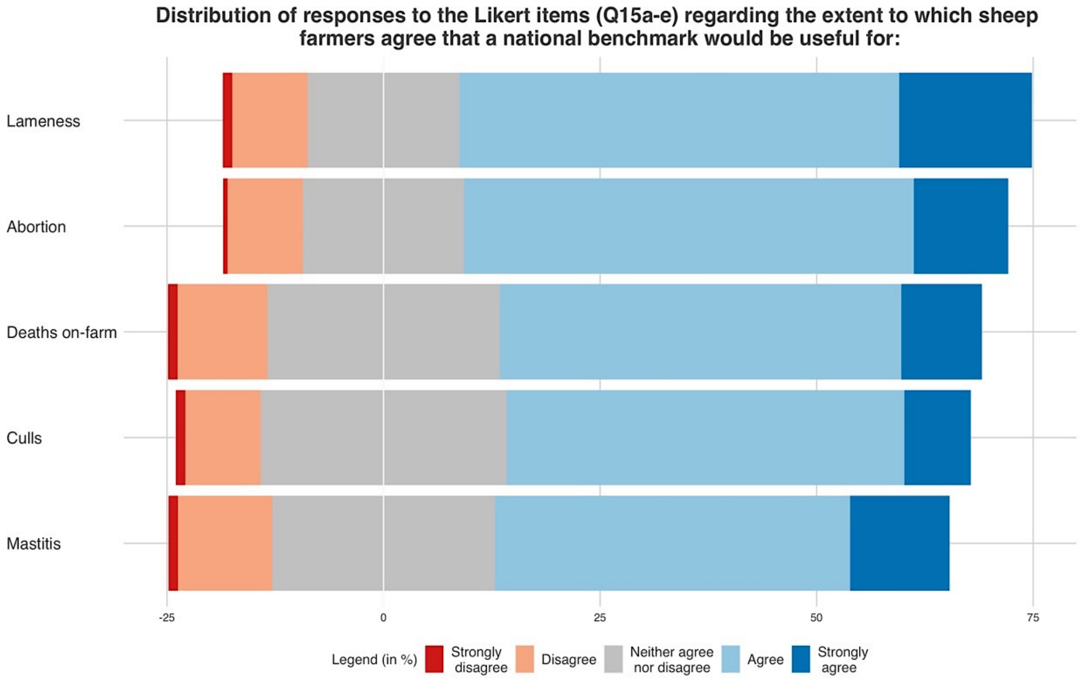


Figure 5-4: Distribution of responses to Likert items: Please indicate the extent to which you agree that a national benchmark on the clinical signs in sheep listed would be useful to you as a sheep farmer: (a) 'abortions'; (b) 'lameness'; (c) 'mastitis'; (d) 'deaths on-farm'; (e) 'culls' (Q15a-e)

With regard to a national benchmark, 66.1% of respondents (strongly) agreed it would be useful for lameness, 62.8% for abortion, 55.7% for deaths on-farm, 53.6% for culls, and 52.5% for mastitis.

As for regional benchmarking, 62.9% of the respondents (strongly) agreed it would be useful for lameness, 62.8% for abortion, 53.6% for mastitis, and 51.9% for deaths on-farm. Only 47.0% of respondents (strongly) agreed a regional benchmark for culls would be useful (Table 5-4).

No significant differences were found between the mean ranks of the five clinical signs for national benchmarking. For regional benchmarking, lameness ($p = 0.018$) and abortion ($p < 0.01$) were scored significantly higher than culls.

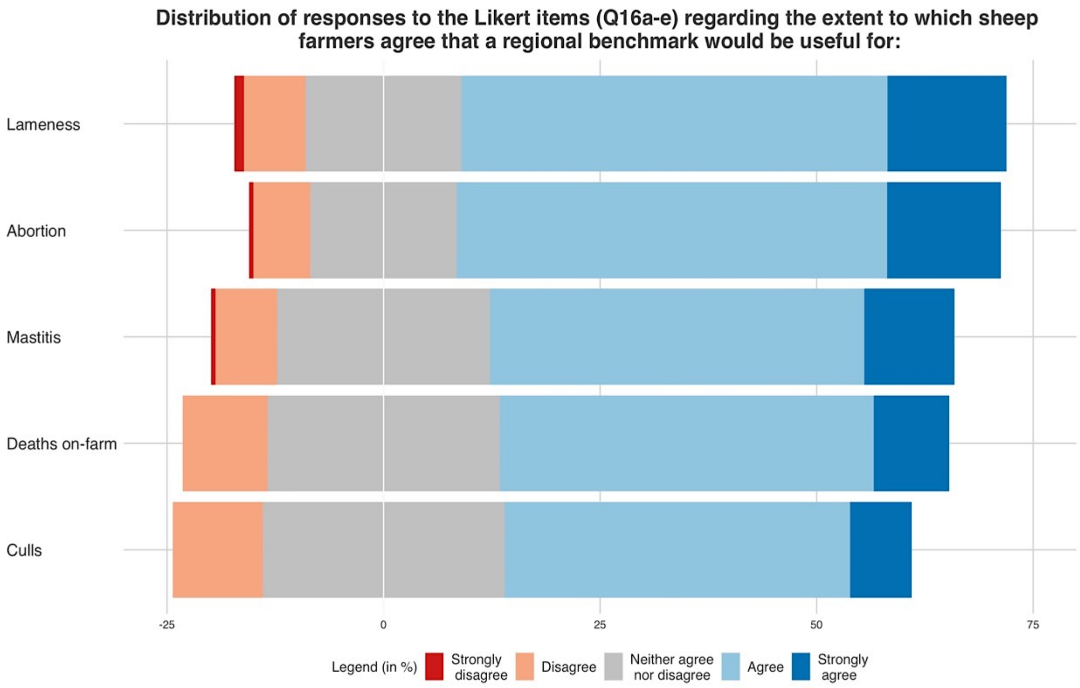


Figure 5-5: Distribution of responses to Likert items: Please indicate the extent to which you agree that a regional benchmark on the clinical signs in sheep listed would be useful to you as a sheep farmer: (a) 'abortions'; (b) 'lameness'; (c) 'mastitis'; (d) 'deaths on-farm'; (e) 'culls' (Q16a-e)

It was assessed whether individual clinical signs would be more useful for national or regional benchmarking. Respondents scored abortion and mastitis significantly higher for regional than national benchmarking (Table 5-4).

Table 5-4: Mean ranks for answers to the Likert items on the usefulness of the surveillance of five clinical signs in sheep

Clinical sign	Mean ranks for national benchmark	Mean ranks for regional benchmark[a]	Differences between national and regional mean rank ($p < 0.05$)
Lameness	3.26	3.25	.
Abortion	3.18	3.28	Z = -2.397, p = 0.017
Mastitis	2.88	2.98	Z = -2.207, p = 0.027
Deaths on-farm	2.85	2.82	.
Culls	2.83	2.68	.

[a]: Friedman test indicated significant differences ($\chi^2 = 52.3$, df = 4, $p < 0.01$)

Respondents could make suggestions for other clinical signs in sheep they would find useful to monitor. Those suggested were mostly linked with fertility and production: e.g. proportion of barren ewes, prenatal losses, twin lambs, milk quality, and birthing numbers. Lamb mortality was mentioned by four respondents.

5.3.1.5 Surveillance of sheep diseases diagnosed on-farm

Five sheep diseases were considered in the questionnaire: (i) Johne's disease, (ii) Maedi-Visna, (iii) caseous lymphadenitis, (iv) enzootic abortion, and (v) sheep scab. The distribution of answers is presented in Figure 5-6 and Figure 5-7.

With regard to a national benchmark, 69.9% of sheep farmers (strongly) agreed it was useful for sheep scab and 60.1% for Johne's disease. National benchmarking of iceberg diseases scored lower: only 47.0% of farmers (strongly) agreed it would be useful for CLA or Maedi-Visna. Johne's disease scored lowest with only 46.5% of respondents (strongly) agreeing a national benchmark would be useful (Figure 5-6).

The percentage of farmers that (strongly) agreed a regional benchmark would be useful for sheep scab was 67.2%, for EAE 60.6%, and for Johne's disease it was 50.3%. A regional benchmark for Maedi-Visna and CLA was not considered useful by the majority of participants (49.7% and 49.1% respectively) (Figure 5-7).

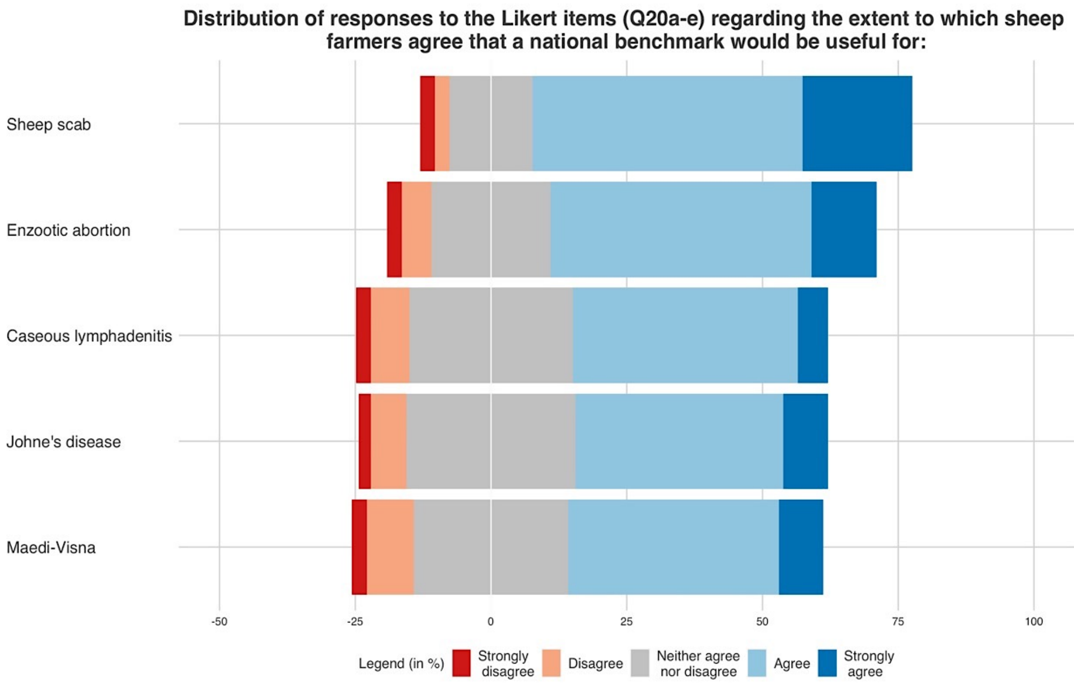


Figure 5-6: Distribution of responses to Likert items: Please indicate the extent to which you agree that a national benchmark on the sheep diseases listed would be useful to you as a sheep farmer: (a) 'Johne's disease', (b) 'Maedi-Visna', (c) 'caseous lymphadenitis', (d) 'enzootic abortion', (e) 'sheep scab' (Q20a-e)

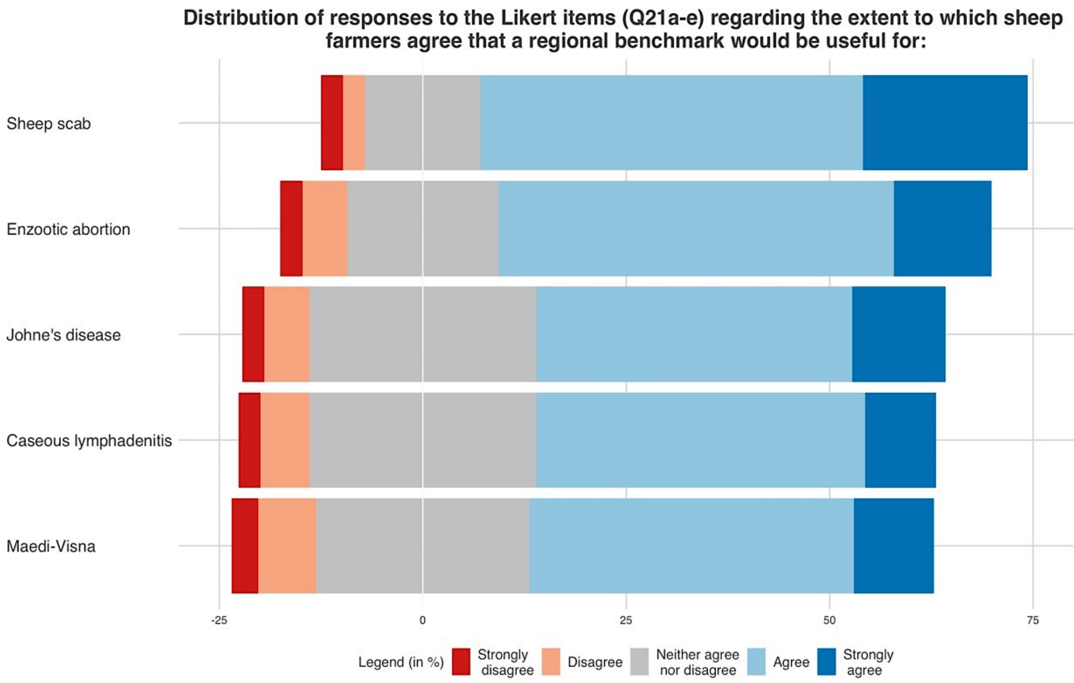


Figure 5-7: Distribution of responses to Likert items: 'Please indicate the extent to which you agree that a regional benchmark on the sheep diseases listed would be useful to you as a sheep farmer: (a) 'Johne's disease', (b) 'Maedi-Visna', (c) 'caseous lymphadenitis', (d) 'enzootic abortion', (e) 'sheep scab' (Q21a-e)

For the purpose of national benchmarking, sheep scab was scored significantly higher by participants than the iceberg diseases Johne's disease ($p < 0.01$), Maedi-Visna ($p < 0.01$), and CLA ($p < 0.01$). Similarly, sheep scab also scored significantly higher than Johne's disease ($p < 0.01$), Maedi-Visna ($p < 0.01$), and CLA ($p < 0.01$) for regional benchmarking. A regional benchmark was considered significantly more useful than a national benchmark for both Johne's disease and CLA (Table 5-5).

Table 5-5: Mean ranks for answers to the Likert items on the usefulness of the surveillance of five sheep diseases

Sheep disease	Mean ranks for national benchmark[a]	Mean ranks for regional benchmark[b]	Differences between national and regional mean rank ($p < 0.05$)
Sheep scab	3.56	3.43	.
EAE	3.10	3.13	.
Maedi-Visna	2.80	2.77	.
Johne's disease	2.78	2.87	$Z = -2.325$, $p = 0.020$
CLA	2.76	2.79	$Z = -2.483$, $p = 0.013$

[a]: Friedman test indicated significant differences ($\chi^2 = 78.2$, df = 4, $p < 0.01$); [b]: Friedman test indicated significant differences ($\chi^2 = 65.4$, df = 4, $p < 0.01$)

Respondents were asked whether any of the five sheep diseases were diagnosed or suspected in their flocks in 2017. Enzootic abortion was the disease most frequently reported (39/173 or 22.5%), followed by sheep scab (22/172 or 12.8%), CLA (12/167 or 7.2%), Johne's disease (11/170 or 6.5%), and Maedi-Visna (6/170 or 3.5%). These results suggest that respondents were more interested in surveillance of diseases they saw more often in their animals.

Respondents had the chance to identify additional sheep diseases they would find useful to monitor. Foot diseases (contagious ovine digital dermatitis and footrot), liver fluke, and gastro-intestinal parasites came up more than once. Eye diseases, ovine pulmonary adenocarcinoma, Orf, tetanus, blow fly, diseases caused by bacteria such as *Campylobacter spp* and *Pasteurella spp*, and new and emerging diseases (e.g. Bluetongue virus) were mentioned as well.

5.3.1.6 The use of outputs from a surveillance system for sheep health

Individual respondents indicated the extent to which they agreed that they would use the outputs from a surveillance system on their own farm to (i) help recognise sheep diseases, (ii) reduce the risk of buying in diseases, (iii) track sheep diseases in the area (iv) reduce economic losses, (v) increase animal production, (vi) demonstrate freedom from disease, (vii) improve the understanding of sheep diseases, (viii) consult info on new disease threats, or (ix) receive advice on sheep diseases. The distributions of responses for all nine Likert items are presented in Figure 5-8.

The use of outputs from a surveillance system to keep informed of new disease threats in the area scored highest, while using outputs for demonstrating freedom from disease, increasing production numbers, and reducing economic losses were scored lowest (Table 5-6).

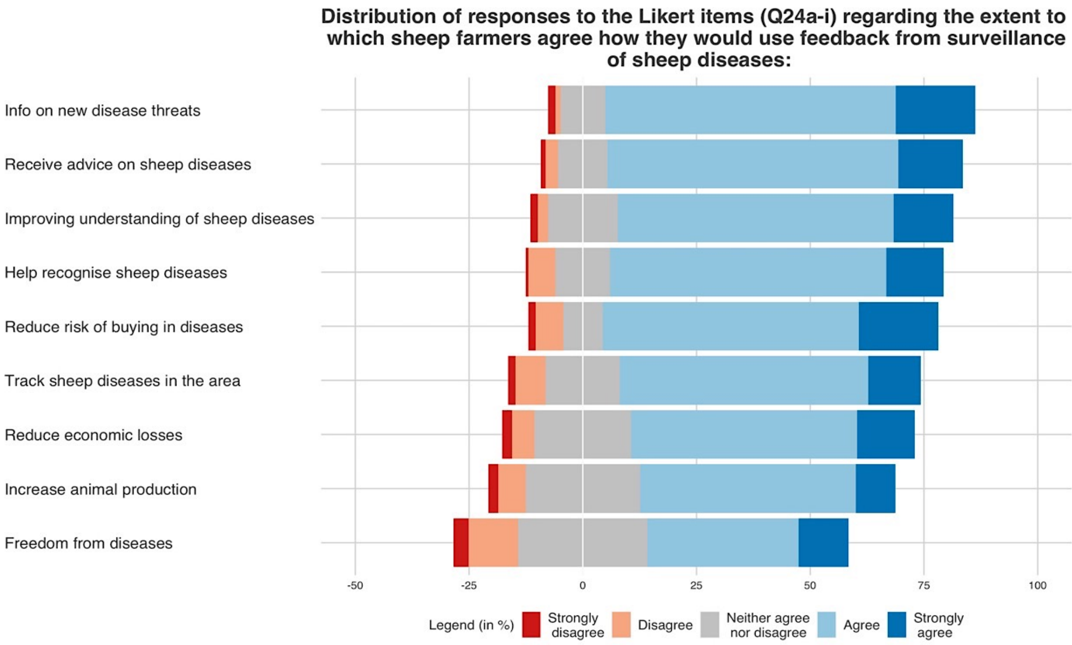


Figure 5-8: Distribution of responses to the Likert items: Please indicate the extent to which you agree with the following statements about the use of feedback from a surveillance system with advice on the presence of sheep diseases: (a) 'I would use feedback to help recognise sheep diseases myself'; (b) 'I would use feedback to reduce the risk of buying in diseases'; (c) 'I would use feedback to track sheep diseases in my area'; (d) 'I would use feedback to help me plan how to reduce economic losses on my farm'; (e) 'I would use feedback to help me plan how to increase animal production on my farm'; (f) 'I would use information to advertise that my flock is free of certain specific diseases'; (g) 'I would use feedback to improve my understanding of sheep diseases'; (h) 'I would use feedback to stay informed of new disease threats'; (i) 'I would find it interesting to receive advice on sheep diseases from a surveillance system' (Q24a-i)

Table 5-6: Mean ranks for answers to the Likert items on the use of feedback from a surveillance system with advice on the presence of sheep diseases

Use of feedback from a surveillance system	Mean rank[a]
Info on new disease threats[b]	5.85
Receive advice on sheep diseases	5.48
Improving understanding of sheep diseases	5.26
Help recognise sheep diseases	5.22
Reduce risk of buying in diseases	5.37
Track sheep diseases in the area	4.91
Reduce economic losses	4.67
Increase animal production	4.39
Demonstrate freedom from disease[c]	3.86

[a]: Friedman test indicated significant differences ($\chi^2 = 122.4$, df = 8, $p < 0.01$); [b]: 'Info on new disease threats' was scored significantly higher than 'Reduce economic losses' ($p = 0.01$), 'Increase animal production' ($p < 0.01$), and 'Demonstrate freedom from disease' ($p < 0.01$); 'Advice on sheep diseases' was also scored higher than 'Increase animal production' ($p = 0.03$), and 'Demonstrate freedom from disease' ($p < 0.01$); [c]: 'Demonstrate freedom from disease' was considered significantly less useful by respondents than 'Track sheep diseases in the area' ($p = 0.046$), 'Help recognise sheep diseases' ($p < 0.01$), 'Improve understanding of sheep diseases' ($p < 0.01$), and 'Reduce risk of buying in diseases' ($p < 0.01$).

5.3.1.7 Predicting farmers' willingness to contribute data to a surveillance system for sheep health: logistic regression

5.3.1.7.1 Farmers' willingness to contribute to a surveillance system for sheep health

Apart from investigating whether farmers believed a surveillance system for clinical signs or diseases diagnosed in sheep would be useful, they were also asked whether they would be prepared to provide data recorded on their own sheep and fund a farmer-driven surveillance system. Table 5-7 provides a breakdown of responses to the questions on farmers' willingness to contribute to a surveillance system for the monitoring of clinical signs and/or a system monitoring sheep diseases.

Table 5-7: Distribution of respondents' willingness to contribute data for and fund surveillance of clinical signs or sheep diseases

Contributing to surveillance?	Clinical signs		Specific diseases	
	n	%	n	%
No	71	38.8	57	31.1
Maybe	53	29.0	54	29.5
Yes	46	25.1	58	31.7
Not responded	13	7.1	14	7.7
Total	*183*	*100.0*	*183*	*100.0*
Prepared to pay?	**Clinical signs**		**Specific diseases**	
	n	%	n	%
No	113	61.7	102	55.7
Maybe	50	27.3	57	31.1
Yes	8	4.4	14	7.7
Not responded	12	6.6	10	5.5
Total	*183*	*100.0*	*183*	*100.0*

Some respondents who answered 'maybe' provided an explanation for their choice. Their answers could be grouped into 4 categories: (i) financial restraints (e.g. smallholders feared surveillance would be too expensive for them compared to larger farms), (ii) confidentiality and data protection (e.g. anonymity would need to be guaranteed), (iii) time and effort required from farmers (e.g. additional paperwork, easy and simple to use), (iv) reliability and relevance of feedback for the farmer.

Reasons for respondents not to contribute data revolved around 3 major topics: (i) surveillance would be too expensive, (ii) the additional time and effort required, and (iii) surveillance of sheep health would not be relevant for them (e.g. some respondents were planning to retire soon). Financial restraints were the main reason provided by respondents who were not willing to pay for surveillance.

5.3.1.7.2 Preparation of data: Principal Component Analysis (PCA)

5.3.1.7.2.1 Missing values: imputation through Expectation Maximisation

Prior to the PCA, the pattern of missing data was established to determine if and how missing data could be imputed. The values for the 37 variables under assessment were scored on a five-point Likert scale. The variables were treated as continuous variables. Little's MCAR test showed that data was missing completely at random for all variables assessed ($p > 0.05$). Therefore, data was imputed using the Expectation Maximisation (EM) technique.

5.3.1.7.2.2 Assessing if the sample size is sufficient for PCA

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was used to investigate if the sample size was suitable for PCA. The value of the KMO test was 0.929. Bartlett's sphericity test was significant ($\chi^2 = 8261.1$, df = 666, $p < 0.01$), indicating that the variables investigated were correlated and PCA was an appropriate method to use.

5.3.1.7.2.3 Correlation and multicollinearity

An observed correlation matrix was constructed using all 37 variables considered in the PCA to ensure variables were sufficiently correlated to proceed with the analysis (> 0.3). No variables were removed since no values were lower than 0.3.

5.3.1.7.2.4 Extraction of principal components (PCs): Kaiser criterion, Scree plot and parallel analysis

Three methods were used to investigate how many PCs should optimally be extracted. Based on the Kaiser criterion only (i.e. PCs with Eigenvalues > 1 are to be retained), five components should be retained. Parallel analysis showed that only three PCs should be retained. The third method to evaluate the number of PCs to keep, was the scree plot. The scree plot suggested retaining four variables (Figure 5-9).

After taking the results from the three methods into account, four PCs, accounting for a total 72.8% of the variance, were retained for further analysis (Table 5-8).

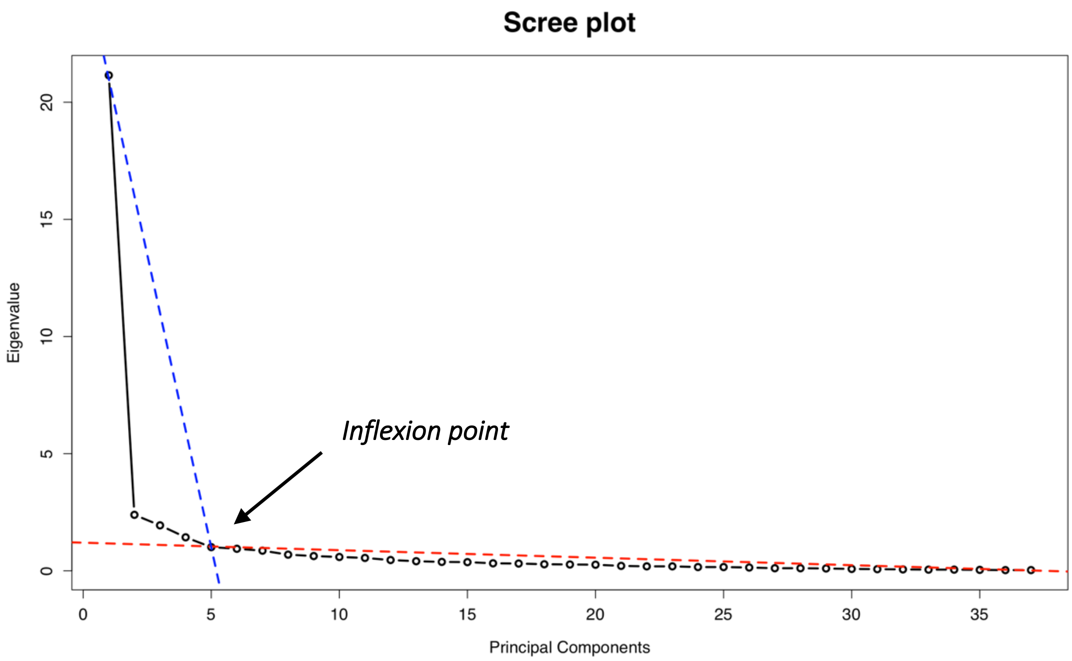


Figure 5-9: The inflexion point on the scree plot suggested that four PCs should be retained from the PCA (sheep farmer questionnaire)

Table 5-8: Principal components extracted with Eigenvalues attributed and percentage of variance explained by the PCs – sheep farmer questionnaire

Principal components	Eigenvalues	Variance (%)
PC1: Sheep diseases	21.15	57.2
PC2: Clinical signs	2.39	6.5
PC3: Use feedback for decision-making	1.94	5.2
PC4: Usefulness of surveillance	1.43	3.9

5.3.1.7.2.5 Loadings and component scores

Oblique (Promax) rotation was used to improve the visualisation and interpretability of the PCs. All 37 variables loaded highly onto one component. Two variables, sheep scab (National) and culls (National) loaded onto two different PCs. However, the difference between the two loadings was higher than 0.2, so both variables were retained and the highest loading PC was used (Appendix 5-8).

All variables concerning the usefulness of the selected diseases loaded onto PC1, the variables on the usefulness of the different clinical signs onto PC2, while the variables on how individual farmers would use outputs from a surveillance system loaded onto PC3, and the usefulness of surveillance for decision-making, industry, national and regional benchmarking loaded onto

PC4. Cronbach's alpha and inter-item (i:i) correlations showed a high reliability for the PCA (Table 5-9).

Table 5-9: Reliability of Likert items loading onto Principal Components using Cronbach's alpha and mean inter-item (i:i) correlations, and the component correlation matrix after PCA - sheep farmer questionnaire

PC	α	i:i	PC1	PC2	PC3	PC4
PC1	0.963	0.721	1			
PC2	0.942	0.652	0.630	1		
PC3	0.959	0.702	0.661	0.660	1	
PC4	0.933	0.638	0.648	0.680	0.667	1

After PCA, multicollinearity was eliminated from the dataset. Table 5-9 presents the newly assembled correlation matrix for the four components. Component score coefficients were calculated and used for further regression analysis.

5.3.1.7.3 Binary logistic regression to assess the willingness of farmers to contribute to a surveillance system for sheep health

5.3.1.7.3.1 Predictors and the outcome variable

The willingness of farmers to contribute data for a surveillance system for clinical signs and sheep diseases was used as the outcome variable for the logistic regression: the data was coded '0' for farmers who did not want to provide data and '1' for farmers who indicated they might be willing to participate ('yes' and 'maybe').

One hundred and twenty-three (67.2%) sheep farmers who completed the postal questionnaire indicated they might be willing to contribute data to a surveillance system for sheep health (Table 5-10). Another 52 (28.4%) respondents said they would not be willing to submit data for a surveillance system. Eight (4.4%) respondents did not answer the questions.

Table 5-10: Farmers' willingness to contribute to surveillance of clinical signs and/or sheep diseases

Contribution to sheep health surveillance?	Number of respondents	
	n	%
No (= '0')	52	28.4
Yes (= '1')	123	67.2
Total	*175*	*95.6*

Predictors evaluated for inclusion in the logistic model were (i) the region where the farm was located (i.e. SW, SE, MID, NW, NE), (ii) membership of the AHDB BRP ('0' = 'no', '1' = 'yes'), (iii) species farmed ('0' = 'sheep', '1' = 'sheep + cattle'), (iv) enterprise ('0' = 'no pedigree flock', '1' = 'pedigree flock', (v) total flock size, (vi) membership of a health scheme ('0' = 'no', '1' = 'yes'), (vii) recording of animal or production data in 2017 ('0' = 'no', '1' = 'yes'), and (viii) the four PCs extracted through PCA.

5.3.1.7.3.2 Univariable regression models

Univariable logistic regression was carried out for all the variables against the outcome variable capturing whether farmers would be willing to contribute to a surveillance system or not. Eight of the variables were significant predictors ($p < 0.05$) for contribution to a surveillance system (Table 5-11).

The odds ratios indicate the effect of the predictors on the willingness to participate. Farmers who already recorded data on their flocks were more likely to be interested in participating in a surveillance system (OR = 3.35), as were farmers who kept pedigree sheep (OR = 2.32), and members of the BRP (OR = 2.28) or a health scheme (OR = 2.94).

All four PCs were significant predictors, which means that respondents were more likely to be willing to contribute to a surveillance system if they agreed that (i) 'surveillance of sheep diseases would be useful' (PC1) (OR = 1.71), (ii) 'surveillance of clinical signs would be useful' (PC2) (OR = 1.68), (iii) 'I would use feedback from a surveillance system' (PC3) (OR = 2.12), or (iv) 'surveillance of sheep health is useful for decision-making, the sheep industry, or benchmarking' (PC4) (OR = 2.30).

Table 5-11: Univariable logistic regression models for the prediction of sheep farmers' willingness to contribute to a surveillance system for sheep health

Predictor	p-value	OR	95% C.I.	
			Lower	Upper
Recording in '17	< 0.01	3.35	1.73	6.49
Health scheme member '17	0.025	2.94	1.15	7.50
Enterprise type	0.029	2.32	1.09	4.93
BRP member '17	0.038	2.28	1.05	4.98
PC1	< 0.01	1.71	1.23	2.39
PC2	< 0.01	1.68	1.21	2.33
PC3	< 0.01	2.12	1.45	3.12
PC4	< 0.01	2.30	1.58	3.34

5.3.1.7.3.3 The final multivariable model

A manual stepwise approach was used to design the final, multivariable model. The eight significant variables in the univariable analysis were assessed for inclusion in a binomial logit model. Significant predictors ($p < 0.05$) were kept in the final model with the outcome variable being the willingness to contribute data to a surveillance system (Table 5-12). The final multivariable model showed that the probability of respondents being willing to contribute to a farmer-driven surveillance system increased if (i) they already recorded data on their flocks in 2017 (OR = 2.95), (ii) they kept pedigree sheep (OR = 2.70), and (iii) they agreed that surveillance would be useful for decision-making, sheep industry or benchmarking (PC4) (OR = 2.25). The null model made correct predictions in 67.2% of cases, whereas the capacity for correct classification for the final model increased to 71.8%.

The deviance (value/df = 1.098) and Pearson Chi-square (value/df = 0.990) indicated that there was no overdispersion in the final model.

The LRT of the null model was 223.948, while the LRT of the final model was significantly lower at 186.638, indicating that the final model fit the data significantly better than the null model. The Hosmer and Lemeshow test was not significant ($p = 0.393$) which indicates a good fit of the model. Evaluation of the standardised residuals indicated a good fit of the final model as well.

Table 5-12: Final multivariable logistic regression model for the prediction of sheep farmers' willingness to contribute to a surveillance system for sheep health

Predictor	b	p-value	OR	95% C.I.	
				Lower	Upper
Recording in '17	1.080	< 0.01	2.95	1.44	6.04
Enterprise type	0.993	0.026	2.70	1.12	6.49
PC4	0.813	< 0.01	2.25	1.52	3.34
(Constant)	(0.098)	(0.692)	(1.10)		

A ROC curve was constructed to calculate the AUC. For the final model, the AUC was 0.772 or 77.2%. No significant improvements ($p > 0.05$) were found when adding or omitting other predictors into the model. This implies that the final model was the best fitting model according to the AUC.

5.3.1.8 Other useful data sources for surveillance according to sheep farmers

Respondents were asked to what extent they agreed that (i) abattoirs, (ii) post-mortem examiners, (iii) diagnostic laboratories, (iv) health schemes, and (v) veterinarians possessed data that could be useful for animal health surveillance purposes. Figure 5-10 presents the distribution of responses to the statements about the five third parties.

Respondents indicated whether they had received useful feedback from these third parties in 2017 (Figure 5-11). The rate of missing responses and NA-answers for this section varied between 42/183 (23.0%) for feedback from the vet and 114/183 (62.3%) for feedback received from a health scheme. This means that only answers for 47 respondents were complete for all five Likert items and thus included in the analysis.

Post-mortem examiners were scored significantly higher than health schemes ($p < 0.01$) and abattoirs ($p = 0.047$) with regard to the usefulness of the data they have. Veterinarians had provided farmers with more useful information than abattoirs ($p < 0.01$), diagnostic laboratories ($p = 0.027$) and health schemes ($p < 0.01$) in 2017 (Table 5-13).

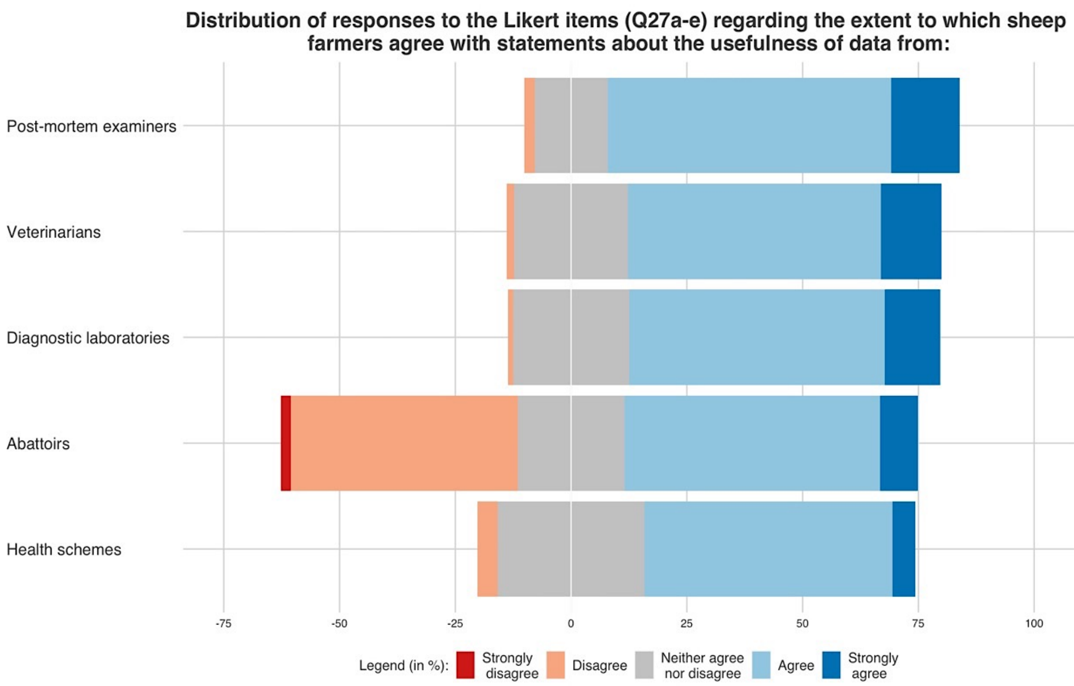


Figure 5-10: Distribution of responses to the Likert items: Please indicate the extent to which you agree with the following statements about the usefulness of data from the sources listed for surveillance of sheep health: (a) 'I believe abattoirs collect useful health data on sheep'; (b) 'I believe post-mortem examiners collect useful health data on sheep'; (c) 'I believe diagnostic laboratories collect useful health data on sheep'; (d) 'I believe health schemes collect useful health data on sheep'; (e) 'I believe vets collect useful health data on sheep' (Q27a-e)

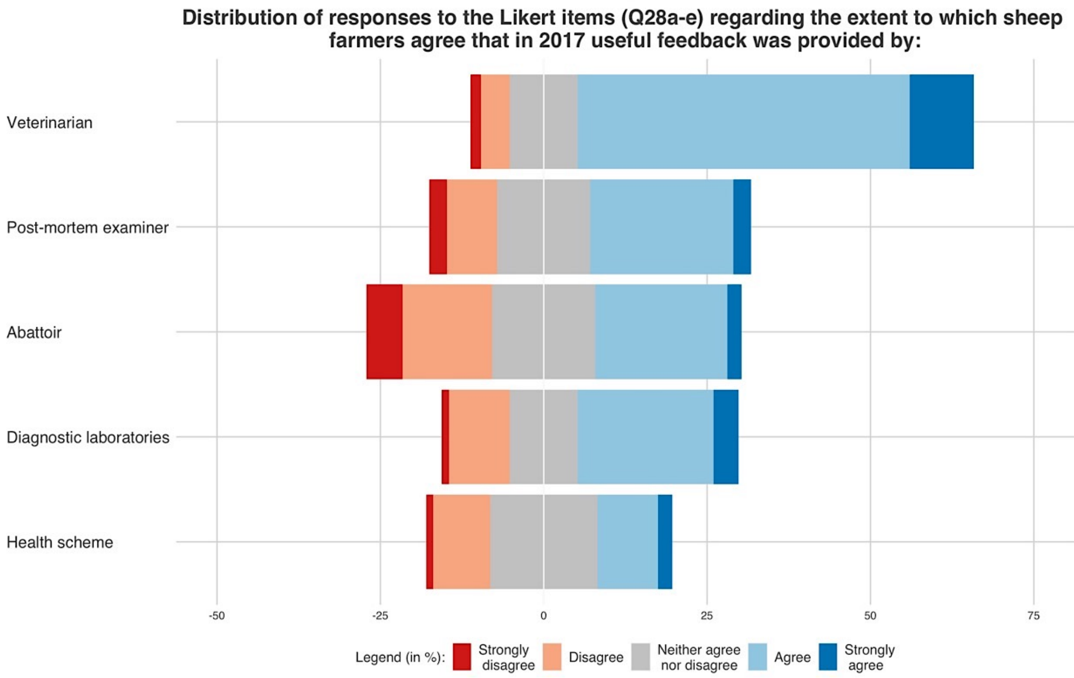


Figure 5-11: Distribution of responses to the Likert items: Please indicate the extent to which you agree with the following statements on who provided useful feedback to you on sheep health in 2017: (a) 'I received useful feedback from the abattoir'; (b) 'I received useful feedback from post-mortem examiners'; (c) 'I received useful feedback from a diagnostic laboratory'; (d) 'I received useful feedback from my health scheme'; (e) 'I received useful feedback from my veterinarian' (Q28a-e)

Table 5-13: Mean ranks for answers to the Likert items on the usefulness of data collected by other sources and the feedback sheep farmers received in 2017

Data source	Mean ranks for data on sheep health from third parties[a]	Mean ranks for feedback received in 2017[b]
Post mortem examiners	3.29	3.05
Veterinarians	3.11	3.87
Diagnostic laboratories	3.12	2.89
Abattoirs	2.80	2.77
Health schemes	2.68	2.41

[a]: Friedman test indicated significant differences (χ^2 = 34.6, df = 4, p < 0.01); [b]: Friedman test indicated significant differences (χ^2 = 36.5, df = 4, p < 0.01)

The sheep farmers were asked to indicate how desirable four channels were to receive feedback (Figure 5-12). Significant differences were present (χ^2 = 27.1, p < 0.01): (i) webpage (mean rank = 2.50), (ii) email (mean rank = 2.68), (iii) mobile app (mean rank = 2.06), and (iv) paper leaflets (mean rank = 2.77). A mobile app was a less desirable method to provide farmers with feedback than email (p < 0.01) and paper (p < 0.01).

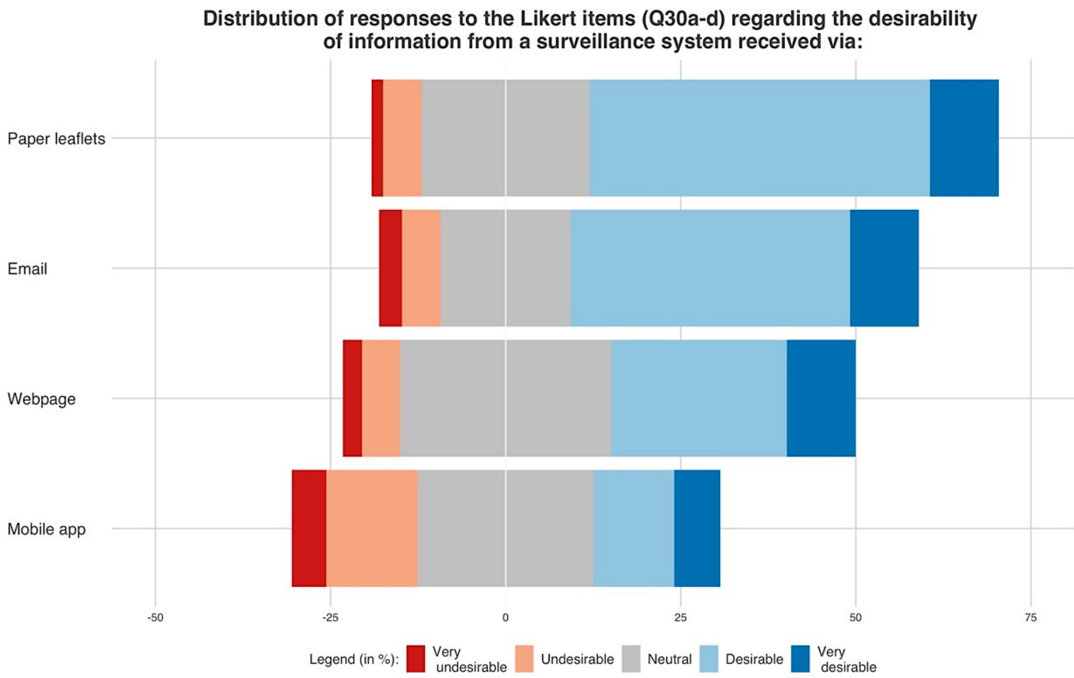


Figure 5-12: Distribution of responses to the Likert items: Ideally, how would you like to receive information on sheep health to help you with decision-making on your farm?: (a) 'Online webpage'; (b) 'Reports via email'; (c) 'Reports via mobile app'; (d) 'Paper leaflets or brochures' (Q30a-d)

5.3.2 Beef cattle farmers' questionnaire

5.3.2.1 Respondents to the questionnaire and herd characteristics

After the questionnaire went out in November 2018, 134/1000 (13.4%) responses were received. A reminder was sent in January 2019, which resulted in an additional 79 (7.9%) responses. In total, 213 (21.3%) questionnaires were returned of which 148 (69.5%) were entered in a dataset. Out of the 148 responses, 9 (6.1%) were not included in the final analysis because there was no reliable information on the county (44.4%), or respondents did not farm cattle (44.4%). One (11.1%) farmer did not complete the question on which species were present on their farm. This resulted in a useable response percentage of 13.9% (139/1000) (Figure 5-13).

Out of 139 respondents, 66 (47.5%) farmed both cattle and sheep. Thirty-three (23.7%) herds were in a health scheme and thirty-five (25.2%) participants were members of the BRP in 2017. Data on the median number of cattle per type of enterprise on-farm was provided (Table 5-14).

Table 5-14: Median herd size of 139 respondents to the postal beef cattle questionnaire

	Suckler (n)	Finisher (n)	Dairy (n)	Bulls (n)	Calves (n)	Total (n)
Median	40	62	180	2	46.5	120
Range	3 - 290	2 - 1300	3 - 480	1 - 100	3 - 315	8 – 1300
Respondents (%)	85 (61.1%)	90 (64.7%)	21 (15.1%)	77 (55.4%)	96 (69.1%)	139 (100%)

5.3.2.2 Recording of health and production data by beef cattle farmers

Seventy-eight (56.1%) respondents had recorded data on their cattle in 2017 (Table 5-15). Sixty-six (84.6%) out of the 78 farmers used the data recorded in 2017 for decision-making on-farm. On 37 (47.4%) farms herd data was recorded electronically to a certain extent. Thirty-two (41.0%) farmers also shared their recorded data in 2017.

Table 5-15: Recording of cattle health and production data by 139 respondents to the online questionnaire

Specifics on data recording in 2017	Respondents	
	n	%
Type of data recorded (total n = 78):		
Clinical signs	21	26.9
Diseases diagnosed	39	50.0
Production data	51	65.4
Other	3	38.5
Frequency of electronic data recording on-farm (total n = 37):		
Daily	6	16.2
Weekly	13	35.1
Monthly	7	18.9
Quarterly	3	8.1
Annually	2	5.4
Other	5	13.5
Data shared with third parties (total n = 32):		
Other farmers	5	15.6
Veterinarian	28	87.5
AHDB Beef & Lamb	2	6.3
Breed societies	4	12.5
Health scheme	8	25.0
Other	12	37.5

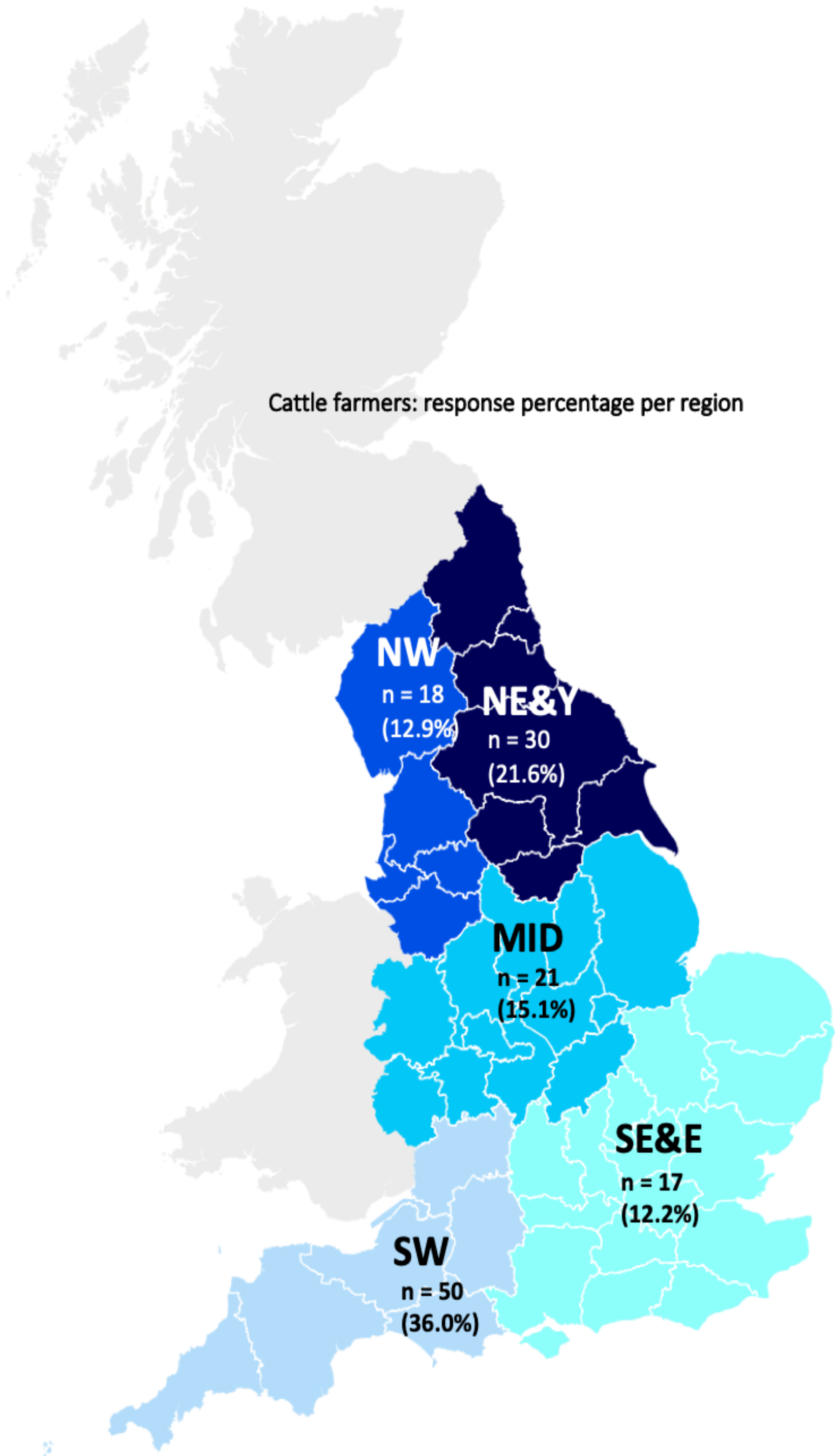


Figure 5-13: Distribution of respondents to the postal version of the beef cattle questionnaire (by region) (the map was created with datawrapper.de, accessed September 2019)

5.3.2.3 Beef cattle farmers' opinions on the usefulness of surveillance of clinical signs and cattle diseases

A total of 69.8% of respondents (strongly) agreed that surveillance of clinical signs would be useful for the beef cattle industry, while 56.1% (strongly) agreed it would be useful for regional benchmarking. Less than half of the beef farmers considered the surveillance of clinical signs to be useful for national benchmarking or for decision-making: only 48.9% and 48.2% of respondents (strongly) agreed respectively (Figure 5-14).

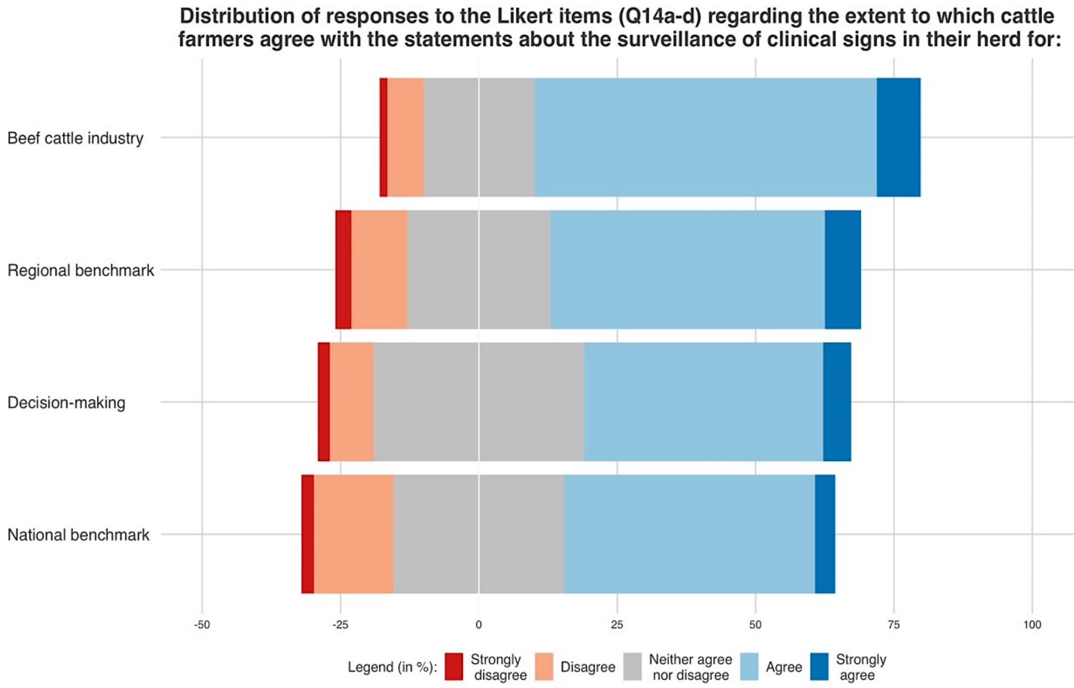


Figure 5-14: Distribution of responses to Likert items: Please indicate the extent to which you agree with the following statements about the surveillance of clinical signs in your herd: (a) 'I believe a summary of clinical signs from a national surveillance system would help me with decision-making on my farm'; (b) 'I believe a summary of clinical signs from a national surveillance system would be useful for the beef industry.'; (c) 'I believe comparing my own herd average with a regional average would be useful for me.'; (d) 'I believe comparing my own herd average with a national average would be useful for me.' (Q14a-d)

The surveillance of cattle diseases was considered most useful for the beef industry (with 68.3% of respondents (strongly) agreeing it would be useful), while 54.7% (strongly) agreed disease surveillance would be useful for regional benchmarking. Only 46.0% of respondents (strongly) agreed surveillance of sheep diseases would be useful for decision-making and national benchmarking (Figure 5-15).

The surveillance of clinical signs for cattle health was scored significantly higher for the beef cattle industry than for decision-making ($p = 0.015$) or national benchmarking ($p < 0.01$).

Surveillance of cattle diseases was scored higher for the beef cattle industry compared to decision-making ($p < 0.01$) and national benchmarking ($p < 0.01$) (Table 5-16).

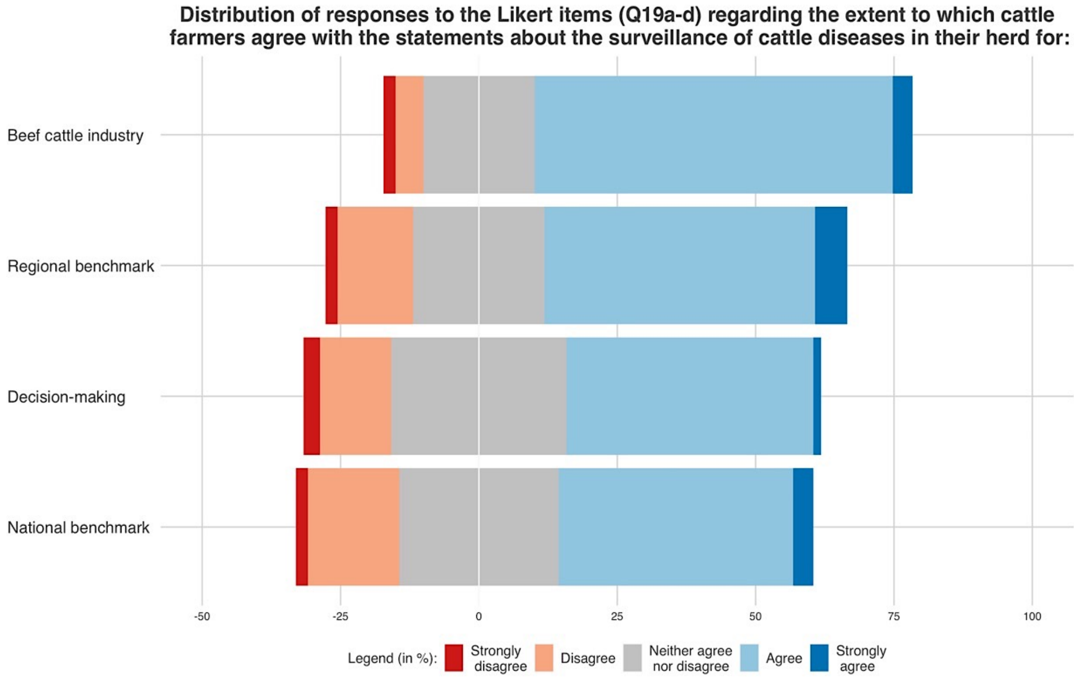


Figure 5-15: Distribution of responses to Likert items: Please indicate the extent to which you agree with the following statements about the surveillance of cattle diseases diagnosed in your herd: (a) 'I believe a summary of cattle diseases from a national surveillance system would help me with decision-making on my farm'; (b) 'I believe a summary of cattle diseases from a national surveillance system would be useful for the beef industry.'; (c) 'I believe comparing my own herd average with a regional average would be useful for me.'; (d) 'I believe comparing my own herd average with a national average would be useful for me.' (Q19a-d)

Table 5-16: Mean ranks for the four Likert items on the usefulness of surveillance of clinical signs and diseases in cattle

Usefulness for	Mean ranks for surveillance of clinical signs[a]	Mean ranks for surveillance of sheep diseases[b]
Beef cattle industry	2.85	2.86
Regional benchmark	2.50	2.55
Decision-making	2.37	2.25
National benchmark	2.28	2.34

[a]: Friedman test indicated significant differences ($\chi^2 = 30.5$, df = 3, $p < 0.01$); [b]: Friedman test indicated significant differences ($\chi^2 = 47.0$, df = 3, $p < 0.01$)

5.3.2.4 On-farm monitoring of clinical signs in beef cattle

Most farmers (strongly) agreed the benchmarking of pneumonia to be useful both on a regional (by 66.9% of respondents) and a national level (by 69.8% of respondents). With regard to national benchmarking, 51.0% of participants (strongly) agreed deaths on-farm would be useful to monitor. However, contrary to the sheep respondents, the majority of cattle farmers did not consider that the remaining clinical signs would be useful to monitor on either a regional or national level. An overview of the distribution of the answers is provided in Figure 5-16 and Figure 5-17.

Benchmarking of pneumonia was scored significantly higher than culls (p = 0.043) on a national level and for mastitis both on a national (p = 0.03) or on a regional level (p = 0.041). Pairwise comparisons of national versus regional surveillance outputs per clinical sign showed that surveillance of abortion was scored higher on a regional than on a national level (Table 5-17).

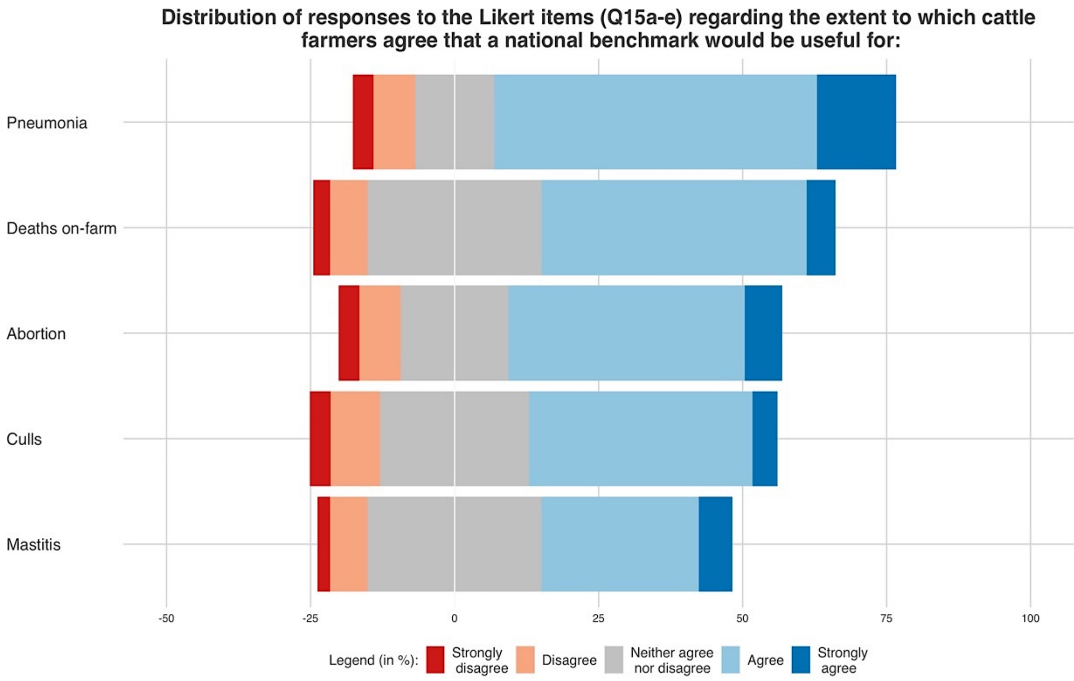


Figure 5-16: Distribution of responses to Likert items: Please indicate the extent to which you agree that a national benchmark on the clinical signs in cattle listed would be useful to you as a cattle farmer: (a) 'abortions'; (b) 'pneumonia'; (c) 'mastitis'; (d) 'deaths on-farm'; (e) 'culls' (Q15a-e)

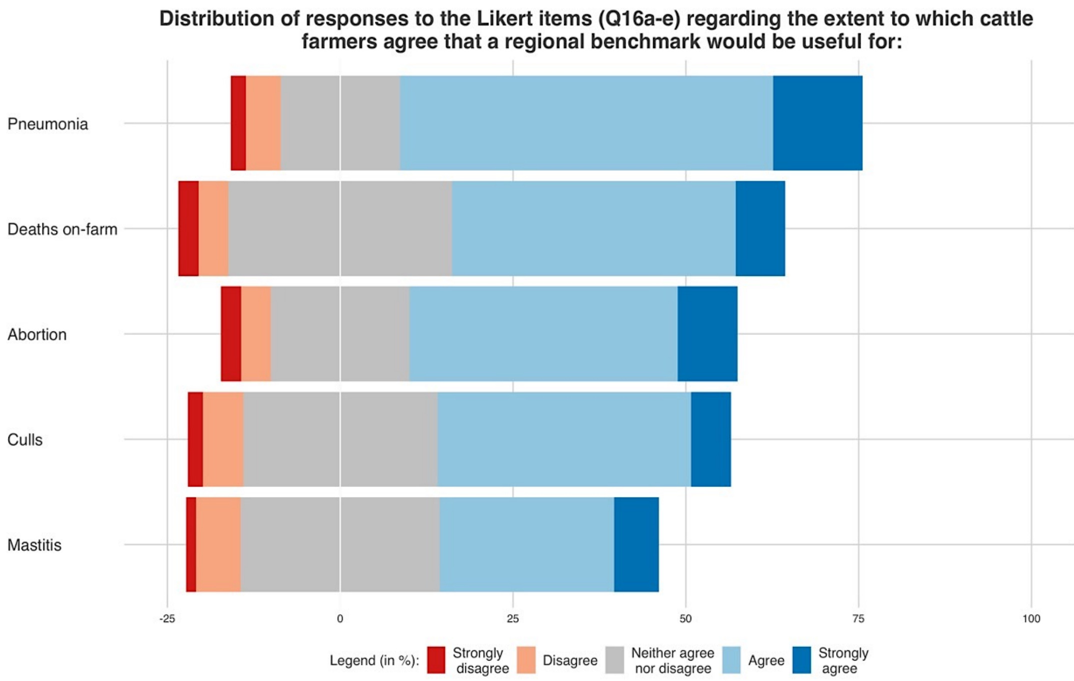


Figure 5-17: Distribution of responses to Likert items: Please indicate the extent to which you agree that a regional benchmark on the clinical signs in cattle listed would be useful to you as a cattle farmer: (a) 'abortions'; (b) 'pneumonia'; (c) 'mastitis'; (d) 'deaths on-farm'; (e) 'culls' (Q16a-e)

Table 5-17: Mean ranks for answers to the Likert items on the usefulness of surveillance of five clinical signs in cattle

Clinical sign	Mean ranks for national benchmark[a]	Mean ranks for regional benchmark[b]	Differences between national and regional mean rank ($p < 0.05$)
Pneumonia	3.41	3.37	.
Abortion	3.10	3.13	Z = -1.976, p = 0.048
Deaths on-farm	2.97	2.92	.
Culls	2.77	2.87	.
Mastitis	2.75	2.71	.

[a]: Friedman test indicated significant differences (χ^2 = 31.6, df = 4, p < 0.01); [b]: Friedman test indicated significant differences (χ^2 = 34.7, df = 4, p < 0.01)

Apart from the five clinical signs listed in the questionnaire, no additional clinical signs were identified by farmers that would be useful to monitor. One respondent defined feed cost and veterinary cost as additional non-specific indicators that would be useful to monitor in a surveillance system.

5.3.2.5 Surveillance of cattle diseases diagnosed on-farm

The usefulness of surveillance of a regional and national benchmark was considered by respondents for five cattle diseases: (i) Johne's disease, (ii) bTB, (iii) leptospirosis, (iv) BVD, and

(v) fasciolosis. With regard to bTB, 63.3% of respondents (strongly) agreed a national benchmark would be useful, for BVD this was 62.6%, for fasciolosis 61.8%, and for Johne's disease 57.6% of farmers. For leptospirosis, only 48.9% of farmers (strongly) agreed a national benchmark would be useful. The distribution of the respondents' answers is presented in Figure 5-18.

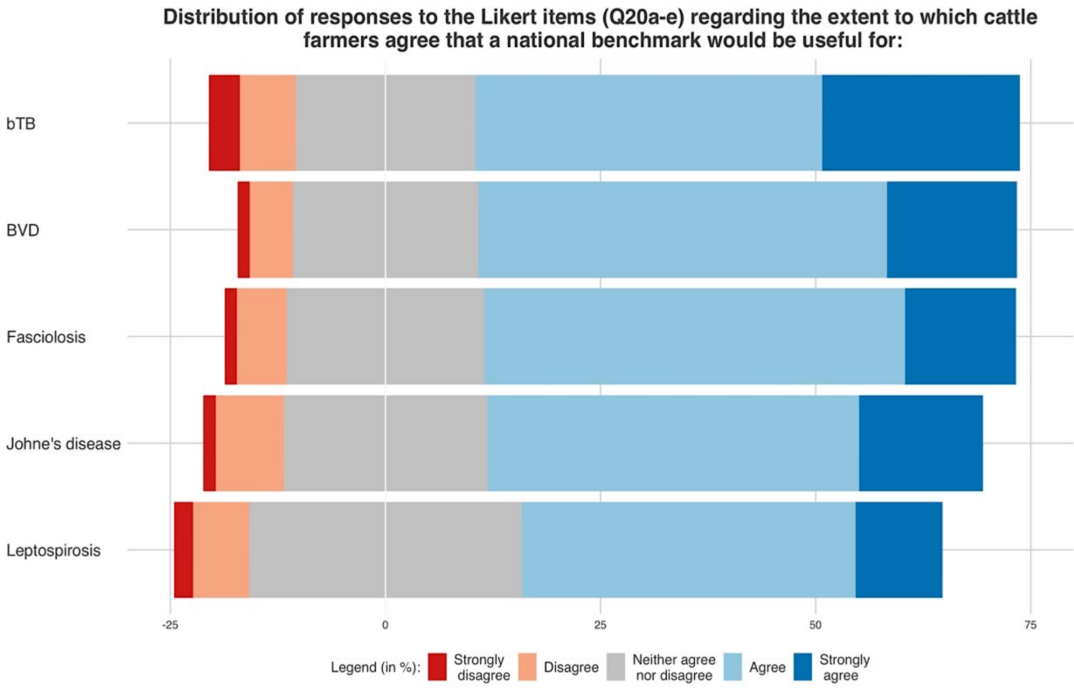


Figure 5-18: Distribution of responses to Likert items: Please indicate the extent to which you agree that a national benchmark on the cattle diseases listed would be useful to you as a cattle farmer: (a) 'Johne's disease', (b) 'bTB', (c) 'leptospirosis', (d) 'BVD', (e) 'liver fluke' (Q20a-e)

Most farmers (strongly) agreed a regional benchmark would be useful for bTB (72.0%), fasciolosis (67.6%), BVD (66.9%), Johne's disease (64.7%), and leptospirosis (57.5%). The distribution of the respondents' answers is presented in Figure 5-19.

According to the respondents, the surveillance of cattle diseases would be more useful on a regional level than on a national level for all diseases except BVD (Table 5-18).

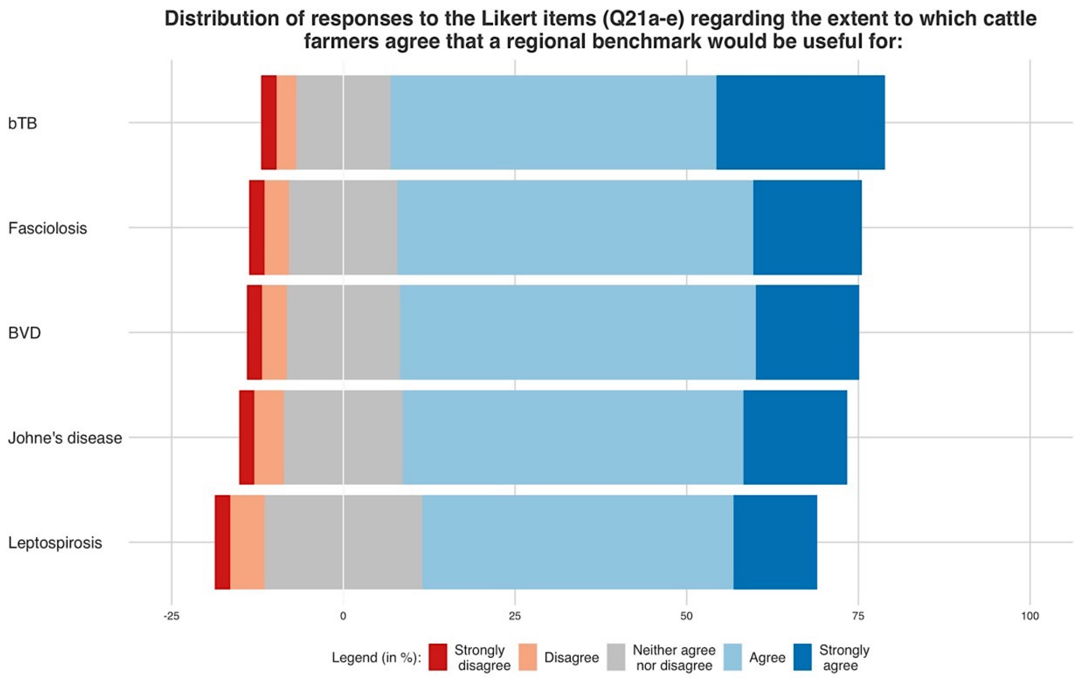


Figure 5-19: Distribution of responses to Likert items: Please indicate the extent to which you agree that a regional benchmark on the cattle diseases listed would be useful to you as a cattle farmer: (a) 'Johne's disease', (b) 'bTB', (c) 'leptospirosis', (d) 'BVD', (e) 'liver fluke' (Q21a-e)

Table 5-18: Mean ranks for answers to the Likert items on the usefulness of surveillance of five cattle diseases

Cattle disease	Mean ranks for national benchmark	Mean ranks for regional benchmark	Differences between national and regional mean rank ($p < 0.05$)
bTB	3.20	3.27	Z = -2.535, p = 0.011
BVD	3.13	3.02	.
Johne's disease	3.00	2.96	Z = -2.029, p = 0.042
Fasciolosis	2.96	3.02	Z = -2.521, p = 0.012
Leptospirosis	2.70	2.73	Z = -2.059, p = 0.040

Respondents indicated whether any of the five cattle diseases listed were diagnosed or suspected in their herds in 2017. Fasciolosis was the disease with the highest reported frequency (59/134 or 42.4%), followed by Johne's disease (32/134 or 23.0%), BVD (26/133 or 18.7%), bTB (23/132 or 16.5%), and leptospirosis (8/132 or 5.8%). This indicated that respondents considered the diseases they encountered most frequently on-farm were the most useful to monitor in a surveillance system.

Infectious bovine rhinotracheitis was mentioned as an additional disease of interest to cattle farmers. Other diseases considered were neosporosis, gastro-intestinal parasites, and foot problems.

5.3.2.6 The use of outputs from a surveillance system for cattle health

Similar to what was described in paragraph 3.1.6, individual cattle farmers indicated the extent to which they agreed with statements about the use of feedback from a surveillance system for cattle diseases. The distributions of responses for all nine Likert items are presented in Figure 5-20.

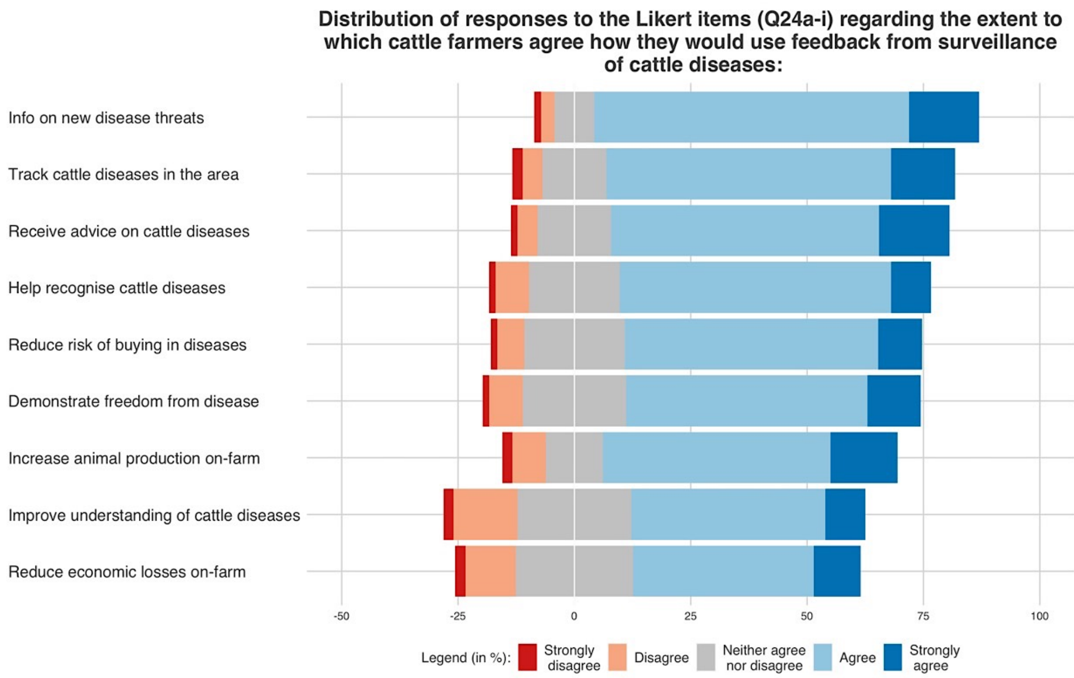


Figure 5-20: Distribution of responses to the Likert items: Please indicate the extent to which you agree with the following statements about the use of feedback from a surveillance system with advice on the presence of cattle diseases: (a) 'I would use feedback to help recognise cattle diseases myself'; (b) 'I would use feedback to reduce the risk of buying in diseases'; (c) 'I would use feedback to track cattle diseases in my area'; (d) 'I would use feedback to help me plan how to reduce economic losses on my farm'; (e) 'I would use feedback to help me plan how to increase animal production on my farm'; (f) 'I would use information to advertise that my herd is free of certain specific diseases'; (g) 'I would use feedback to improve my understanding of cattle diseases'; (h) 'I would use feedback to stay informed of new disease threats'; (i) 'I would find it interesting to receive advice on cattle diseases from a surveillance system' (Q24a-i)

Info on new disease threats was the most useful purpose individual farmers would use feedback for and scored significantly higher than increase animal production ($p < 0.01$) and demonstrate freedom from disease ($p = 0.028$) (Table 5-19).

Table 5-19: Mean ranks for answers to the Likert items on the use of feedback from a surveillance system with advice on the presence of cattle diseases

Use of feedback from a surveillance system	Mean rank[a]
Info on new disease threats	5.70
Improving understanding of sheep diseases	5.39
Receive advice on sheep diseases	5.33
Reduce risk of buying in diseases	5.27
Reduce economic losses	5.04
Track sheep diseases in the area	4.96
Help recognise sheep diseases	4.73
Demonstrate freedom from diseases	4.41
Increase animal production	4.18

[a]: Friedman test indicated significant differences (χ^2 = 60.7, df = 8, $p < 0.01$)

5.3.2.7 Predicting farmers' willingness to contribute data to a surveillance system for cattle health: logistic regression

5.3.2.7.1 Farmers' willingness to contribute to a surveillance system for cattle health

Beef farmers were asked whether they would be prepared to provide data recorded on their own cattle and fund a farmer-driven surveillance system. Table 5-20 provides a breakdown of responses to the questions on their willingness to contribute to a surveillance system for the monitoring of clinical signs and/or a system monitoring cattle diseases.

Some respondents who answered 'maybe' elaborated on the reasons behind their choice. The reasons from the cattle farmers could be grouped into the same 4 categories as for the sheep farmers: (i) financial restraints, (ii) confidentiality and data protection, (iii) time and effort required from farmers, (iv) relevance of information for the farmer.

Reasons for respondents not to contribute data revolved around 3 major topics: (i) surveillance would be too expensive, (ii) additional time and paperwork required, and (iii) confidentiality and data protection. Financial restraints were also the main reason why respondents were not willing to pay for surveillance.

Table 5-20: Distribution of respondents' willingness to contribute data and fund a surveillance system for the monitoring clinical signs or surveillance of cattle diseases

Contributing to surveillance	Clinical signs		Specific diseases	
	n	%	n	%
No	49	35.3	87	62.6
Maybe	51	36.7	38	27.3
Yes	34	24.5	9	6.5
Not responded	5	3.6	5	3.6
Total	*139*	*100.0*	*139*	*100.0*
Prepared to pay?	**Clinical signs**		**Specific diseases**	
	n	%	n	%
No	87	62.6	45	32.4
Maybe	38	27.3	43	30.9
Yes	9	6.5	45	32.4
Not responded	5	3.6	6	4.3
Total	*139*	*100.0*	*139*	*100.0*

5.3.2.7.2 Preparation of data: Principal Component Analysis (PCA)

5.3.2.7.2.1 Missing values: imputation through Expectation Maximization (EM)

As described in paragraph 5.3.1.7.2.1, the pattern of missing data was assessed. Little's MCAR test did not generate p-values lower than 0.05, which means data was missing completely at random. Subsequently, EM was used as for the imputation of data.

5.3.2.7.2.2 Assessing if the sample size is sufficient for PCA

The value of the KMO test was 0.9 and Bartlett's sphericity test was significant ($\chi^2 = 5207.6$, df = 435, $p < 0.01$), indicating that the variables investigated were correlated and PCA was appropriate.

5.3.2.7.2.3 Correlation and multicollinearity

Variables with more than one correlation coefficient below 0.3 were excluded: the Likert items measuring (i) the usefulness of surveillance of cattle diseases for the beef cattle industry, (ii) the usefulness of national benchmarks for abortion, pneumonia, mastitis and deaths on-farm,

(iii) the usefulness of a national benchmark for fasciolosis, and (iv) the increase of animal production on-farm were all excluded from further analysis. Thirty variables were retained.

5.3.2.7.2.4 Extraction of principal components (PCs): Kaiser criterion, Scree plot and parallel analysis

Based on the Kaiser criterion only (i.e. Eigenvalue > 1), five components should be retained. Still, parallel analysis showed that only two PCs should be retained. The scree plot indicated that four PCs should be kept (Figure 5-21). Finally, four PCs were retained, accounting for 75.4% of the total variance (Table 5-21).

Table 5-21: Principal components extracted with Eigenvalues attributed and percentage of variance explained by the PCs – cattle farmers

Principal components	Eigenvalues	Variance (%)
PC1: Cattle diseases (+ Regional benchmark)	17.60	58.7
PC2: Use of feedback by farmers	2.04	6.8
PC3: Clinical signs	1.60	5.3
PC4: Usefulness of surveillance	1.39	4.6

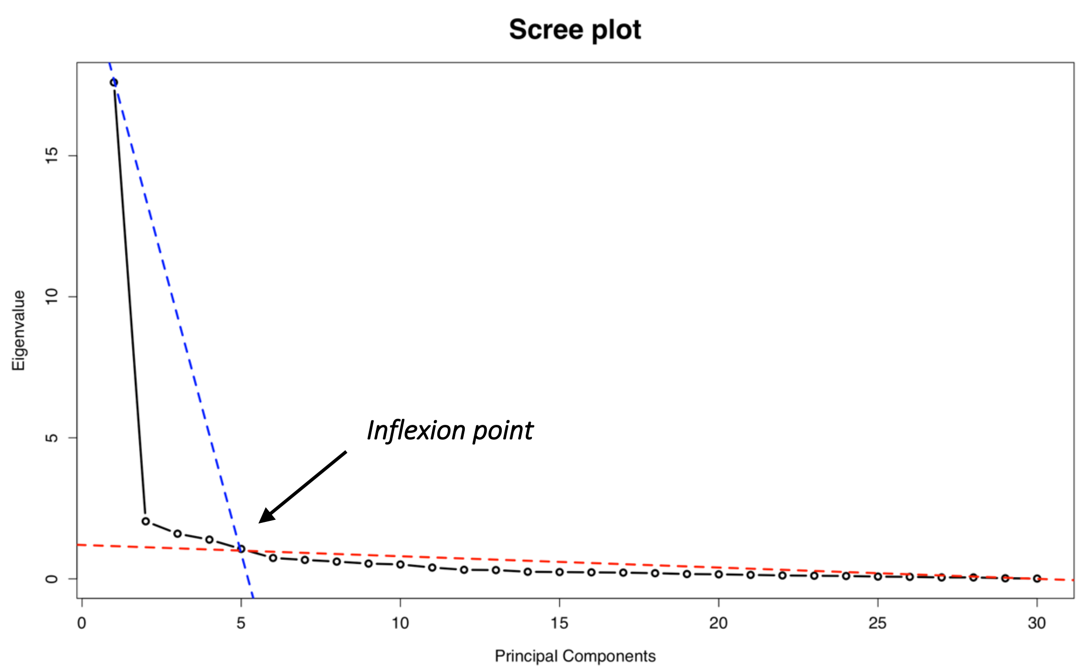


Figure 5-21: The inflexion point on the scree plot suggested four PCs should be retained from the PCA (beef cattle farmer questionnaire)

5.3.2.7.2.5 Loadings and component scores

Oblique (Promax) rotation was used to improve the visualisation and interpretability of the PCs. All 30 variables loaded highly onto one component. Two variables loaded onto two different PCs. However, the difference between the two loadings was higher than 0.2, so both variables were retained and the highest loading PC was used (Appendix 5-9).

All variables concerning (i) the usefulness of the selected diseases and a regional benchmark loaded onto PC1, (ii) the variables on how individual farmers would use outputs from a surveillance system loaded onto PC2, (iii) the variables on the usefulness of the different clinical signs onto PC3, and (iv) the usefulness of surveillance for decision-making, industry and national benchmarking loaded onto PC4. Cronbach's alpha and inter-item correlations (i:i) indicated a high reliability for the PCA. After PCA, multicollinearity was eliminated from the dataset. Table 5-22 presents the newly assembled correlation matrix for the four components. Component score coefficients were calculated per variable and component. The score coefficients were used for further regression analysis.

Table 5-22: Reliability of Likert items loading onto Principal Components using Cronbach's alpha and mean inter-item (i:i) correlations, and the component correlation matrix after PCA - cattle farmers

PC	α	i:i	PC1	PC2	PC3	PC4
PC1	0.960	0.712	1			
PC2	0.943	0.680	0.686	1		
PC3	0.949	0.760	0.682	0.598	1	
PC4	0.902	0.605	0.611	0.582	0.550	1

5.3.2.7.3 Binary logistic regression to assess the willingness of farmers to contribute to a surveillance system for cattle health

5.3.2.7.3.1 Predictors and the outcome variable

The willingness of farmers to contribute data for a surveillance system monitoring clinical signs and cattle diseases was used as the outcome variable for the logistic regression: '0' was used for farmers who did not want to provide data and '1' for farmers who might be found willing to participate ('yes' and 'maybe'). Ninety-five (68.3%) cattle farmers who completed the postal questionnaire indicated they might be willing to contribute data they recorded to a surveillance system for cattle health by answering 'Yes' or 'Maybe' to the questions (Table 5-

23). Another 42 (30.2%) respondents said they would not be willing to submit data for a surveillance system. Two (1.4%) respondents did not fill in the questions.

Table 5-23: Farmers' willingness to contribute to surveillance of clinical signs and/or cattle diseases

Contributing to surveillance?	Number of respondents	
	n	%
No (= '0')	42	30.2
Yes (= '1')	95	68.3
Total	*137*	*98.6*

Predictors evaluated for inclusion in the logistic model were the same as for the sheep farmers questionnaire (i) region where the farm was located, (ii) membership of the BRP ('0' = 'no', '1' = 'yes'), (iii) species farmed ('0' = 'cattle, '1' = 'sheep + cattle'), (iv) enterprise ('0' = 'no suckler herd', '1' = 'suckler herd', (v) total herd size, (vi) membership of a health scheme ('0' = 'no', '1' = 'yes'), (vii) recording of animal or production data in 2017 ('0' = 'no', '1' = 'yes'), and (viii) the four PCs extracted through PCA.

5.3.2.7.3.2 Univariable regression models

Univariable logistic regression was carried out as described in paragraph 3.1.7.3.2. Five of the variables were significant predictors (i.e. $p < 0.05$) for contribution to a surveillance system for cattle health (Table 5-24).

Table 5-24: Univariable logistic regression models for the prediction of cattle farmers' willingness to contribute to a surveillance system for cattle health

Predictor	p-value	OR	95% C.I.	
			Lower	Upper
Recording in '17	< 0.01	4.42	2.06	9.51
PC1	< 0.01	2.02	1.34	3.04
PC2	< 0.01	2.64	1.64	4.26
PC3	< 0.01	1.80	1.21	2.67
PC4	< 0.01	2.39	1.56	3.64

Farmers who recorded data on their herds in 2017 were more likely to be interested in participating in a surveillance system (OR = 4.42). No other categorical predictors were found to be significant.

All four PCs were significant predictors, which means that respondents were more likely to be willing to contribute to a surveillance system if they agreed that (i) 'surveillance of cattle diseases and particularly a regional benchmark would be useful' (PC1) (OR = 2.02), (ii) 'I would use feedback from a surveillance system' (PC2) (OR = 2.64), (iii) 'surveillance of clinical signs would be useful' (PC3) (OR = 1.80), or (iv) 'surveillance of cattle health is useful for decision-making, the beef cattle industry, or benchmarking' (PC4) (OR = 2.39).

5.3.2.7.3.3 The final multivariable model

The same approach to build the model was used as described in paragraph 3.1.7.3.3. Significant predictors ($p < 0.05$) were kept in the final model with the outcome variable being the willingness to contribute data to a surveillance system (Table 5-25). Two predictors were included in the final model: (i) recording in 2017 (OR = 4.07), and (ii) 'I would use the outputs from a surveillance system' (PC2) (OR = 2.60).

The correct classification improved from 68.3% for the null model to 75.5% for the final model. Overdispersion was not present in the final model as indicated by the deviance (value/df = 1.043) and Pearson Chi-square (value/df = 1.131).

Table 5-25: Final multivariable logistic regression model for the prediction of cattle farmers' willingness to contribute to a surveillance system for cattle health

Predictor	b	p-value	OR	95% C.I.	
				Lower	Upper
Recording in '17	1.403	< 0.01	4.07	1.78	9.30
PC2	0.956	< 0.01	2.60	1.57	4.31
(Constant)	(0.169)	(0.542)	(1.18)		

The LRT of the null model was 173.577 and the LRT of the final model was significantly lower at 139.728, indicating that the final model fit significantly better than the null model. The Hosmer and Lemeshow test was not significant ($p = 0.066$) which indicates a good fit of the model. The evaluation of the standardised residuals indicated that the final multivariable model was a good fit. The AUC of the ROC curve was 0.775 or 77.5% for the final model. No significant improvements ($p > 0.05$) were found adding or omitting other predictors into the model.

Since recording in '17 was identified as a significant predictor in the final multivariable model, it was assessed for the respondents who had recorded data in 2017 whether there were associations between their willingness to contribute data to a surveillance system and (i) the type of data recorded (i.e. production data, clinical signs and/or diseases diagnosed), (ii) how data were recorded (paper or electronic), (iii) whether respondents used the data for decision-making on-farm in 2017, and (iv) whether they shared the data they had recorded on-farm in 2017.

The only variable that was a significant predictor for cattle farmers was whether they had shared the data they had collected in 2017 (p = 0.029, OR = 5.69, 95% C.I. = 1.159 – 27.921). This result indicates that respondents who had shared their data with third parties were 5.69 times as likely to be willing to contribute as respondents who had not shared data.

Although recording in '17 was a predictor in the final model for sheep respondents as well, sharing data in 2017 was not significantly associated with the willingness to contribute data to a surveillance system for the sheep respondents who had recorded data in 2017.

5.3.2.8 Other useful data sources for surveillance according to beef cattle farmers

Farmers indicated to which extent they agreed that (i) abattoirs, (ii) post-mortem examiners, (iii) diagnostic laboratories, (iv) health schemes, and (v) veterinarians had data that could be useful for animal health surveillance (Figure 5-22).

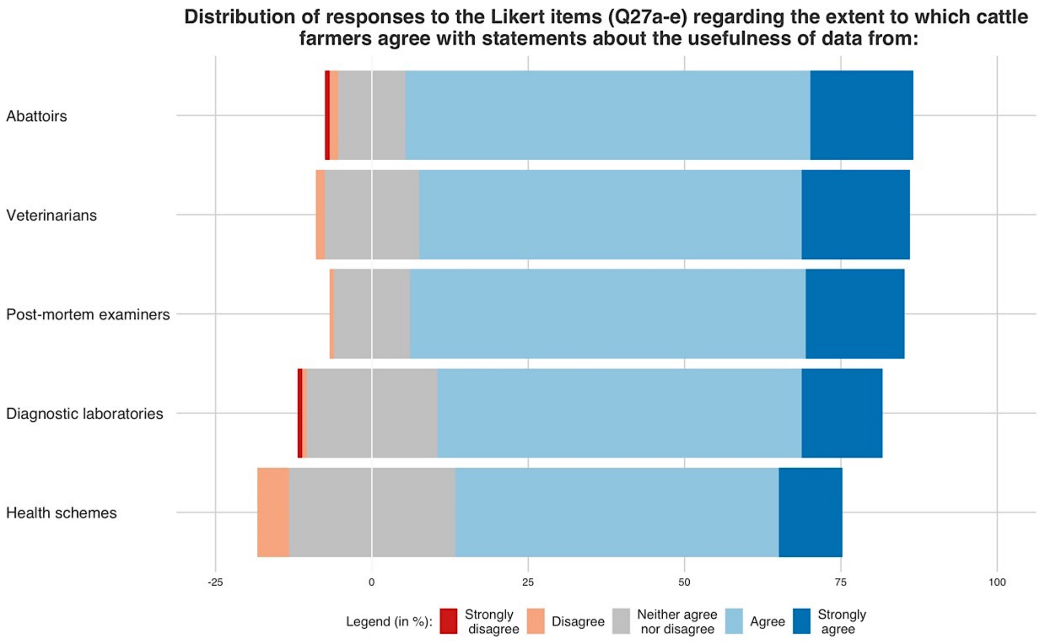


Figure 5-22: Distribution of responses to the Likert items: Please indicate the extent to which you agree with the following statements about the usefulness of data from the sources listed for surveillance of cattle health: (a) 'I believe abattoirs collect useful health data on cattle'; (b) 'I believe post-mortem examiners collect useful health data on cattle'; (c) 'I believe diagnostic laboratories collect useful health data on cattle'; (d) 'I believe health schemes collect useful health data on cattle'; (e) 'I believe vets collect useful health data on cattle' (Q27a-e)

Respondents scored health schemes significantly lower compared than abattoirs (p = 0.043) and post mortem examiners (p = 0.024) with regard to useful data owned (Table 5-26).

Table 5-26: Mean ranks for answers to the Likert items on the usefulness of data collected by other sources and the feedback sheep farmers received in 2017

Data source	Mean ranks for data on sheep health from third parties[a]	Mean ranks for feedback received in 2017[b]
Post mortem examiners	3.20	2.86
Veterinarians	3.15	3.78
Diagnostic laboratories	2.90	2.81
Abattoirs	3.16	3.06
Health schemes	2.59	2.49

[a]: Friedman test indicated significant differences (χ^2 = 32.6, df = 4, p < 0.01); [b]: Friedman test indicated significant differences (χ^2 = 25.3, df = 4, p < 0.01)

Only 39/139 (28.1%) participants contributed data for all five Likert items considering if they had received useful information from (i) abattoirs, (ii) veterinarians, (iii) diagnostic laboratories, (iv) post-mortem examiners, and (v) health schemes in 2017 (Figure 5-23). Similar to the result from sheep farmers, veterinarians provided significantly more useful information to cattle farmers than health schemes (p < 0.01) (Table 5-26).

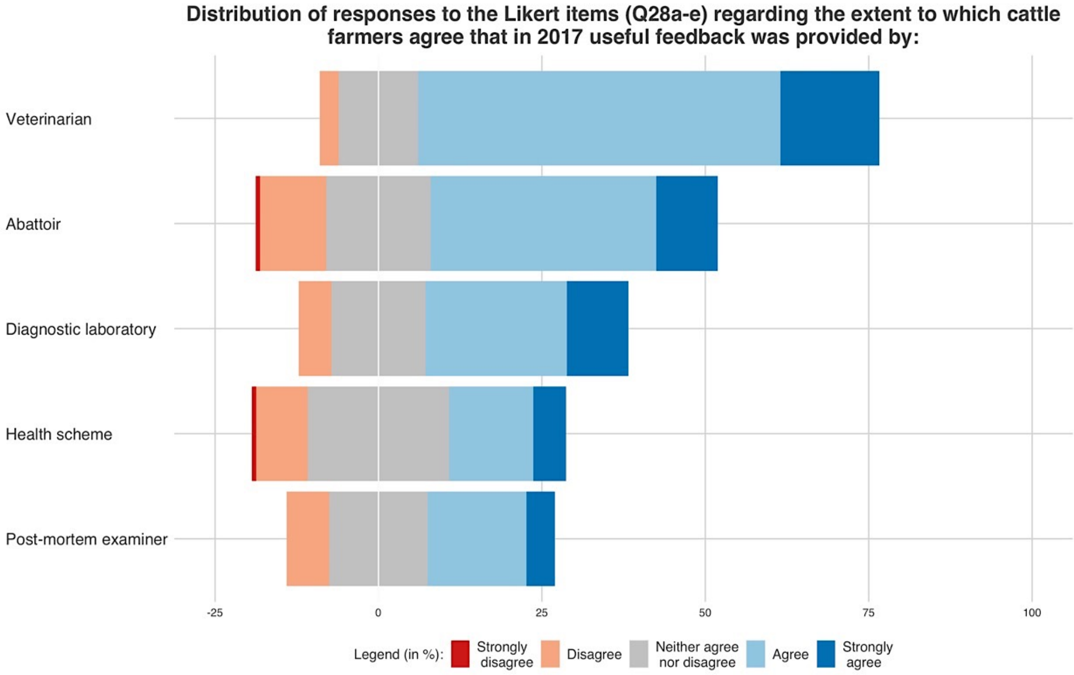


Figure 5-23: Distribution of responses to the Likert items: Please indicate the extent to which you agree with the following statements on who provided useful feedback to you on cattle health in 2017: (a) 'I received useful feedback from the abattoir'; (b) 'I received useful feedback from post-mortem examiners'; (c) 'I received useful feedback from a diagnostic laboratory'; (d) 'I received useful feedback from my health scheme'; (e) 'I received useful feedback from my veterinarian' (Q28a-e)

Farmers indicated the desirability of feedback via four different channels (Figure 5-24). Significant differences in mean ranks for (i) a webpage (mean rank = 2.62), (ii) email (mean rank = 2.90), (iii) a mobile app (mean rank = 1.98), and (iv) paper leaflets (mean rank = 2.49) were found (χ^2 = 37.5, df = 3, p < 0.01). A mobile app was scored significantly lower than email (p < 0.01), paper leaflets (p = 0.042), and a webpage (p < 0.01).

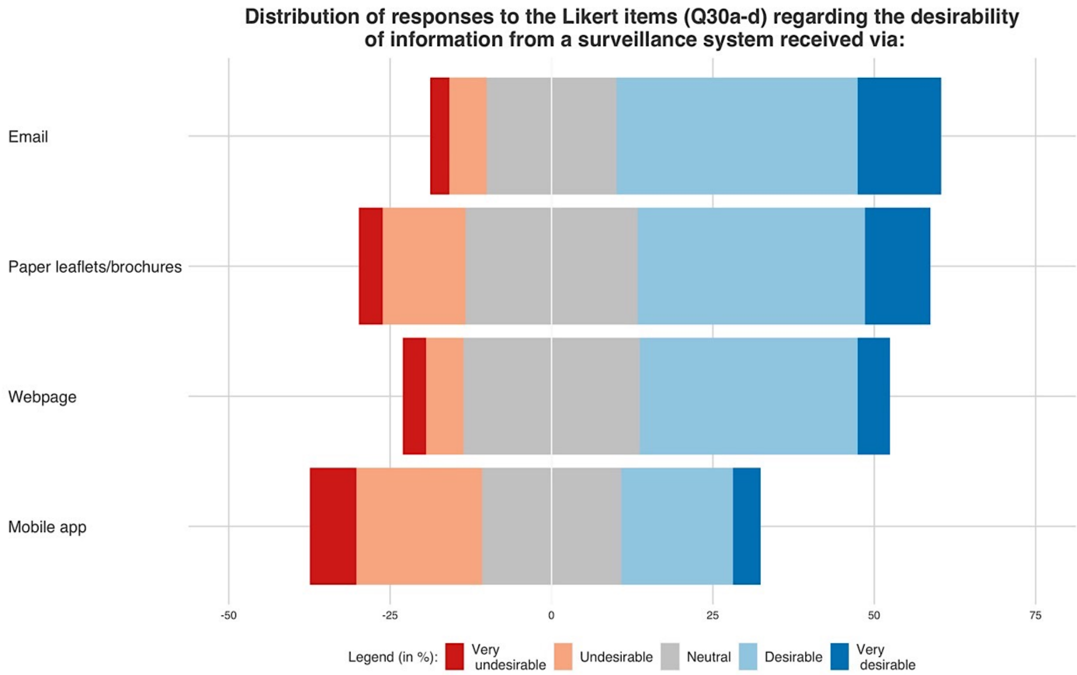


Figure 5-24: Distribution of responses to the Likert items: Ideally, how would you like to receive information on cattle health to help you with decision-making on your farm?: (a) 'Online webpage'; (b) 'Reports via email'; (c) 'Reports via mobile app'; (d) 'Paper leaflets or brochures' (Q30a-d)

5.4 Discussion

5.4.1 The willingness to contribute to a farmer-driven surveillance system: sheep farmers, beef cattle farmers and their behaviour

The percentages of farmers who might be willing to contribute to animal health surveillance were very equal with 67.2% of sheep and 68.3% of beef cattle farmers. The most remarkable difference was that only 6.5% of beef farmers confirmed (i.e. answered 'yes') they would want to provide data on specific diseases compared to 31.7% of sheep farmers. However, 32.4% of beef farmers said 'yes' when asked if they would be willing to pay for a farmer-driven surveillance system for specific diseases. This adds to what was previously reported for the focus group discussions: farmers would like to know about the diseases in their neighbours' flock/herd, but many participants were hesitant to share their own data with others.

As previously hypothesised in Chapter 3, the logistic regression models showed that both sheep and beef cattle farmers who had recorded health data on their livestock in 2017 would be more willing to contribute to a surveillance system. Farmers' attitudes are shaped by e.g. knowledge, empathy and motivation, and therefore can affect behaviour and decision-making (Edwards-Jones, 2006).

Enterprise type was a significant predictor for the willingness of sheep farmers to contribute data to a surveillance system: participants with pedigree flocks were more willing to participate in a surveillance system than commercial farmers (Chapter 3). However, a similar result for cattle farmers with suckler compared to non-suckler herds (Chapter 3), but neither univariable nor multivariable logistic regression showed beef enterprise type to be a significant predictor.

Flock health scheme membership was a significant predictor for the willingness to contribute to surveillance in a univariable logistic model, however no significant difference ($p > 0.05$) was found when the variable was added into the final multivariable model. Moreover, membership of a herd health scheme for cattle was not a significant predictor in either a univariable or multivariable model for the willingness to contribute to a surveillance system for beef cattle farmers, contrary to what was suggested previously by Gilbert *et al.* (2014). However, it should be noted that 15/20 (75.0%) of respondents in their study from farmed dairy cattle, whereas the current study was targeted at beef farmers. It could therefore be hypothesised that the behaviour between beef and dairy farmers differs on other predictors as well. However, since only beef farmers were targeted in our study, there was no possibility to test this hypothesis within the scope of this project.

Sustaining a farmer-driven surveillance system would also require sustaining disease awareness, which is affected by the characteristics of the specific diseases that are targeted as well as the recent history of the disease in a certain country or area, since farmers are more likely to be aware and thus concerned about diseases they had already experienced on their farm in the past or were more aware of (Hadorn and Stärk, 2008; Hadorn *et al.*, 2008).

The results from the questionnaire confirmed that it would be difficult to get farmers to actively contribute data voluntarily, particularly when data would need to be submitted electronically such as by means of electronic questionnaires (Elbers *et al*., 2008; Elbers *et al*., 2010) or as reported for the online monitoring tool for blowfly strike (Tongue *et al.*, 2017). Aside from incentives to increase participation, factors were identified that might prevent farmers from contributing, such as the perceived high cost of disease surveillance that was most frequently identified as an obstacle. This was particularly true for participants with only small flocks/herds. Therefore, to ensure a surveillance system for sheep and beef cattle health would be sustainable and provide useful information for farmers, the system should rely on other data sources such as laboratory test data, abattoir findings or post-mortem examinations rather than active reporting by livestock farmers.

5.4.2 Alternatives to data collection by farmers

The current study investigated which data sources respondents believed possessed useful data for animal health surveillance. Veterinarians, and diagnostic and post mortem laboratories were considered to have the most useful data on animal health. These sources could provide alternatives to data collection from sheep and beef farmers. Cattle farmers indicated that abattoirs would be useful data sources as well, while the sheep farmers considered abattoirs to be less useful. This might be partially explained by sheep farmers indicating they did not receive accurate feedback or any feedback from abattoirs.

In the past two decades, many initiatives have been launched where the reliability and feasibility of (syndromic) surveillance based on routinely collected data have been assessed: e.g. abortions (Carpenter *et al*., 2007), auction market data (Van Metre *et al.*, 2009), milk production indicators (Madouasse *et al*., 2013), laboratory test requests (Dórea *et al*., 2014), and abattoir condemnation data (Vial and Reist, 2015). These datasets were assessed and have been shown to have potential for animal health surveillance, more specifically with regard to syndromic surveillance (Dórea *et al*., 2011; Hoinville *et al*., 2013; Dupuy *et al*., 2013a). From the current study, it could be concluded that respondents considered that analysis of data from third parties could provide useful information to sheep and beef cattle farmers.

5.4.3 The aim and purpose of a surveillance system for sheep and beef cattle health

The use of surveillance outputs to (i) keep informed about new threats (e.g. the emergence of Bluetongue and Schmallenberg viruses in recent years), (ii) generate advice for the individual farmer, and (iii) reduce the risk of buying in diseased animals suggested that the most important aim of a surveillance system was to aid in prevention and timely intervention, preferably before the disease is introduced to an individual flock or herd.

Sheep scab and EAE were the most useful diseases to benchmark both nationally and regionally. These were also the diseases most frequently seen in 2017 and 2018 by farmers (Chapter 4). Previous research identified EAE and sheep scab as some of the most important threats to sheep health and welfare (Bennett and Ijpelaar, 2003; Nieuwhof and Bishop, 2005).

The results from the current study suggest that iceberg diseases had a lower prevalence and were considered less useful to monitor. An explanation might be that farmers are often not aware of their presence and therefore also are unaware of the production losses caused by these diseases (Sergeant, 2001; Daniels *et al*., 2002). Iceberg diseases were identified as important by the focus group participants, who often considered themselves to be progressive farmers. This might also contribute to the findings presented in this chapter that Johne's disease, CLA and Maedi-Visna scored lower: the more 'average' farmer is less aware about these diseases than the progressive farmers (Chapter 3).

In cattle, fasciolosis, bTB and BVD were most frequently identified in 2017 and 2018 through the questionnaire on disease presence (Chapter 4). For bTB and BVD, high profile surveillance initiatives are already in place, such as the mandatory control programme for bTB carried out by APHA or the BVDFree scheme (Anonymous, 2019) that was launched in 2016. Bronner *et al*. (2014) found that most farmers were less concerned about diseases for which the probability of an outbreak occurring is considered very low (e.g. brucellosis).

In this chapter, it was assessed if disease surveillance would be more valuable for farmers than syndromic surveillance of non-specific clinical signs (Chapter 3). In general, surveillance of clinical signs or sheep and cattle diseases was thought to be most useful for the industry according to sheep and beef respondents. Remarkably, the questionnaire results showed that, contrary to what focus group participants expressed, both sheep and beef cattle farmers considered that the ability for benchmarking clinical signs would be more useful than specific diseases for decision-making by the farmers. This highlights the finding that not every farmer is interested in the same information (Chapter 3). Moreover, this implies that it is very difficult to design a surveillance system that would provide useful outputs for all sheep and beef cattle farmers.

5.4.4 Considering sheep and beef farmers' opinions for the development of a new animal health surveillance system

The questionnaires were kept as concise as possible whilst trying to capture as much data as possible. Tick box questions and five-point Likert items were used to limit the time required from respondents to complete the questionnaire, although there was ample space provided for farmers if they wanted to raise additional answers or opinions. Participants in the focus group discussions for sheep and beef farmers indicated that a surveillance system for animal health where data collection relied on farmers' willingness to contribute data should produce useful and relevant feedback (Chapter 3). It was important to take the users' (i.e. the farmers') needs into account. Therefore, the questionnaires presented in both Chapter 4 and the current chapter were developed with regard to the results from the focus groups.

Similar to the outputs of the focus group discussions (Chapter 3), through this questionnaire confidentiality and anonymity were confirmed to be areas of concern through. Since collecting personal identifier information from farmers could not only reduce the number of farmers willing to complete the questionnaire, an additional issue that could arise is that respondents might provide answers that they believed researchers or the public in general would want to hear, thus introducing social desirability bias into the dataset (O'Kane *et al*., 2017; Gilbert *et al*., 2014; Raut *et al.*, 2018). By offering farmers the possibility to complete the questionnaire anonymously, it was attempted to prevent social desirability bias and to reduce the fear of acquiring the reputation of bad farmer in case a disease was diagnosed in their livestock.

When attempting to improve farmers' attitudes and uptake towards the usefulness of general disease surveillance, both the provider and the content of the feedback need to be considered as reliable and trustworthy by the farmer. Trust issues can originate from a perceived lack of power by the individual farmer (Brooks *et al.*, 2017). Uptake of a surveillance system and its feedback by farmers might be improved if the advice originated from a trusted source or institution that stimulated as well as regulated co-operation by farmers (Heffernan *et al.*, 2008; Gilbert and Rushton, 2018). A lack of trust in e.g. other farmers and their ability to recognise diseases in their livestock as well as the fear of acquiring a bad reputation if a disease was to be reported might prevent farmers to contribute data to a farmer-driven surveillance system and help explain the low response percentages acquired.

5.4.5 Low response percentages from online and postal questionnaires

Online questionnaires were developed bearing in mind three key features for collection of data by farmers as identified from the focus groups, namely (i) easy and straightforward, (ii) very quick to do for the farmer, and (iii) anonymity and confidentiality should be guaranteed (Chapter 3). Nowack (1990) suggested that response percentages decrease the longer the questionnaire. Therefore, the questionnaires were designed so it would take a limited amount of time (an estimated 15 to 20 minutes) to complete.

By sending out the questionnaires late in the year, it was attempted to avoid busy periods of the year for the farmers (e.g. lambing season for sheep farmers). The invites for the online questionnaires were sent in late Summer (3rd September 2018), while the paper versions went out at the end of November 2018.

The usable response percentages for the online questionnaire on disease presence in 2017 and 2018 were 10.4% and 8.0% respectively (Chapter 4). However, for the online questionnaire presented in the current chapter, only 2.8% of sheep farmers and 2.0% of beef cattle farmers fully completed the questionnaire. It is indeed challenging to obtain high response percentages from online surveys, especially for those who rely on voluntary participation from farmers. Although an electronic (online) tool to collect data from sheep and beef cattle farmers was preferred over a postal survey by the focus group participants, it was shown in the current chapter that farmers were more likely to complete a postal questionnaire than respond to an invite to an online survey. Gargiulo *et al*. (2018) suggested that respondents to online surveys that relied on voluntary participation were more interested or better informed on the topic of the survey than non-responders.

The usable response percentages from the paper versions were markedly higher than for the online editions: 18.3% for sheep farmers and 13.9% for cattle farmers. The difference between response percentages to the online and paper versions of the questionnaire indicated that respondents might be less likely to respond to electronic requests for data. Since no farmer-specific information was collected, it could not be verified whether there were differences between farmers characteristics and if these could be linked to certain categories of farmers (e.g. older versus younger, male versus female) being more or less willing to adopt novel technologies and use electronic devices.

5.5 Conclusions, implications of the study and the use for the wider industry

Based on the low number of respondents, it was clear that developing an efficient, sustainable and voluntary surveillance system would not be feasible. However, there were farmers who would be willing to participate. As opposed to a general, voluntary farmer-driven surveillance system for all sheep and/or beef cattle farmers, sentinel surveillance might possibly offer a useful and effective alternative (McCluskey, 2003; Mubamba *et al*., 2018).

An interesting alternative to using data collected by farmers would be the use of data from other sources such as diagnostic laboratories, veterinarians or abattoirs. Further research therefore should focus on assessing the feasibility, usefulness and sustainability of surveillance based on data from third parties.

Since respondents considered regional surveillance outputs the most useful, an early warning system could provide feedback on disease spread and the introduction of new diseases in the area. This would be compliant with the finding that both sheep and beef cattle farmers scored the usefulness of surveillance outputs for the detection of new disease threats highest.

Respondents believed animal health surveillance would be most useful for the sheep and/or beef cattle industry. For example, AHDB Beef & Lamb could use the results to organise information sessions and workshops for farmers on 'hot topics', or target knowledge transfer and research into specific health problems (Chapter 3).

Chapter 6

GENERAL DISCUSSION AND FUTURE RESEARCH

6.1 Discussion and implications for farmers and the industry

The results presented in this thesis show that a surveillance system that relies on data recording and active submission by farmers of diseases or clinical signs in sheep or beef cattle is not sustainable in the near future (Chapter 3; Chapter 5). Important issues regarding surveillance included (i) farmers not wanting to collect and submit new data outside of what they already recorded because they believed that reporting into a surveillance system would require additional work that would cost them more than it would gain, (ii) progressive farmers expressing their concern that other farmers would not be willing to participate and this low interest of the average farmer could therefore also negatively affect the more progressive farmers' decision on whether to contribute (Gilbert and Rushton, 2018), and (iii) the perceived cost of developing and maintaining a surveillance system. Rather than individual farmers directly receiving outputs on the surveillance of endemic sheep and cattle diseases for decision-making, outputs were expected to be more useful for the industry, as indicated by both the participants in the focus group discussions (Chapter 3) and respondents to the questionnaire (Chapter 5).

The pilot survey on disease presence of five sheep and five cattle diseases in 2017 and 2018 (Chapter 4) was developed to assess the validity of the finding that a farmer-driven surveillance system would not be feasible and sustainable. The results of the systematic reviews (Chapter 2) and focus group interviews (Chapter 3) were used to design the questionnaire for the pilot study. The specific diseases selected for sheep and cattle were also identified through the focus group discussions and were chosen, rather than clinical signs, because the focus group participants had indicated they considered surveillance of diseases to be more useful and informative (Chapter 3). The very low response rate indicated that even a 5 minute questionnaire sent once a year would not provide data of sufficient quality or quantity for an active surveillance system.

Although the low response percentages for the pilot study strongly indicated that a farmer-driven surveillance system would not be sustainable, there were farmers who would be willing to record and submit data (Chapter 5). Therefore, sentinel surveillance where a limited but representative sample of farms serves as a sentinel for the regional or national sheep flock or (beef) cattle herd, might be an alternative and reliable type of surveillance (Chapter 3; Chapter 5). However, the pilot survey showed that sheep farmers were less likely to have suspected disease confirmed by a veterinarian or laboratory than beef cattle farmers who usually had diseases confirmed by diagnostic testing in laboratories, abattoirs (most often for fasciolosis), or their veterinarian. (Chapter 4). So, although they said they would prefer a surveillance system based on disease (Chapter 3) they might not be able to provide disease data that has been diagnostically confirmed.

In general, farmers were more positive about the use of existing data that could be used to form a surveillance system, including the data they already collect on-farm (Chapter 3; Chapter 5). This suggests that future surveillance initiatives should use data from sources other than active reporting by livestock farmers.

The results from the project presented in this thesis contribute to the understanding of farmers' opinions and behaviour towards sheep and beef cattle disease surveillance (Chapter 3, Chapter 5). Not all farmers are interested in the same information, but the outputs of the study suggest farmers would be more interested in a system that would provide information to enable them to be prepared for potential new diseases being introduced into their own flock/herd or region (e.g. early warning system for Bluetongue and other vector borne diseases when introduced into the country) and advice on how to deal with diseases (Chapter 5).

6.2 Limitations of the study

During all stages of the project, issues and challenges for the development and implementation of surveillance were identified and, where possible, accounted for in the different studies such as providing incentives to farmers to increase the chances that they would respond. For example, participation in the pilot study for disease data in 2018 was incentivised by offering farmers a summary with results from the previous year, 2017. However, the response rate for 2018 did not improve. In general, the response percentages for the studies conducted as part of the current project were low.

The low response percentages might have been affected by farmers fearing that sharing their data would have negative consequences and they were concerned that disclosure of the presence of livestock diseases on-farm would result in them being considered as bad farmers by peers or consumers.

Since not all farmers had diagnostic confirmation of the diseases they reported, the results on the prevalence reported in Chapter 4 should be interpreted with caution because the data collected in the study could be inaccurate. Farmers' limited experience with diagnosing diseases or social desirability bias are examples of factors that potentially might have led to errors in reporting.

6.3 Recommendations and future work

Sheep and beef cattle farmers are interested in acquiring knowledge on endemic, new and emerging diseases, but farmers who participated in our studies indicated that they did not have financial resources to invest in such a system (Chapter 3; Chapter 5). Therefore, increasing the need to make more use of data that is already being collected.

Industry organisations such as AHDB Beef & Lamb and sector bodies (e.g. SHAWG and CHAWG) could use surveillance outputs to target future strategies and fund research as well as organise information sessions and workshops for livestock farmers on topics that would be relevant at a specific point in time, thus benefiting livestock farmers in an indirect manner. Also, the uncertainty and effects of the UK exiting the EU on future trade of sheep and beef products might create a need for a new national strategy on surveillance of livestock diseases to comply with requirements in future trade agreements, such as demonstrating the health status of the national flock/herd, or freedom from certain specific diseases.

6.3.1 Data sources to investigate for disease surveillance in sheep and cattle

Potential data sources that should be investigated for their implementation in a surveillance system for sheep and cattle health include (i) laboratory records (e.g. from APHA), (ii) abattoir data (through the FSA and CCIR), (iii) post-mortem reports, (iv) demographic data such as movement, birth and mortality numbers (from the British Cattle Movement Service or BCMS and the Animal Reporting and Movement Service or ARAMS for sheep, goats and deer), (v) milk recording data (where results from dairy herds could serve as a potential sentinel for beef cattle health), (vi) other production and reproductive parameters (e.g. key performance indicators), (vii) treatments and medication records, and (viii) flock/herd management software and EID technology. The potential relevance of some of these data sources will be discussed here.

The usefulness of diagnostic data from laboratories and abattoirs has been discussed in previous chapters, but more research is needed to explore the available records and assess how they could best be implemented in a surveillance system for endemic diseases. Monthly disease counts for many sheep and cattle diseases can be found through the disease dashboards, dating back to 2012 (Surveillance Intelligence Unit, 2020). Additionally, in the CCIR dataset, case counts for conditions seen at ante- or post-mortem inspection are aggregated and available as monthly numbers, together with the total throughput and number of abattoirs. Cattle and sheep farmers would be interested in feedback on diseases from abattoir inspection (Hanley *et al*., 2020). The analysis of the CCIR and dashboard data and the information generated could be used to improve animal health.

Changes in trends and seasonality in cattle mortality, births and movements can be monitored through analysing data from the BCMS for cattle (Robinson and Christley, 2006; Hyde *et al*., 2020) and the ARAMS for sheep, goats and deer. Currently, an initiative to improve livestock traceability, driven by AHDB and Defra, is underway to develop a new Livestock Information System for cattle, sheep, goats, pigs and deer which is scheduled to be launched in 2020 (GOV.UK, 2018; AHDB, 2019). Data from such a system on multiple livestock species could be very useful to analyse in a surveillance system for sheep and beef cattle health and generate useful information for the government (e.g. with regard to the surveillance for new and emerging diseases) as well as the industry and provide additional information on changing trends and incidence of endemic livestock diseases.

Apart from data owned by third parties, on-farm data that is already collected e.g. key performance indicators, EID records or data with regard to health scheme compliance would also be useful for animal health surveillance. Additionally, precision livestock farming (PLF) technology has evolved rapidly in recent years and although still mostly applied in the context of intensively managed livestock enterprises, could offer opportunities to monitor the health and welfare of extensively managed livestock (Berckmans, 2014; Terrasson *et al*., 2017; Lima *et al*., 2018; May, 2018). Since PLF relies on electronic, real-time monitoring of indicators, recording data does not require additional effort and time from the farmer and could therefore be of interest for disease surveillance. Stakeholders that might benefit from PLF include farmers, retailers, consumers, industry and government (Berckmans, 2014; Ramirez et al., 2019).

6.3.2 Analysis of animal health data and the availability of statistical resources

When developing a system, multiple statistical approaches need to be considered and evaluated in order to select the best option for the particular surveillance initiative. Regression models (e.g. Poisson models, negative binomial models), process control charts (e.g. Shewhart charts, cumulative sums), and time-series analysis (e.g. ARIMA) are some of the most applied methods in statistical analysis (Faverjon and Berezowski, 2018).

Analysing data from open sources such as CCIR and the cattle and sheep dashboards could be a starting point for surveillance. Although, more explanatory analysis of the different data available needs to be carried out to evaluate and determine how these data could be used in an optimal way.

Although routinely collected data are often used for the purpose of early warning, there is also merit in analysing the data to produce information on animal health and diseases (Dórea *et al*., 2015a). Retrospective analysis of historical data can determine baseline levels of diseases or health indicators of interest and be used to identify trends or explain seasonal changes, and significant changes in the case counts (Dórea *et al*., 2011; Dórea *et al*., 2014). The Holt-Winters exponential smoothing algorithm (Dórea *et al*., 2013c) is a data-driven method that can be applied for prospective analysis and to investigate increases in disease prevalence and incidence.

Apart from the potential for existing data to be used to detect new or emerging diseases, a rise or fall in endemic disease numbers could be observed and forecasting algorithms could be used for prospective analysis and subsequently to target resources for prevention or timely intervention (Dórea *et al*., 2013c; Faverjon and Berezowski, 2018).

6.3.3 The analysis of routinely collected diagnostic data: Johne's disease as an example

An example of how diagnostic data can be used is presented for Johne's disease in cattle. Monthly numbers of Johne's disease diagnosed in cattle between January 2016 and December 2019 were retrieved from the cattle dashboard (Surveillance Intelligence Unit, 2019b). The statistical analysis was carried out using the freely available R package 'vetsyn' (Dórea *et al*., 2015a).

The algorithm used in this example is Holt-Winters exponential smoothing (Dórea *et al*., 2015a). Numbers from 2016 until 2018 were used as training data for the Holt-Winters algorithm against which data from 2019 were predicted. Observed data for 2019 were then compared with the algorithm's predictions to assess if there were unexpected changes in monthly disease numbers. As illustrated in Figure 6-1, the retrospective analysis showed that the number for Johne's disease in July 2019 was higher than would have been expected based on the data from the previous years.

This example was developed to show how diagnostic data could be used to generate information on livestock diseases. Outputs from such analysis could provide useful information for many different beneficiaries and stakeholders including livestock farmers, veterinarians, the industry, as well as the government.

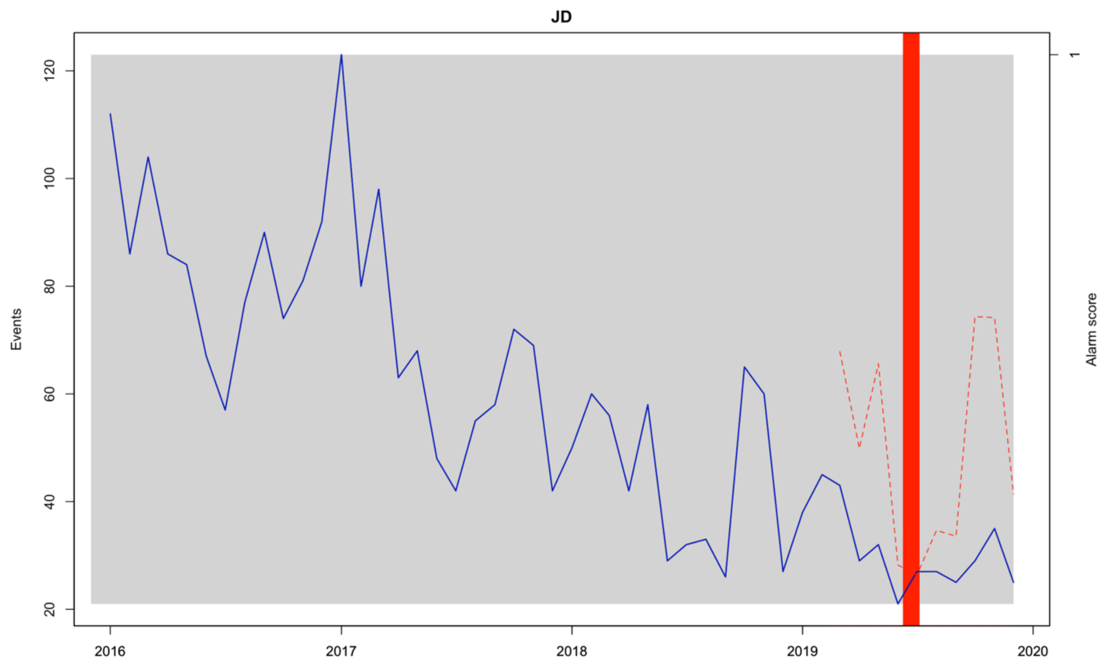


Figure 6-1: Retrospective analysis of Johne's disease (JD) in cattle: monthly case numbers for 4 years (2016, 2017, 2018 and 2019) were obtained via the cattle dashboard (Surveillance Intelligence Unit, 2019b). Data from the first 3 years were used as baseline data after which it was investigated whether there were significant increases identified by the Holt-Winters algorithm in 2019; the red dotted line represents the upper limit of the confidence interval for the expected value that, when exceeded by the observed value, generates an alert (red rod). In this graph it is shown that for July 2019, a significant and unexpected increase in case counts for Johne's disease in cattle was detected.

6.3.4 Costs associated with implementing a surveillance system for the analysis of routinely collected data

There is limited information in the literature on the requirements and costs for implementing a surveillance system based on routinely collected data. The animal health syndromic surveillance system reported by Dórea *et al*. (2015b) is the only peer reviewed publication that describes the costs and the stepwise implementation of a system and that demonstrates that accompanying costs would be low, since data is already available online and software that could be used is freely available. The practical analysis of routinely collected data for the purpose of surveillance can be relatively cheap through using software that is freely available, such as R and the specific packages developed that include the 'vetsyn' (Dórea *et al*., 2015a) and 'surveillance' (Salmon *et al*., 2016) packages.

6.4 General conclusion

Through a combination of qualitative and quantitative research methods, this thesis contributes to the further understanding of sheep and beef cattle farmers' opinions and behaviour towards the surveillance of endemic livestock diseases. Although sheep and beef farmers' needs differ in some areas, they would in general prefer information on livestock diseases. Surveillance outputs would be the most useful for early warning of (new) diseases in their area as well as advice and information on the regional spread of endemic diseases.

In light of the current findings, further research into the development of a surveillance system for endemic sheep and beef cattle diseases should focus on using existing diagnostic and non-diagnostic data as collected by e.g. laboratories (testing of samples and post-mortem examination records), abattoir inspections, production data collected on- and off-farm, and demographic data. This list is not inexhaustible. It should be established how data from all different sources could generate useful information and thus contribute to improving sheep and beef cattle health in England.

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Appendix 3-1: Focus group discussions: email invites, study information, response form and consent form

Re: Invitation to beef cattle and sheep farmers to participate in a focus group discussion

Dear Sir / Madam,

We are currently conducting a study at the University of Warwick to find out which **beef cattle and sheep diseases** are most important on your farm. This study is part of the project funded by the University and AHDB Beef & Lamb to investigate whether it is possible to develop a system to record and monitor these diseases across England. The results will help you compare levels of disease on your farm with regional and national levels of disease. This information would also be used to decide topics to update farmers on new information e.g. at farm events and through the BRP manuals or website and to develop further research where it is required.

We would like to invite you to participate in a **group discussion** to help us identify which diseases are important and should be recorded, how this recording could best be done and how you would use information recorded. Each session will last about **90 minutes.** Participation is completely voluntary, but we would greatly appreciate your contribution in one of our group meetings. All matters we will discuss in the meeting will be stored securely and used anonymously. We will provide you with snacks and drinks and after the meeting you will be given **£20** as a token of our appreciation.

The focus group meetings will be held:

- **22 June** in **Escrick** (North Yorkshire):
  - *13:00* Beef cattle farmers
  - *16:00* Sheep farmers
- **1 July** in **North Petherton** (Somerset)
  - *13:00* Beef cattle farmers
  - *16:00* Sheep farmers
- **4 July** in **Oakham** (Northamptonshire)
  - *13:00* Beef cattle farmers
  - *16:00* Sheep farmers

If you are interested to take part in a meeting, may we ask you to click on the following link to a **short online questionnaire** - this will only take you one minute to fill out: [redacted]

*(Please bear in mind that in order for us to be able to contact you it is necessary that you provide us with your **email address and/or telephone number**).*
We will then contact you later on to confirm your participation and provide you with more details on the venue.

Attached you will be able to find answers to any questions you might have regarding confidentiality and the security of data, but in case you have any further questions, please do not hesitate to contact us!

We very much hope to hear from you. Your participation would be greatly appreciated.

Yours sincerely,

Hanne Nijs and Prof Laura Green

For more information, please contact:
Hanne Nijs
University of Warwick | School of Life Sciences
Gibbet Hill Campus | Coventry | CV4 7AL
[redacted]

STUDY INFORMATION

Will the information I provide be confidential?

Yes. All information you provide will be completely confidential and used solely for research purposes in accordance with the 1998 Data Protection Act. No personally identifying data or opinions will be passed to anyone else. During the study data will be stored at the University of Warwick and will be accessed only by the researchers working on the project. Stored data about your farm or management practices will be anonymous and not stored with your name or address.

What will be the benefits of this study?

Currently no surveillance system is in place to monitor endemic diseases in beef cattle and sheep although these diseases cause substantial economic losses. This project will investigate the feasibility of on-farm recording of endemic diseases by farmers.

Who is conducting this research?

This research is being carried out by Hanne Nijs and Prof Laura Green (University of Warwick) in cooperation with AHDB Beef & Lamb.

Who can I contact if I have a question about the study?

If you have any questions about the project then do not hesitate to email Hanne Nijs on [redacted]

Who has reviewed this study?

This study has been reviewed and approved by the University of Warwick's Biomedical & Scientific Research Ethics Committee.

Who can I contact if I want to make a complaint about my experience participating in this study?

Registrar's Office

University House

University of Warwick

Coventry

CV4 8UW

Complaints@warwick.ac.uk

024 7657 4774

Please tick one of the four options below and return the form in the self addressed envelope provided

1. ☐ I am interested in participating in the study **(please answer the questions below)**

A) Age: ☐ Under 25 ☐ 26-35 ☐ 36-50 ☐ >50 ☐ I do not wish to say

B) Gender: ☐ Male ☐ Female

C) Flock size: ________________ ewes

Herd size: ________________ beef cattle

D) Any other enterprises: ☐ No ☐ Yes (please specify)____________

E) I would like to participate in the ☐ sheep focus groups ☐ beef cattle focus groups

We will contact you with further information

2. ☐ I am not interested in participating in the current study but please contact me in the future if the opportunity to be involved in another study arises

3. ☐ I am not interested in participating in the current study and please do not contact me again in the future

4. ☐ I am no longer farming sheep

5. ☐ I am no longer farming beef cattle

Please check your contact details below

[Insert farmer address]

Telephone number (please add) ____________________

Thank you for taking the time to respond!

Yours sincerely,

Hanne Nijs   Prof Laura Green

WARWICK
THE UNIVERSITY OF WARWICK

CONSENT FORM: BEEF CATTLE AND SHEEP FARMER PARTICIPATION

Study number: REGO-2016-1792

Participant identification for this study: [__________________]

Title of Project: Developing an efficient, validated, sustainable on-farm syndromic surveillance system for beef cattle and sheep

Name of Researcher(s): Hanne Nijs and Prof Laura Green

Please initial all boxes

1. I confirm that I have read and understand the introductory letter to the study and the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and the data that I will have provided will not be used (if not already written up in a final report or publication). ☐
3. I understand that data collected during the study may be looked at by research staff from The University of Warwick involved in this project. I give permission for these individuals to have access to the records and data that I have provided during the study. ☐
4. I agree to take part in the above study. ☐

Name of Participant	Date	Signature
Name of Person taking consent	Date	Signature

Hanne Nijs
University of Warwick
School of Life Sciences
Gibbet Hill Campus
Coventry CV4 7AL UK
Telephone: [redacted]
Email: [redacted]
www.warwick.ac.uk

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Appendix 3-2: Semi-structured guidelines for the farmer focus group discussions (June – July 2016)

Introduction:

Sign consent forms.

Researchers present: Laura Green (Escrick, North Petherton), Rachel Clifton (North Petherton, Oakham), Hanne Nijs (Escrick, North Petherton, Oakham)

Project: 'developing an efficient, sustainable on-farm syndromic surveillance system for beef cattle and sheep' funded by University of Warwick and AHDB Beef & Lamb.

This project has obtained **ethical approval** from the University of Warwick.

Everyday livestock diseases cause significant animal and economic losses, but levels of these diseases are difficult to estimate. 'Syndromic surveillance' means that clinical / visual signs that are representative of a disease are recorded, ideally electronically. By keeping track of the levels of disease on individual farms a general overview can be generated on a regional or national level. These results can be useful for you to compare the performance of their animals or management practices.

These focus group discussions are developed to identify which diseases are most interesting to you as a sheep / beef farmer and to assess the feasibility of monitoring these on your own farm. We will cover 3 sections today:

- we would like you to identify which diseases are most important to you and how monitoring these could be valuable to you
- how would you like to receive feedback and what incentives could persuade you to record diseases on your farm?
- is data collection on-farm feasible, which methods do you think are appropriate / user friendly and are there other important data sources apart from clinical signs that you would be interested in?

To start off, may I ask everyone to quickly introduce yourself: your name, number of sheep/beef cattle and also if and how you are currently recording any diseases or production parameters on your farm.

Section 1: Identification of the use and scope of a syndromic surveillance programme

Key questions for the first section are:

- *Which diseases would you like to see monitored through syndromic surveillance:*
    - *Endemic?*
        - *Identify the most important diseases (BRP directories)*
    - *Other:*
        - *New, re-emerging or exotic diseases?*
        - *Zoonoses and notifiable diseases?*
- *How can a continuous on-farm monitoring system be valuable to you?*
    - *How can the outputs be used – what do you expect – what would be useful?*
- *What are you already recording, how and how are you using it?*

Section 2: Dissemination of feedback from the system and incentives for farmers

Key questions for the third section are:

- *How would you like to receive feedback from the system?*
    - *Electronically: email – website – mobile phone app or message*
    - *How often would you like this information?*
- *What would be important incentives to ensure the efficiency and sustainability of a syndromic surveillance programme?*
    - *Benchmarking*
        - *Regional or national*
        - *Disease trends over time*
    - *Implementing additional data streams*
    - *Free specialist advice*
    - *(Financial compensations)*

Possible incentives:

- Benchmarking can be a very useful incentive for farmers. Providing farmers with their results compared to a regional or national benchmark will allow them to identify strengths and weaknesses of their activities and adjust where needed.
- Results on endemic disease levels on a single farm can also be compared over time. By using aberration detection algorithms, alarms are generated when predefined thresholds are exceeded. Farmers will be able to assess the performance of their stock over time. Research institutes and the industry will be able to visualise and analyse disease trends.
- Integrating and linking other data streams in a syndromic surveillance system can also be used as an incentive. Farmers and industry will receive a more complete and detailed view of the current animal health situation. Information from other data sources can provide answers to prominent questions farmers might have, e.g. abattoir or post-mortem examinations confirming specific pathogens that have caused significant clinical symptoms of disease in the animal.
- Providing specialist advice with suggestions to improve results.
- Financial incentives, e.g. compensations at abattoirs, lab orders or post-mortem examinations.

Section 3: Practical and technological realisation of data recording

Key questions for this section are:

- *How realistic is the active on-farm monitoring of diseases?*
    - *What would be the best methods to record clinical information? (show examples of collection systems: Surveymonkey, SMS texts, EpiCollect, Epi Info, standardised (electronic) form, website)*
    - *EID reader useful?*
    - *How frequently should data be transmitted (annually – quarterly – monthly – weekly – daily – real time)?*
    - *How many diseases would you like to record?*
    - *Different time intervals for different diseases?*
- *Which useful additional data sources should be linked within the syndromic surveillance programme (e.g.: Movement and population – Abattoir – Laboratory - ...)?*

Is there anything else you would like to say or ask us?

Thank you for your contribution.

Appendix 4-1: Questionnaire on the presence of sheep and beef diseases in England (with introduction and information on confidentiality and consent)

Introduction to the study:

At the **University of Warwick** we are investigating the feasibility of a monitoring system where farmers report diseases in their livestock. This could be used to provide you with summary information about your own farm and how your farm compares with other similar farms nearby, identify diseases which are spreading and help direct funding for research and technology exchange about diseases of interest. This project is funded by AHDB Beef & Lamb and the University of Warwick.

Sheep and cattle farmers identified five diseases of interest. We have created a very brief questionnaire on your experiences with these diseases **from January to December 2017**. All the information you provide will be aggregated and used anonymously.

The questionnaire should take **5 minutes** to complete.

If you fill in your contact details at the end of this questionnaire, we will send you a summary of each disease in your county and across England in the Autumn of 2018.

Confidentiality and consent:

The responses to the questionnaire will be stored securely and will only be used for the purpose of this research project. The data you provide will be treated confidentially and will not be shared with third parties. Personal information will be stored separately and only for the duration of the project (end date: 9th January 2020). To help us improve the accuracy of the results, we ask you to select the county where your farm is located. All results will be reported anonymously.

Your participation in this study is completely voluntary and you can withdraw your data at any point before reports or publications on this study have been published provided you fill in your name at the end of this questionnaire. Please note that withdrawing your data will not be possible if you do not provide your name because we will not be able to trace your submission.

This project has received ethical approval from the Biomedical and Scientific Research Ethics Committee (University of Warwick). If you have any questions about the project, do not hesitate to contact Hanne Nijs [redacted].

If you want to make a complaint, please contact:

Deputy Director/ Head of Research Governance

Research & Impact Services

University House

University of Warwick

Coventry

CV4 8UW

Tel: 024 76 522746

Email: researchgovernance@warwick.ac.uk

By completing the questionnaire you acknowledge that your participation is voluntary, you are at least 18 years of age and you are aware you may choose to withdraw at any given time until reports or publications are finalised.

1. Please indicate the county where your farmhouse is located:

(Please select from dropdown list below)

Bedfordshire Berkshire Bristol Buckinghamshire Cambridgeshire Cheshire City of London Cornwall Cumbria Derbyshire Devon Dorset Durham East Riding of Yorkshire East Sussex Essex Gloucestershire Greater London Greater Manchester Hampshire Herefordshire Hertfordshire Isle of Wight Kent Lancashire Leicestershire Lincolnshire Merseyside Norfolk North Yorkshire Northamptonshire Northumberland Nottinghamshire Oxfordshire Rutland Shropshire Somerset South Yorkshire Staffordshire Suffolk Surrey Tyne and Wear Warwickshire West Midlands West Sussex West Yorkshire Wiltshire Worcestershire

2. Which livestock were present on your farm between January and December 2017?

(Please select all relevant answers by clicking the appropriate options)

- ☐ Sheep
- ☐ Beef Cattle
- ☐ Dairy Cattle
- ☐ Pigs
- ☐ Poultry

3. What type of **sheep** enterprise did you have on your farm in 2017?

(Please select all correct answers by clicking the appropriate options)

- ☐ Pedigree
- ☐ Commercial
- ☐ Store lambs

4. What was the size of your **sheep** flock in 2017?

(Fill in the boxes below)

- ○ Average number of ewes: ____________________
- ○ Maximum number of lambs: ____________________

5. Which type of **beef** enterprise did you have on your farm in 2017?

(Please select all correct answers by clicking the appropriate options)

- ☐ Pedigree suckler
- ☐ Cross bred suckler
- ☐ Finishing cattle
- ☐ Rearing cattle
- ☐ Calves

6. What was the size of your **beef cattle** herd in 2017?

(Fill in the boxes below)

- ○ Average number of adult cattle: ____________________
- ○ Maximum number of calves: ____________________

7. Please specify the size of your **dairy cattle** herd in 2017?

(Fill in the boxes below)

- ○ Average number of adult cattle: ____________________
- ○ Maximum number of calves: ____________________

Please indicate whether you saw the diseases listed below in your flock **between 1 January 2017 and 31 December 2017**.

8. Which of the diseases listed did you see in your **sheep**?

(Select only one answer for every disease)

	Yes	Suspected	No	I do not know
Johne's disease (JD)	○	○	○	○
Maedi-Visna (MV)	○	○	○	○
Caseous lymphadenitis (CLA / cheesy gland)	○	○	○	○
Enzootic abortion (Chlamydia / EAE)	○	○	○	○
Sheep scab	○	○	○	○

9. Who identified the **sheep** diseases you saw in 2017?

(Tick as many answers as apply)

	Me	My veterinarian	Samples sent to a laboratory	Animal sent for post mortem	Report from an abattoir	Other
Johne's disease	☐	☐	☐	☐	☐	☐
Maedi-Visna	☐	☐	☐	☐	☐	☐
Caseous Lymphadenitis (CLA / cheesy gland)	☐	☐	☐	☐	☐	☐
Enzootic abortion (Chlamydia / EAE)	☐	☐	☐	☐	☐	☐
Sheep scab	☐	☐	☐	☐	☐	☐

Please indicate whether you saw the diseases listed below in your herd **between 1 January 2017 and 31 December 2017.**

10. Which of the diseases listed below did you see in your **beef cattle**?

(Select only one answer for each disease)

	Yes	Suspected	No	I do not know
Johne's disease (JD)	○	○	○	○
Bovine tuberculosis (bTB)	○	○	○	○
Leptospirosis	○	○	○	○
Bovine viral diarrhoea (BVD)	○	○	○	○
Liver fluke	○	○	○	○

11. Who identified the diseases seen in your **beef cattle** diseases in 2017?

(Tick as many answers as apply)

	Me	My veterinarian	Samples sent to a laboratory	Animal sent for post mortem	Report from an abattoir	Other
Johne's disease	☐	☐	☐	☐	☐	☐
Leptospirosis	☐	☐	☐	☐	☐	☐
Bovine viral diarrhoea (BVD)	☐	☐	☐	☐	☐	☐
Liver fluke (Fasciolosis)	☐	☐	☐	☐	☐	☐

12. Please specify how bovine tuberculosis (bTB) was detected on your farm:

(Tick as many answers as apply)

	Report from an abattoir	Compulsory TB test	Pre-/Post-movement TB testing of cattle	Other
Bovine tuberculosis (bTB)	☐	☐	☐	☐

If you wish to receive a summary with the results of the study, please complete the form below.

Title:

(Please select from dropdown list below)

Mr Mrs Ms Miss I do not wish to say

Please fill in your name:

- First Name ____________________
- Last Name ____________________

If you would like to be kept informed about the results of this study, please provide us with your e-mail address:

(Please make sure you enter your e-mail address correctly)

____

If you have any comments on this questionnaire, please make these in the text box below.

____

____

____

For more information about the study or the project funded by AHDB Beef & Lamb and the University of Warwick, you are most welcome to use the information below to contact us.

Hanne Nijs
School of Life Sciences
University of Warwick
Gibbet Hill Campus
CV4 7AL
E-mail: [redacted]

Appendix 4-2: Questionnaire on the presence of sheep and beef diseases in England: email invite

Click here if you are having trouble viewing this message.

AHDB

University of Warwick: livestock disease survey

This project is funded by AHDB Beef & Lamb and The University of Warwick.

May 2018

Dear Sir / Madam

At the University of Warwick we are investigating the feasibility of a monitoring system where farmers report diseases in their livestock. This could be used to provide you with summary information about your own farm and how your farm compares with other similar farms nearby, identify diseases which are spreading and help direct funding for research and technology exchange about diseases of interest.

Sheep and cattle farmers identified five diseases of interest. We have created a very brief questionnaire on your experiences with these diseases **from January to December 2017**. All the information you provide will be aggregated and used anonymously.

The questionnaire should take **5 minutes** to complete.

If you fill in your contact details at the end of this questionnaire, we will send you a

summary of each disease in your county and across England in the Autumn of 2018.

Please click here to access the online questionnaire

How we will use the data:

We will use all the data anonymously and send you a summary of each disease in your county and across England in the summer of 2018.

A second questionnaire will be sent to you in January 2019 and we will send you results from both years in the summer of 2019.

We very much hope that you will complete this brief questionnaire. Your participation is greatly appreciated.

Yours sincerely,

Hanne Nijs and Prof Laura Green

Confidentiality and consent:

The responses from all participants will be stored in a secure way and will only be used for the purpose of this research project. The data you provide will be treated confidentially and will not be shared with third parties. All results will be reported anonymously.

Your participation in this study is completely voluntary and you can withdraw your data at any point before reports or publications on this study have been published if you fill in your name at the end of this questionnaire. Please note that withdrawing your data will not be possible if you participate anonymously since we might not be able to trace your submission.

This project has received ethical approval from the Biomedical and Scientific Research Ethics Committee (University of Warwick).

If you have any questions about the project, do not hesitate to contact Hanne Nijs [redacted]

If you want to make a complaint, please contact:

Registrar's Office
University House

University of Warwick
Coventry
CV4 8UW
Complaints@warwick.ac.uk
024 7657 4774

For more information about the research project, please contact:

Hanne Nijs
University of Warwick | School of Life Sciences
Gibbet Hill Campus | Coventry | CV4 7AL
Email: [redacted]

AHDB Beef & Lamb, Stoneleigh Park, Kenilworth, Warwickshire, CV8 2TL

T 02476692051
E comms@ahdb.org.uk
W beefandlamb.ahdb.org.uk

BEEF & LAMB

Appendix 4-3: Questionnaire on the presence of sheep and beef diseases in England: reminder for farmers

Dear Sir / Madam,

Last month we sent you an invite to participate in our online survey on livestock diseases you have seen on your farm in 2017. This invite was sent to 2000 sheep and/or beef cattle farmers in England.

If you have responded recently, we would like to thank you for your valuable input. If not, please do complete the online questionnaire. The survey will close by 30 June 2018. It will only take up 5 minutes of your time. If you wish to receive a summary with the results, you can provide us with your email address at the end of the survey.

Please access the questionnaire by clicking ***here***.

Your contribution is very much appreciated!

If you have any questions, please contact Hanne Nijs [redacted]

Sincerely,
Hanne Nijs and Prof Laura Green

Appendix 4-4: Questionnaire on the presence of sheep and beef diseases in England: summary of results from 2017

Summary of results on sheep and beef diseases in 2017

In total, 208 sheep and beef farmers provided diseases data from their flock and/or herd: 160 (76.9%) participants had sheep on their farm, while 140 (67.3%) farmers had cattle.

The level of sheep diseases either diagnosed or suspected on-farm in 2017 is shown in the table below.

Presence of sheep diseases in England in 2017

Sheep disease	***Positive farms***	
	No. (on a total of 160)	*Percentage*
Enzootic abortion (EAE/Chlamydia)	24	15%
Caseous lymphadenitis (CLA/Cheesy gland)	15	9.4%
Sheep scab (P. ovis)	13	8.1%
Johne's disease (JD)	5	3.1%
Maedi-Visna (MV)	1	0.6%

The level of cattle diseases either diagnosed or suspected on-farm in 2017 is shown in the table below.

Presence of cattle diseases in England in 2017

Cattle disease	***Positive farms***	
	No. (on a total of 140)	*Percentage*
Fasciolosis (Liver fluke/F. hepatica)	51	36.4%
Bovine tuberculosis (bTB)	20	14.3%
Bovine viral diarrhoea (BVD)	14	10%
Johne's disease (JD)	14	10%
Leptospirosis (Lepto)	4	2.9%

Appendix 5-1: Questionnaire on sheep farmer recording and surveillance of production and disease

Questionnaire: Sheep farmer recording and surveillance of production and disease

Farm ID: ******

Section 1. Farm specifics

1. Please specify in which **county** your farm is located: ________________________

2. Were you a member of the **AHDB Better Returns Programme** in 2017? *(Please circle the appropriate answer)*

Yes **No** **I do not wish to say** **I do not know**

3. Which **type of livestock** were on your farm in 2017? *(Please circle all that apply)*

Sheep **Beef cattle** **Dairy cattle** **Pigs** **Poultry** **Horses**

4. Which of the **sheep enterprises** below did you have in 2017? *(Please circle all that apply)*

Pedigree **Commercial** **Store lambs**

5. What **size** was your sheep flock in 2017? *(Please fill in the numbers below)*

- **Average number of ewes in 2017:** ____________
- **Maximum number of lambs in 2017:** ____________
- **Average number of rams/tups in 2017:** ____________

6. Were your sheep in a **health scheme** in 2017? *(Please circle the correct answer)*

Yes **No** **I do not wish to say** **I do not know**

In this project we are investigating whether it would be useful to develop a system where you can submit data on your own flock and get useful information back from ***a surveillance system for farmers.***

Throughout this questionnaire, **'Diseases diagnosed'** is used for instances where the presence of a **specific disease is confirmed** on your farm (e.g. positive results from lab testing of samples for Johne's disease); **'Clinical signs'** are issues you notice in your flock where **further investigation is necessary to identify the cause** (e.g. lameness in sheep is a clinical sign that can be caused by diseases such as interdigital dermatitis, footrot, or CODD).

Page **1** of **11**

Farm ID: ******

Section 2. Recording flock data on your farm

7. Did you record any data on your flock in **2017**? *(Please circle the correct answer)*

Yes **No** *(please proceed to question 14.)* **I do not wish to say** *(please proceed to question 14.)*

8. What flock data did you record in **2017**? *(Please circle all that apply)*

Diseases diagnosed **Clinical signs** **Production data** **Other:** *(please specify)* ____________

9. How did you record flock data in **2017**? *(Please circle all that apply)*

Paper *(please proceed to question 11.)* **Computer** **EID reader** **Other:** *(please specify)* ____________

10. How often did you record flock data electronically in **2017**? *(Please circle the best option)*

Daily **Weekly** **Monthly** **Quarterly** **Annually** **Other:** *(please specify)* ____________

11. Did you use the data you recorded for decision-making on your farm in **2017**? *(Please circle the correct answer)*

Yes **No** **I do not wish to say**

12. Did you share any of your flock data with anyone in **2017**? *(Please circle the correct answer)*

Yes **No** *(please proceed to question 14.)* **I do not wish to say** *(please proceed to question 14.)*

13. Who did you share your recorded flock data with in **2017**? *(Please circle all that apply)*

Other farmers **My vet** **AHDB Beef & Lamb** **Breed societies** **Health scheme** **Other:** *(please specify)* ____________

Page **2** of **11**

Section 3. The use and value of surveillance of clinical signs in livestock

14. Please indicate the extent to which you agree with the following statements about **the surveillance of clinical signs** in your flock: *(Please circle the appropriate answer for each statement)*

a. *'I believe a summary of clinical signs from a national surveillance system would help me with decision-making on my farm.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

b. *'I believe a summary of clinical signs from a national surveillance system would be useful for the sheep industry.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

c. *'I believe comparing my own flock average with a regional average would be useful for me.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

d. *'I believe comparing my own flock average with a national average would be useful for me.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

15. Please indicate the extent to which you agree that a **national** benchmark on the **clinical signs** in sheep listed below would be useful to you as a sheep farmer: *(Please circle the appropriate answer for every option)*

a. Abortions:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
b. Lameness:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
c. Mastitis:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
d. Deaths on-farm:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
e. Culls:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
f. Other: (please specify the sign) ________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
g. Other: (please specify the sign) ________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

16. Please indicate the extent to which you agree that a **regional** benchmark on the **clinical signs** in sheep listed below would be useful to you as a sheep farmer: *(Please circle the appropriate answer for every option)*

a. Abortions:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
b. Lameness:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
c. Mastitis:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
d. Deaths on-farm:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
e. Culls:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
f. Other: (please specify the sign) ________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
g. Other: (please specify the sign) ________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

17. Would you be prepared to provide **clinical signs** on your flock to a surveillance system? *(Please circle the appropriate answer and explain where necessary)*

Yes **Maybe** *(please specify below)* **No** *(please specify below)*

18. Would you be prepared to pay for a **farmer-funded** surveillance system for clinical signs? *(Please circle the appropriate answer and explain where necessary)*

Yes **Maybe** *(please specify below)* **No** *(please specify below)*

Section 4. The use and value of surveillance for livestock diseases

19. Please indicate the extent to which you agree with the following statements about **the surveillance of sheep diseases diagnosed** in your flock: *(Please circle the appropriate answer for each statement)*

a. *'I believe a summary of sheep diseases from a national surveillance system would help me with decision-making on my farm.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

b. *'I believe a summary of sheep diseases from a national surveillance system would be useful for the sheep industry.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

c. *'I believe comparing disease presence in my own flock with a regional average would be useful for me.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

d. *'I believe comparing disease presence in my own flock with a national average would be useful for me.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

20. Please indicate the extent to which you agree that a **national** benchmark on the **sheep diseases** listed below would be useful to you as a sheep farmer: *(Please circle the appropriate answer for every option)*

a. Johne's disease:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
b. Maedi-Visna:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
c. Caseous lymphadenitis (CLA):	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
d. Enzootic abortion (EAE/Chlamydia):	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
e. Sheep scab:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
f. Other: (please specify the disease) ____________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
g. Other: (please specify the disease) ____________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

21. Please indicate the extent to which you agree that a **regional** benchmark on the **sheep diseases** listed below would be useful to you as a sheep farmer: *(Please circle the appropriate answer for every option)*

a. Johne's disease:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
b. Maedi-Visna:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
c. Caseous lymphadenitis (CLA):	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
d. Enzootic abortion (EAE/Chlamydia):	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
e. Sheep scab:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
f. Other: (please specify the disease) ____________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
g. Other: (please specify the disease) ____________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

22. Which of the **diseases** listed below did you see in your sheep in 2017? *(Please circle the appropriate answer for every option)*

a. Johne's disease:	**Yes**	**Suspected**	**No**	**I do not know**
b. Maedi-Visna:	**Yes**	**Suspected**	**No**	**I do not know**
c. Caseous lymphadenitis (CLA):	**Yes**	**Suspected**	**No**	**I do not know**
d. Enzootic abortion (EAE/Chlamydia):	**Yes**	**Suspected**	**No**	**I do not know**
e. Sheep scab:	**Yes**	**Suspected**	**No**	**I do not know**

23. **Who** identified the sheep diseases you saw in 2017? *(Please circle the appropriate answers for every option)*

a. Johne's disease:	**Me**	**My vet**	**Laboratory**	**Post mortem examiner**	**Abattoir**	**Other**
b. Maedi-Visna:	**Me**	**My vet**	**Laboratory**	**Post mortem examiner**	**Abattoir**	**Other**
c. Caseous lymphadenitis (CLA):	**Me**	**My vet**	**Laboratory**	**Post mortem examiner**	**Abattoir**	**Other**
d. Enzootic abortion (EAE/Chlamydia):	**Me**	**My vet**	**Laboratory**	**Post mortem examiner**	**Abattoir**	**Other**
e. Sheep scab:	**Me**	**My vet**	**Laboratory**	**Post mortem examiner**	**Abattoir**	**Other**

24. Please indicate the extent to which you agree with the following statements about the use of **feedback** from a surveillance system with advice on the **presence of sheep diseases** (e.g. spread of diseases, reports or photos to help recognise specific diseases, preventive measures): *(Please circle the appropriate answer for each statement)*

a. *'I would use feedback from a surveillance system to help recognise sheep diseases myself.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

b. *'I would use feedback from a surveillance system to reduce the risk of buying in diseases.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

c. *'I would use feedback from a surveillance system to track sheep diseases in my area.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

d. *'I would use feedback from a surveillance system to help me plan how to reduce economic losses on my farm.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

e. *'I would use feedback from a surveillance system to help me plan how to increase animal production on my farm.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

f. *'I would use information from a surveillance system to advertise that my flock is free of certain specific diseases.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

g. *'I would use feedback from a surveillance system to improve my understanding of sheep diseases.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

h. *'I would use feedback from a surveillance system to stay informed of new disease threats.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

i. *'I would find it interesting to receive advice on sheep diseases from a surveillance system.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

25. Would you be prepared to provide data on **diseases diagnosed in your flock** for a surveillance system? *(Please circle the appropriate answer and explain where necessary)*

Yes **Maybe** *(please specify below)* **No** *(please specify below)*

26. Would you be prepared to pay for a **farmer-funded** surveillance system for diseases diagnosed in sheep? *(Please circle the appropriate answer and explain where necessary)*

Yes **Maybe** *(please specify below)* **No** *(please specify below)*

Section 5. Useful resources for important livestock data

27. Please indicate the extent to which you agree with the following statements about the **usefulness of data from the sources listed below** for surveillance of sheep health: *(Please circle the appropriate answer for each statement)*

a. *'I believe abattoirs collect useful health data on sheep.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

b. *'I believe post mortem examiners collect useful health data on sheep.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

c. *'I believe diagnostic laboratories collect useful health data on sheep.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

d. *'I believe health schemes collect useful health data on sheep.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

e. *'I believe vets collect useful health data on sheep.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

28. Please indicate the extent to which you agree with the following statements on **who provided useful feedback to you** on sheep health in 2017: *(Please circle the appropriate answer for each statement)*

a. *'I received useful feedback on my sheep from the abattoir in 2017.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

b. *'I received useful feedback on my sheep from post mortem examiners in 2017.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

c. *'I received useful feedback on my sheep from a diagnostic lab in 2017.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

d. *'I received useful feedback on my sheep from my health scheme in 2017.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

e. *'I received useful feedback on my sheep from my vet in 2017.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

29. How often did your vet visit your farm to discuss your sheep in 2017? *(Please circle the correct answer)*

Monthly **Quarterly** **Once in the year** **Not at all** **Other:** *(please specify)* ____________________

30. Ideally, how would you like to receive information on sheep health to help you with decision-making on your farm? *(Please circle the appropriate answer for every option)*

a. Online webpage:	**Very desirable**	**Desirable**	**Neutral**	**Undesirable**	**Very undesirable**	**Not applicable**
b. Reports via email:	**Very desirable**	**Desirable**	**Neutral**	**Undesirable**	**Very undesirable**	**Not applicable**
c. Reports via mobile app:	**Very desirable**	**Desirable**	**Neutral**	**Undesirable**	**Very undesirable**	**Not applicable**
d. Paper leaflets or brochures:	**Very desirable**	**Desirable**	**Neutral**	**Undesirable**	**Very undesirable**	**Not applicable**
e. Other: (please specify what method) ____________________	**Very desirable**	**Desirable**	**Neutral**	**Undesirable**	**Very undesirable**	**Not applicable**

Section 6: Reporting the results from the study

Thank you for taking the time to complete this questionnaire. Your participation is greatly appreciated!

If you would like to be informed about the results of this study, please fill in your email address below. Please be advised that this information will only be used to provide you with the results of this project.

Please provide your email address below:

If you would like to share any other thoughts or comments on the surveillance of sheep and beef cattle diseases in England, please make these in the box below:

For more information about the study or the project funded by AHDB Beef & Lamb and the University of Warwick, you are most welcome to use the information below to contact us.

Hanne Nijs

School of Life Sciences

University of Warwick

Gibbet Hill Campus

CV4 7AL

Coventry

Email: [redacted]

PLEASE RETURN YOUR COMPLETED QUESTIONNAIRE IN THE FREEPOST ENVELOPE PROVIDED

Appendix 5-2: Questionnaire on beef farmer recording and surveillance of production and disease

WARWICK THE UNIVERSITY OF WARWICK

Questionnaire: Beef farmer recording and surveillance of production and disease

Farm ID: ******

Section 1. Farm specifics

1. Please specify in which county your farm is located: ____________________

2. Were you a member of the **AHDB Better Returns Programme** in 2017? *(Please circle the appropriate answer)*

Yes **No** **I do not wish to say** **I do not know**

3. Which **type of livestock** were on your farm in 2017? *(Please circle all that apply)*

Sheep **Beef cattle** **Dairy cattle** **Pigs** **Poultry** **Horses**

4. Which of the **cattle enterprises** below did you have in 2017? *(Please circle all that apply)*

Pedigree suckler **Crossbred suckler** **Finishing cattle** **Rearing cattle** **Rearing calves** **Dairy**

5. What **size** was your cattle herd in 2017? *(Please fill in the numbers below)*

- **Average number of adult sucklers in 2017:** ____________
- **Maximum number of finishing cattle in 2017:** ____________
- **Average number of dairy cattle in 2017:** ____________
- **Average number of bulls in 2017:** ____________
- **Maximum number of calves in 2017:** ____________

6. Were your cattle in a **health scheme** in 2017? *(Please circle the correct answer)*

Yes **No** **I do not wish to say** **I do not know**

In this project we are investigating whether it would be useful to develop a system where you can submit data on your own herd and get useful information back from ***a surveillance system for farmers****.*

Throughout this questionnaire, **'Diseases diagnosed'** is used for instances where the presence of a **specific disease is confirmed** on your farm (e.g. positive results from lab testing of samples for Johne's disease); **'Clinical signs'** are issues you notice in your herd where **further investigation is necessary to identify the cause** (e.g. abortion in cattle is a clinical sign that can be caused by diseases such as Neosporosis, BVD, or Brucellosis).

Page **1** of **11**

Farm ID: ******

Section 2. Recording herd data on your farm

7. Did you record any data on your herd in **2017**? *(Please circle the correct answer)*

Yes **No** *(please proceed to question 14.)* **I do not wish to say** *(please proceed to question 14.)*

8. What herd data did you record in **2017**? *(Please circle all that apply)*

Diseases diagnosed **Clinical signs** **Production data** **Other:** *(please specify)* ____________

9. How did you record herd data in **2017**? *(Please circle all that apply)*

Paper *(please proceed to question 11.)* **Computer** **Other:** *(please specify)* ____________

10. How often did you record herd data electronically in **2017**? *(Please circle the best option)*

Daily **Weekly** **Monthly** **Quarterly** **Annually** **Other:** *(please specify)* ____________

11. Did you use the data you recorded for decision-making on your farm in **2017**? *(Please circle the correct answer)*

Yes **No** **I do not wish to say**

12. Did you share any of your herd data with anyone in **2017**? *(Please circle the correct answer)*

Yes **No** *(please proceed to question 14.)* **I do not wish to say** *(please proceed to question 14.)*

13. Who did you share your recorded herd data with in **2017**? *(Please circle all that apply)*

Other farmers **My vet** **AHDB Beef & Lamb** **Breed societies** **Health scheme** **Other:** *(please specify)* ____________

Page **2** of **11**

Section 3. The use and value of surveillance of clinical signs in livestock

14. Please indicate the extent to which you agree with the following statements about **the surveillance of clinical signs** in your herd: *(Please circle the appropriate answer for each statement)*

a. *'I believe a summary of clinical signs from a national surveillance system would help me with decision-making on my farm.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

b. *'I believe a summary of clinical signs from a national surveillance system would be useful for the beef industry.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

c. *'I believe comparing my own herd average with a regional average would be useful for me.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

d. *'I believe comparing my own herd average with a national average would be useful for me.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

15. Please indicate the extent to which you agree that a **national** benchmark on the **clinical signs** in cattle listed below would be useful for you as a cattle farmer: *(Please circle the appropriate answer for every option)*

a. Abortions:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
b. Pneumonia:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
c. Mastitis:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
d. Deaths on-farm:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
e. Culls:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
f. Other: (please specify the sign) ___________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
g. Other: (please specify the sign) ___________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

16. Please indicate the extent to which you agree that a **regional** benchmark on the **clinical signs** in cattle listed below would be useful for you as a cattle farmer: *(Please circle the appropriate answer for every option)*

a. Abortions:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
b. Pneumonia:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
c. Mastitis:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
d. Deaths on-farm:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
e. Culls:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
f. Other: (please specify the sign) ___________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
g. Other: (please specify the sign) ___________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

17. Would you be prepared to provide **clinical signs** on your cattle to a surveillance system? *(Please circle the appropriate answer and explain where necessary)*

Yes **Maybe** *(please specify below)* **No** *(please specify below)*

18. Would you be prepared to pay for a **farmer-funded** surveillance system for clinical signs? *(Please circle the appropriate answer and explain where necessary)*

Yes **Maybe** *(please specify below)* **No** *(please specify below)*

Section 4. The use and value of surveillance for livestock diseases

19. Please indicate the extent to which you agree with the following statements about **the surveillance of cattle diseases diagnosed** in your herd: *(Please circle the appropriate answer for each statement)*

a. *'I believe a summary of cattle diseases from a national surveillance system would help me with decision-making on my farm.'*

Strongly agree	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

b. *'I believe a summary of cattle diseases from a national surveillance system would be useful for the cattle industry.'*

Strongly agree	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

c. *'I believe comparing disease presence in my own herd with a regional average would be useful for me.'*

Strongly agree	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

d. *'I believe comparing disease presence in my own herd with a national average would be useful for me.'*

Strongly agree	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

20. Please indicate the extent to which you agree that a **national** benchmark on the **cattle diseases** listed below would be useful for you as a cattle farmer: *(Please circle the appropriate answer for every option)*

a. Johne's disease:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
b. Bovine tuberculosis (bTB):	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
c. Leptospirosis:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
d. Bovine viral diarrhoea (BVD):	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
e. Liver fluke:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
f. Other: (please specify the disease) ____________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
g. Other: (please specify the disease) ____________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

21. Please indicate the extent to which you agree that a **regional** benchmark on the **cattle diseases** listed below would be useful for you as a cattle farmer: *(Please circle the appropriate answer for every option)*

a. Johne's disease:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
b. Bovine tuberculosis (bTB):	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
c. Leptospirosis:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
d. Bovine viral diarrhoea (BVD)	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
e. Liver fluke:	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
f. Other: (please specify the disease) ____________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**
g. Other: (please specify the disease) ____________	**Strongly agree**	**Agree**	**Neither agree nor disagree**	**Disagree**	**Strongly disagree**	**Not applicable**

22. Which of the **diseases** listed below did you see in your cattle in 2017? *(Please circle the appropriate answer for every option)*

a. Johne's disease:	**Yes**	**Suspected**	**No**	**I do not know**
b. Bovine tuberculosis:	**Yes**	**Suspected**	**No**	**I do not know**
c. Leptospirosis):	**Yes**	**Suspected**	**No**	**I do not know**
d. Bovine viral diarrhoea	**Yes**	**Suspected**	**No**	**I do not know**
e. Liver fluke:	**Yes**	**Suspected**	**No**	**I do not know**

23. **Who** identified the cattle diseases you saw in 2017? *(Please circle the appropriate answers for every option)*

a. Johne's disease:	**Me**	**My vet**	**Laboratory**	**Post mortem examiner**	**Abattoir**	**Other**
b. Leptospirosis:	**Me**	**My vet**	**Laboratory**	**Post mortem examiner**	**Abattoir**	**Other**
c. Bovine viral diarrhoea	**Me**	**My vet**	**Laboratory**	**Post mortem examiner**	**Abattoir**	**Other**
d. Liver fluke:	**Me**	**My vet**	**Laboratory**	**Post mortem examiner**	**Abattoir**	**Other**
e. Bovine tuberculosis:	**Abattoir**	**Compulsory TB test**	**Pre-/post-movement TB testing**	**Other**		

24. Please indicate the extent to which you agree with the following statements about the use of **feedback** from a surveillance system with advice on the **presence of cattle diseases** (e.g. spread of diseases, reports or photos to help recognise specific diseases, preventive measures): *(Please circle the appropriate answer for each statement)*

a. *'I would use feedback from a surveillance system to help recognise cattle diseases myself.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

b. *'I would use feedback from a surveillance system to reduce the risk of buying in diseases.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

c. *'I would use feedback from a surveillance system to track cattle diseases in my area.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

d. *'I would use feedback from a surveillance system to help me plan how to reduce economic losses on my farm.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

e. *'I would use feedback from a surveillance system to help me plan how to increase animal production on my farm.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

f. *'I would use information from a surveillance system to advertise that my herd is free of certain specific diseases.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

g. *'I would use feedback from a surveillance system to improve my understanding of cattle diseases.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

h. *'I would use feedback from a surveillance system to stay informed of new disease threats.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

i. *'I would find it interesting to receive advice on cattle diseases from a surveillance system.'*

Strongly agree **Agree** **Neither agree nor disagree** **Disagree** **Strongly disagree** **Not applicable**

25. Would you be prepared to provide data on **diseases diagnosed in your herd** for a surveillance system? *(Please circle the appropriate answer and explain where necessary)*

Yes **Maybe** *(please specify below)* **No** *(please specify below)*

26. Would you be prepared to pay for a **farmer-funded** surveillance system for diseases diagnosed in cattle? *(Please circle the appropriate answer and explain where necessary)*

Yes **Maybe** *(please specify below)* **No** *(please specify below)*

Section 5. Useful resources for important livestock data

27. Please indicate the extent to which you agree with the following statements about the **usefulness of data from the sources listed below** for surveillance of cattle health: *(Please circle the appropriate answer for each statement)*

a. *'I believe abattoirs collect useful health data on cattle.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

b. *'I believe post mortem examiners collect useful health data on cattle.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

c. *'I believe diagnostic laboratories collect useful health data on cattle.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

d. *'I believe health schemes collect useful health data on cattle.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

e. *'I believe vets collect useful health data on cattle.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

28. Please indicate the extent to which you agree with the following statements on **who provided useful feedback to you** on cattle health in 2017: *(Please circle the appropriate answer for each statement)*

a. *'I received useful feedback on my cattle from the abattoir in 2017.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

b. *'I received useful feedback on my cattle from post mortem examiners in 2017.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

c. *'I received useful feedback on my cattle from a diagnostic lab in 2017.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

d. *'I received useful feedback on my cattle from my health scheme in 2017.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

e. *'I received useful feedback on my cattle from my vet in 2017.'*

Strongly agree | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** | **Not applicable**

29. How often did your vet visit your farm to discuss your cattle in 2017? *(Please circle the correct answer)*

Monthly | **Quarterly** | **Once in the year** | **Not at all** | **Other:** *(please specify)* ____________

30. Ideally, how would you like to receive information on cattle health to help you with decision-making on your farm? *(Please circle the appropriate answer for every option)*

a. Online webpage:	**Very desirable**	**Desirable**	**Neutral**	**Undesirable**	**Very undesirable**	**Not applicable**
b. Reports via email:	**Very desirable**	**Desirable**	**Neutral**	**Undesirable**	**Very undesirable**	**Not applicable**
c. Reports via mobile app:	**Very desirable**	**Desirable**	**Neutral**	**Undesirable**	**Very undesirable**	**Not applicable**
d. Paper leaflets or brochures:	**Very desirable**	**Desirable**	**Neutral**	**Undesirable**	**Very undesirable**	**Not applicable**
e. Other: (please specify what method) ____________	**Very desirable**	**Desirable**	**Neutral**	**Undesirable**	**Very undesirable**	**Not applicable**

Section 6: Reporting the results from the study

Thank you for taking the time to complete this questionnaire. Your participation is greatly appreciated!

If you would like to be informed about the results of this study, please fill in your email address below. Please be advised that this information will only be used to provide you with the results of this project.

Please provide your email address below:

If you would like to share any other thoughts or comments on the surveillance of sheep and beef cattle diseases in England, please make these in the box below:

For more information about the study or the project funded by AHDB Beef & Lamb and the University of Warwick, you are most welcome to use the information below to contact us.

Hanne Nijs

School of Life Sciences

University of Warwick

Gibbet Hill Campus

CV4 7AL

Coventry

Email: [redacted]

PLEASE RETURN YOUR COMPLETED QUESTIONNAIRE IN THE FREEPOST ENVELOPE PROVIDED

Appendix 5-3: Sheep farmer recording and surveillance of production and disease: email invite for the online survey

Tuesday, September 11, 2018 at 2:53:53 PM British Summer Time

Subject: [TEST]: Sheep diseases and productivity survey
Date: Wednesday, August 29, 2018 at 8:42:35 AM British Summer Time
From: *AHDB Levy Payer Communications
To: Emma Walker

Click here if you are having trouble viewing this message.

AHDB

Sheep diseases and productivity survey

This project is funded by AHDB Beef & Lamb and The University of Warwick.

September 2018

Dear Sir/Madam,

We are investigating whether sheep and beef cattle farmers in England are interested in a surveillance system where you, the farmer, provide data from your own livestock and receive summarised anonymised information on **diseases and productivity** from your region and nationally.

In this questionnaire, we are asking how you currently record and use information on your livestock and what information on sheep or cattle would be useful to you from a surveillance system.

We appreciate that you are very busy, this questionnaire takes about **15 minutes** to complete. You can use the tabs at the bottom of each section to navigate backwards or forwards while completing the questionnaire. Once you start the survey, your answers will be saved for up to a week, so you can complete the survey at a later

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date if you wish. The survey will be closed after **7th October 2018.**

Take the survey here

Please be advised that your answers will be used anonymously and no personal information will be made public. However, if you are interested in the results of this study, please fill in your name and email address at the end of the questionnaire and we will send you a summary of the results (early 2019).

Yours sincerely,

Hanne Nijs and Prof Laura Green

Confidentiality and consent:

The responses from all participants will be stored in a secure way and will only be used for the purpose of this research project. The data you provide will be treated confidentially and will not be shared with third parties. All results will be reported anonymously.

Your participation in this study is completely voluntary and you can withdraw your data at any point before reports or publications on this study have been published if you fill in your name at the end of this questionnaire. Please note that withdrawing your data will not be possible if you participate anonymously since we might not be able to trace your submission.

This project has received ethical approval from the Biomedical and Scientific Research Ethics Committee (University of Warwick).

If you have any questions about the project, do not hesitate to contact Hanne Nijs [redacted]

If you want to make a complaint, please contact:

Registrar's Office
University House
University of Warwick
Coventry
CV4 8UW
Complaints@warwick.ac.uk
024 7657 4774

For more information about the research project, please contact:

Hanne Nijs
University of Warwick | School of Life Sciences

Page 2 of 3

Gibbet Hill Campus | Coventry | CV4 7AL
Email: [redacted]

AHDB Beef & Lamb, Stoneleigh Park, Kenilworth, Warwickshire, CV8 2TL

T 02476692051
E comms@ahdb.org.uk
W beefandlamb.ahdb.org.uk

BEEF & LAMB

Appendix 5-4: Beef farmer recording and surveillance of production and disease: email invite for the online survey

Tuesday, September 11, 2018 at 2:53:41 PM British Summer Time

Subject: [TEST]: Beef diseases and productivity survey
Date: Wednesday, August 29, 2018 at 8:43:21 AM British Summer Time
From: *AHDB Levy Payer Communications
To: Emma Walker

Click here if you are having trouble viewing this message.

AHDB

Beef diseases and productivity survey

This project is funded by AHDB Beef & Lamb and The University of Warwick.

September 2018

Dear Sir/Madam,

We are investigating whether sheep and beef cattle farmers in England are interested in a surveillance system where you, the farmer, provide data from your own livestock and receive summarised anonymised information on **diseases and productivity** from your region and nationally.

In this questionnaire, we are asking how you currently record and use information on your livestock and what information on sheep or cattle would be useful to you from a surveillance system.

We appreciate that you are very busy, this questionnaire takes about **15 minutes** to complete. You can use the tabs at the bottom of each section to navigate backwards or forwards while completing the questionnaire. Once you start the survey, your answers will be saved for up to a week, so you can complete the survey at a later

Page 1 of 3

date if you wish. The survey will be closed after 7th **October 2018**.

Take the survey here

Please be advised that your answers will be used anonymously and no personal information will be made public. However, if you are interested in the results of this study, please fill in your name and email address at the end of the questionnaire and we will send you a summary of the results (early 2019).

Yours sincerely,

Hanne Nijs and Prof Laura Green

Confidentiality and consent:

The responses from all participants will be stored in a secure way and will only be used for the purpose of this research project. The data you provide will be treated confidentially and will not be shared with third parties. All results will be reported anonymously.

Your participation in this study is completely voluntary and you can withdraw your data at any point before reports or publications on this study have been published if you fill in your name at the end of this questionnaire. Please note that withdrawing your data will not be possible if you participate anonymously since we might not be able to trace your submission.

This project has received ethical approval from the Biomedical and Scientific Research Ethics Committee (University of Warwick).

If you have any questions about the project, do not hesitate to contact Hanne Nijs [redacted]

If you want to make a complaint, please contact:

Registrar's Office
University House
University of Warwick
Coventry
CV4 8UW
Complaints@warwick.ac.uk
024 7657 4774

For more information about the research project, please contact:

Hanne Nijs
University of Warwick | School of Life Sciences

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Gibbet Hill Campus | Coventry | CV4 7AL
[redacted]

AHDB Beef & Lamb, Stoneleigh Park, Kenilworth, Warwickshire, CV8 2TL

T 02476692051
E comms@ahdb.org.uk
W beefandlamb.ahdb.org.uk

BEEF & LAMB

Appendix 5-5: Sheep farmer recording and surveillance of production and disease: postal invite, reminder and study information

WARWICK
THE UNIVERSITY OF WARWICK

November 2018

Dear Sir/Madam,

At the University of Warwick, we are investigating whether **sheep farmers** in England are interested in a surveillance system for common sheep diseases. In the questionnaire enclosed we are asking how you currently record and use information on your livestock and what information on sheep health from a surveillance system would be useful to you.

We appreciate that you are very busy, this questionnaire takes about **15 minutes** to complete. Please return the completed questionnaire in the freepost envelope provided. There are no right or wrong answers please just answer all the questions as accurately and honestly as you can. Your response is very important to us. We will send two follow up reminders.

Your answers are confidential and will be used anonymously. No personal information will be made public. However, if you are interested in the results of this study, please fill in your email address at the end of the questionnaire so we can send you a summary of the results. Completing this questionnaire is completely **voluntary**. Submission of the questionnaire will be taken as consent to use your data for research purposes only. More information on the ethical approval for this study is provided on the next page of this letter.

This study is funded by **AHDB Beef & Lamb** and the **University of Warwick**. Your contribution to this study is greatly appreciated. If you have any questions about the project, do not hesitate to contact Hanne Nijs [redacted]

Yours sincerely,

Hanne Nijs and Prof Laura Green

Hanne Nijs
School of Life Sciences
University of Warwick
Gibbet Hill Road
Coventry CV4 7AL UK
Email: [redacted]
www.warwick.ac.uk

WARWICK
THE UNIVERSITY OF WARWICK

January 2018

Recording and surveillance of production and disease in sheep

Dear Sir/Madam,

On 23rd November 2018 we invited you to participate in our survey on recording and surveillance of production and disease in sheep. This survey was sent to 1000 sheep farmers in England.

If you have responded recently, thank you for your valuable input. If you have not yet completed the questionnaire we would really value your response, each reply adds to our understanding. The questionnaire takes about 15 minutes to complete. There are no right or wrong answers, please just answer all the questions as accurately and honestly as you can. Your response is very important to us.

Please return the completed questionnaire in the freepost envelope provided.

Your answers are confidential and will be used anonymously. No personal information will be made public. If you are interested in the results of this study, please fill in your email address at the end of the questionnaire so that we can send you a summary of the results. Completing this questionnaire is completely voluntary. Submission of the questionnaire will be taken as consent to use your data for research purposes only. More information on the ethical approval for this study is provided on the next page of this letter.

This study is funded by AHDB and the University of Warwick. Your contribution to this study is greatly appreciated. If you have any questions about the project, do not hesitate to contact Hanne Nijs [redacted]

Yours sincerely,

Hanne Nijs and Prof Laura Green

Hanne Nijs
School of Life Sciences
University of Warwick
Gibbet Hill Road
Coventry CV4 7AL UK
Email: [redacted]
www.warwick.ac.uk

WARWICK
THE UNIVERSITY OF WARWICK

STUDY INFORMATION

Will the information I provide be confidential?
Yes. All information you provide will be completely confidential and used solely for research purposes. No personally identifying data or opinions will be passed to anyone else. During the study data will be securely stored at the University of Warwick and will be accessed only by authorized researchers working on the project. Data will be kept at least 10 years and then destroyed. Data about your farm or management practices will be stored separately from your name or contact details. **If you have any concerns or wish to withdraw your consent for the use of your data, please contact the Information and Data Compliance team:**

Anjeli Bajaj, Data Protection Officer
University House, University of Warwick, Coventry CV4 8UW Tel: [redacted]
Email: [redacted]

Why does the University of Warwick have my name and mailing address?
Your personal information has not been given to the University of Warwick. All questionnaires were printed by a third party working with AHDB Beef and Lamb. Each study participant has been given a unique identification code (printed on the top of their questionnaire), which will be used by the University in all data storage and communications with AHDB. The University of Warwick will not have any of your personal information unless you choose to disclose it to us.

What will be the benefits of this study?
Currently no surveillance system for farmers is in place to monitor endemic diseases in beef cattle and sheep although these diseases cause substantial economic losses. This project investigates the feasibility of on-farm recording of endemic diseases by farmers.

Who is conducting this research?
This research is being carried out by Hanne Nijs and Prof Laura Green at the Universities of Warwick and Birmingham, in cooperation with AHDB Beef & Lamb.

Who is funding this research?
This research is funded by the University of Warwick and AHDB Beef & Lamb.

Who can I contact if I have a question about the study?
If you have any questions about the study then do not hesitate to email Hanne Nijs on [redacted]

Who has reviewed this study?
This study has been reviewed and approved by the University of Warwick's Biomedical and Scientific Research Ethics Committee.

Who can I contact if I wish to make a complaint about my experience participating in this study?
Please contact the Research and Impact Services, who are entirely independent of this study:

Jane Prewett, Head of Research Governance
University House, University of Warwick, Coventry CV4 8UW, Tel: [redacted]
Email: [redacted]

2|2

Appendix 5-6: Beef farmer recording and surveillance of production and disease: postal invite, reminder and study information

November 2018

Dear Sir/Madam,

At the University of Warwick, we are investigating whether **beef farmers** in England are interested in a surveillance system for common cattle diseases. In the questionnaire enclosed we are asking how you currently record and use information on your livestock and what information on cattle health from a surveillance system would be useful to you.

We appreciate that you are very busy, this questionnaire takes about **15 minutes** to complete. Please return the completed questionnaire in the freepost envelope provided. There are no right or wrong answers, please just answer all the questions as accurately and honestly as you can. Your response is very important to us. We will send two follow up reminders.

Your answers are confidential and will be used anonymously. No personal information will be made public. However, if you are interested in the results of this study, please fill in your email address at the end of the questionnaire so we can send you a summary of the results. Completing this questionnaire is completely **voluntary**. Submission of the questionnaire will be taken as consent to use your data for research purposes only. More information on the ethical approval for this study is provided on the next page of this letter.

This study is funded by **AHDB Beef & Lamb** and the **University of Warwick**. Your contribution to this study is greatly appreciated. If you have any questions about the project, do not hesitate to contact Hanne Nijs [redacted]

Yours sincerely,

Hanne Nijs and Prof Laura Green

Hanne Nijs
School of Life Sciences
University of Warwick
Gibbet Hill Road
Coventry CV4 7AL UK
Email: [redacted]
www.warwick.ac.uk

January 2018

Recording and surveillance of production and disease in beef cattle

Dear Sir/Madam,

On 23rd November 2018 we invited you to participate in our survey on recording and surveillance of production and disease in beef cattle. This survey was sent to 1000 beef cattle farmers in England.

If you have responded recently, thank you for your valuable input. If you have not yet completed the questionnaire we would really value your response, each reply adds to our understanding. The questionnaire takes about 15 minutes to complete. There are no right or wrong answers, please just answer all the questions as accurately and honestly as you can. Your response is very important to us.

Please return the completed questionnaire in the freepost envelope provided.

Your answers are confidential and will be used anonymously. No personal information will be made public. If you are interested in the results of this study, please fill in your email address at the end of the questionnaire so that we can send you a summary of the results. Completing this questionnaire is completely voluntary. Submission of the questionnaire will be taken as consent to use your data for research purposes only. More information on the ethical approval for this study is provided on the next page of this letter.

This study is funded by AHDB and the University of Warwick. Your contribution to this study is greatly appreciated. If you have any questions about the project, do not hesitate to contact Hanne Nijs [redacted]

Yours sincerely,

Hanne Nijs and Prof Laura Green

Hanne Nijs
School of Life Sciences
University of Warwick
Gibbet Hill Road
Coventry CV4 7AL UK
Email: [redacted]
www.warwick.ac.uk

STUDY INFORMATION

Will the information I provide be confidential?
Yes. All information you provide will be completely confidential and used solely for research purposes. No personally identifying data or opinions will be passed to anyone else. During the study data will be securely stored at the University of Warwick and will be accessed only by authorized researchers working on the project. Data will be kept at least 10 years and then destroyed. Data about your farm or management practices will be stored separately from your name or contact details. **If you have any concerns or wish to withdraw your consent for the use of your data, please contact the Information and Data Compliance team:**

Anjeli Bajaj, Data Protection Officer
University House, University of Warwick, Coventry CV4 8UW Tel: [redacted]
Email: [redacted]

Why does the University of Warwick have my name and mailing address?
Your personal information has not been given to the University of Warwick. All questionnaires were printed by a third party working with AHDB Beef and Lamb. Each study participant has been given a unique identification code (printed on the top of their questionnaire), which will be used by the University in all data storage and communications with AHDB. The University of Warwick will not have any of your personal information unless you choose to disclose it to us.

What will be the benefits of this study?
Currently no surveillance system for farmers is in place to monitor endemic diseases in beef cattle and sheep although these diseases cause substantial economic losses. This project investigates the feasibility of on-farm recording of endemic diseases by farmers.

Who is conducting this research?
This research is being carried out by Hanne Nijs and Prof Laura Green at the Universities of Warwick and Birmingham, in cooperation with AHDB Beef & Lamb.

Who is funding this research?
This research is funded by the University of Warwick and AHDB Beef & Lamb.

Who can I contact if I have a question about the study?
If you have any questions about the study then do not hesitate to email Hanne Nijs on [redacted]

Who has reviewed this study?
This study has been reviewed and approved by the University of Warwick's Biomedical and Scientific Research Ethics Committee.

Who can I contact if I wish to make a complaint about my experience participating in this study?
Please contact the Research and Impact Services, who are entirely independent of this study:

Jane Prewett, Head of Research Governance
University House, University of Warwick, Coventry CV4 8UW, Tel: [redacted]
Email: [redacted]

Appendix 5-7: Overview of responses by sheep and beef farmers to the online and postal versions of the questionnaire on farmer recording and surveillance of production and disease

A) Sheep farmers: descriptive results from the online questionnaire

The response percentage for the online questionnaire was low: 46/1000 (0.46%) farmers filled in the survey to a certain extent. The useable response percentage was 0.28% (28/1000). All 28 respondents kept both adult sheep and lambs. The median and range of flock sizes is presented in Table A-1. Six (21.4%) respondents farmed both sheep and cattle. Pedigree sheep flocks were kept on 13 (46.4%) farms, 22 (78.6%) respondents kept commercial flocks, and eight (28.6%) had store lambs. Seven (25.0%) flocks were in a health scheme and 16 (57.1%) were members of the AHDB Better Returns Programme (BRP) in 2017.

Table A-1: Median flock size of 28 respondents to the online sheep questionnaire

	Ewes (n)	Lambs (n)	Rams (n)	Total (n)
Median	250	440	9	704
Range	12 - 2100	15 - 3850	2 - 100	38 - 5995

Twenty seven (96.4%) respondents recorded flock data in 2017 and 17 (63.0%) of respondents recorded data electronically to some extent (Table A-2). Twenty six (96.3%) farmers used the data they recorded for decision-making. Twelve (44.4%) farmers also shared their flock data with third parties in 2017.

Table A-2: Recording of sheep health and production data by 28 respondents to the online questionnaire

Specifics on data recording in 2017		Respondents	
		n	%
Type of data recorded (total n = 27):			
	Clinical signs	13	48.2
	Diseases diagnosed	7	25.9
	Production data	25	92.6
	Other	7	25.9
Frequency of electronic data recording on-farm (total n = 17):			
	Daily	4	23.5
	Monthly	3	17.6
	Quarterly	5	29.4
	Annually	2	11.8
	Other	3	17.6
Data shared with third parties (total n = 12):			
	Other farmers	2	16.7
	Veterinarian	8	66.7
	AHDB Beef & Lamb	5	41.7
	Breed societies	4	33.3
	Health scheme	4	33.3
	Other	1	8.3

Table A-3: Number of responses (percentage) on whether farmers agreed surveillance of clinical signs in sheep would be useful for decision-making, the sheep industry, regional or national benchmarking

Purpose	Strongly disagree n (%)	Disagree n (%)	Neither agree nor disagree n (%)	Agree n (%)	Strongly agree n (%)	Not applicable/ Missing n (%)
			Online respondents (n = 28)			
Decision-making	0 (0.0)	0 (0.0)	7 (25.0)	14 (50.0)	6 (21.4)	1 (3.6)
Industry	0 (0.0)	1 (3.6)	2 (7.1)	18 (64.3)	7 (25.0)	0 (0.0)
Benchmark (Regional)	1 (3.6)	2 (7.1)	2 (7.1)	19 (67.9)	4 (14.3)	0 (0.0)
Benchmark (National)	1 (3.6)	2 (7.1	4 (14.3)	19 (67.9)	2 (7.1)	0 (0.0)
			Postal respondents (n = 183)			
Decision-making	2 (1.1)	10 (5.5)	60 (32.8)	90 (49.2)	15 (8.2)	6 (3.3)
Industry	2 (1.1)	4 (2.2)	35 (19.1)	120 (65.6)	20 (10.9)	2 (1.1)
Benchmark (Regional)	3 (1.6)	11 (6.0)	45 (24.6)	95 (51.9)	17 (9.3)	12 (6.6)
Benchmark (National)	2 (1.1)	14 (7.7)	55 (30.1)	86 (47.0)	12 (6.6)	14 (7.7)

Table A-4: Number of responses (percentage) for 28 sheep farmers for the statement 'Please indicate the extent to which you agree that a national/regional benchmark on the clinical signs in sheep listed below would be useful to you as a sheep farmer' (Online questionnaire)

Clinical sign	Strongly disagree n (%)	Disagree n (%)	Neither agree nor disagree n (%)	Agree n (%)	Strongly agree n (%)	Not applicable n (%)
			National benchmark			
Abortion	2 (7.1)	4 (14.3)	4 (14.3)	12 (42.9)	5 (17.9)	1 (3.6)
Lameness	1 (3.6)	4 (14.3)	5 (17.9)	13 (46.4)	4 (14.3)	1 (3.6)
Mastitis	0 (0.0)	3 (10.7)	7 (25.0)	11 (39.3)	6 (21.4)	1 (3.6)
Deaths	1 (3.6)	3 (10.7)	6 (21.4)	14 (50.0)	3 (10.7)	1 (3.6)
Culls	2 (7.1)	2 (7.1)	4 (14.3)	13 (46.4)	6 (21.4)	1 (3.6)
			Regional benchmark			
Abortion	2 (7.1)	1 (3.6)	6 (21.4)	13 (46.4	5 (17.9)	1 (3.6)
Lameness	1 (3.6)	1 (3.6)	5 (17.9)	13 (46.4)	7 (25.0)	1 (3.6)
Mastitis	0 (0.0)	1 (3.6)	5 (17.9)	15 (53.6)	6 (21.4)	1 (3.6)
Deaths	0 (0.0)	1 (3.6)	5 (17.9)	15 (53.6)	6 (21.4)	1 (3.6)
Culls	1 (3.6)	1 (3.6)	6 (21.4)	14 (50.0)	5 (17.9)	1 (3.6)

Table A-5: Number of responses (percentage) for 183 sheep farmers for the statement 'Please indicate the extent to which you agree that a national/regional benchmark on the clinical signs in sheep listed below would be useful to you as a sheep farmer' (Postal questionnaire)

Clinical sign	Strongly disagree n (%)	Disagree n (%)	Neither agree nor disagree n (%)	Agree n (%)	Strongly agree n (%)	Not applicable/ Missing n (%)
			National benchmark			
Abortion	1 (0.5)	16 (8.7)	34 (18.6)	95 (51.9)	20 (10.9)	17 (9.3)
Lameness	2 (1.1)	16 (8.7)	32 (17.5)	93 (50.8)	28 (15.3)	12 (6.6)
Mastitis	2 (1.1)	20 (10.9)	47 (25.7)	75 (41.0)	21 (11.5)	18 (9.8)
Deaths	2 (1.1)	19 (10.4)	49 (26.8)	85 (46.4)	17 (9.3)	11 (6.0)
Culls	2 (1.1)	16 (8.7)	52 (28.4)	84 (45.9)	14 (7.7)	15 (8.2)
			Regional benchmark			
Abortion	1 (0.5)	12 (6.6)	31 (16.9)	91 (49.7)	24 (13.1)	24 (13.1)
Lameness	2 (1.1)	13 (7.1)	33 (18.0)	90 (49.2)	25 (13.7)	20 (10.9)
Mastitis	1 (0.5)	13 (7.1)	45 (24.6)	79 (43.2)	19 (10.4)	26 (14.2)
Deaths	0 (0.0)	18 (9.8)	49 (26.8)	79 (43.2)	16 (8.7)	21 (11.5)
Culls	0 (0.0)	19 (10.4)	51 (27.9)	73 (39.9)	13 (7.1)	27 (14.8)

Table A-6: Number of responses (percentage) on whether farmers agreed surveillance of sheep diseases would be useful for decision-making, the sheep industry, regional or national benchmarking

Purpose	Strongly disagree n (%)	Disagree n (%)	Neither agree nor disagree n (%)	Agree n (%)	Strongly agree n (%)	Not applicable / Missing n (%)
			Online questionnaire (n = 28)			
Decision-making	0 (0.0)	1 (36)	5 (17.9)	16 (57.1)	5 (17.9)	1 (3.6)
Industry	0 (0.0)	0 (0.0)	2 (7.1)	20 (71.4)	6 (21.4)	0 (0.0)
Benchmark (Regional)	1 (3.6)	1 (3.6)	3 (10.7)	16 (57.1)	7 (25.0)	0 (0.0)
Benchmark (National)	1 (3.6)	1 (3.6)	4 (14.3)	19 (67.9)	3 (10.7)	0 (0.0)
			Postal questionnaire (n = 183)			
Decision-making	7 (3.8)	17 (9.3)	51 (27.9)	82 (44.8)	11 (6.0)	15 (8.2)
Industry	4 (2.2)	5 (2.7)	28 (15.3)	113 (61.7)	23 (12.6)	10 (5.5)
Benchmark (Regional)	4 (2.2)	12 (6.6)	36 (19.7)	98 (53.6)	18 (9.8)	15 (8.2)
Benchmark (National)	4 (2.2)	18 (9.8)	44 (24.0)	84 (45.9)	15 (8.2)	18 (9.8)

Table A-7: Number of responses (percentage) for 28 sheep farmers on the question 'Please indicate the extent to which you agree that a national/regional benchmark on the sheep diseases listed below would be useful to you as a sheep farmer' (Online questionnaire)

Sheep disease	Strongly disagree n (%)	Disagree n (%)	Neither agree nor disagree n (%)	Agree n (%)	Strongly agree n (%)	Strongly disagree n (%)
			National benchmark			
Johne's disease	2 (7.1)	5 (17.9)	8 (28.6)	10 (35.7)	3 (10.7)	0 (0.0)
Maedi-Visna	2 (7.1)	6 (21.4)	5 (17.9)	9 (32.1)	6 (21.4)	0 (0.0)
CLA	3 (10.7)	2 (7.1)	8 (28.6)	10 (35.7)	5 (17.9)	0 (0.0)
EAE	2 (7.1)	2 (7.1)	6 (21.4)	12 (42.9)	6 (21.4)	0 (0.0)
Sheep scab	2 (7.1)	4 (14.3)	6 (21.4)	10 (35.7)	6 (21.4)	0 (0.0)
			Regional benchmark			
Johne's disease	1 (3.6)	2 (7.1)	9 (32.1)	8 (28.6)	7 (25.0)	1 (3.6)
Maedi-Visna	2 (7.1)	2 (7.1)	6 (21.4)	10 (35.7)	8 (28.6)	0 (0.0)
CLA	2 (7.1)	3 (10.7)	6 (21.4)	9 (32.1)	8 (28.6)	0 (0.0)
EAE	3 (10.7)	0 (0.0)	6 (21.4)	13 (46.4)	6 (21.4)	0 (0.0)
Sheep scab	1 (3.6)	4 (14.3)	4 (14.3)	11 (39.3)	8 (28.6)	0 (0.0)

Table A-8: Number of responses (percentage) for 28 sheep farmers on the question 'Please indicate the extent to which you agree that a national/regional benchmark on the sheep diseases listed below would be useful to you as a sheep farmer' (Postal questionnaire)

Sheep disease	Strongly disagree n (%)	Disagree n (%)	Neither agree nor disagree n (%)	Agree n (%)	Strongly agree n (%)	Not applicable/ Missing n (%)
			National benchmark			
Johne's disease	4 (2.2)	12 (6.6)	57 (31.1)	70 (38.3)	15 (8.2)	25 (13.7)
Maedi-Visna	5 (2.7)	16 (8.7)	52 (28.4)	71 (38.8)	15 (8.2)	24 (13.1)
CLA	5 (2.7)	13 (.1)	55 (30.1)	76 (41.5)	10 (5.5)	24 (13.1)
EAE	5 (2.7)	10 (5.5)	40 (21.9)	88 (48.1)	22 (12.0)	18 (9.8)
Sheep scab	5 (2.7)	5 (2.7)	28 (15.3)	91 (49.7)	37 (20.2)	17 (9.3)
			Regional benchmark			
Johne's disease	5 (2.7)	10 (5.5)	51 (27.9)	71 (38.8)	21 (11.5)	25 (13.7)
Maedi-Visna	6 (3.3)	13 (7.1)	48 (26.2)	73 (39.9)	18 (9.8)	25 (13.7)
CLA	5 (2.7)	11 (6.0)	51 (27.9)	74 (40.4)	16 (8.7)	26 (14.2)
EAE	5 (2.7)	10 (5.5)	34 (18.6)	89 (48.6)	22 (12.0)	23 (12.6)
Sheep scab	5 (2.7)	5 (2.7)	26 (14.2)	86 (47.0)	37 (20.2)	24 (13.1)

Table A-9: Number of responses (percentage) for 183 sheep farmers on how they would use feedback from a surveillance system for sheep health

'I would use feedback from a surveillance system to…'	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Missing
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Help recognise diseases	1 (0.5)	11 (6.0)	22 (12.0)	111 (60.7)	23 (12.6)	15 (8.2)
Reduce the risk of buying in diseased animals	3 (1.6)	11 (6.0)	16 (8.7)	103 (56.3)	32 (17.5)	18 (9.8)
Track diseases in my area	3 (1.6)	12 (6.6)	30 (16.4)	100 (54.6)	21 (11.5)	17 (9.3)
Reduce economic losses	4 (2.2)	9 (4.9)	39 (21.3)	91 (49.7)	23 (12.6)	17 (9.3)
Increase production	4 (2.2)	11 (6.0)	46 (25.1)	87 (47.5)	16 (8.7)	19 (10.4)
Help demonstrate freedom from disease	6 (3.3)	20 (10.9)	52 (28.4)	61 (33.3)	20 (10.9)	24 (13.1)
Increase understanding of diseases	3 (1.6)	4 (2.2)	28 (15.3)	111 (60.7)	24 (13.1)	13 (7.1)
New threats	3 (1.6)	2 (1.1)	18 (9.8)	117 (63.9)	32 (17.5)	11 (6.0)
Receive advice	2 (1.1)	5 (2.7)	20 (10.9)	117 (63.9)	26 (14.2)	13 (7.1)

Table A-10: Number of responses (percentage) for 183 sheep farmers on whether they agree the data sources listed have useful data for sheep health surveillance

Data source	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable /Missing
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Abattoir	4 (2.2)	9 (4.9)	42 (23.0)	101 (55.2)	15 (8.2)	12 (6.6)
Post mortem examiners	0 (0.0)	4 (2.2)	29 (15.8)	112 (61.2)	27 (14.8)	11 (6.0)
Laboratories	0 (0.0)	2 (1.1)	46 (25.1)	101 (55.2)	22 (12.0)	12 (6.6)
Health schemes	0 (0.0)	8 (4.4)	58 (31.7)	98 (53.6)	9 (4.9)	10 (5.5)
Veterinarians	0 (0.0)	3 (1.6)	45 (24.6)	100 (54.6)	24 (13.1)	11 (6.0)

Table A-11: Number of responses (percentage) for 183 sheep farmers on where farmers had received useful feedback from in 2017

Feedback from	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable/ Missing
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Abattoir	10 (5.5)	25 (13.7)	29 (15.8)	37 (20.2)	4 (2.2)	78 (42.6)
Post mortem examiners	5 (2.7)	14 (7.7)	26 (14.2)	40 (21.9)	5 (2.7)	93 (50.8)
Laboratories	2 (1.1)	17 (9.3)	19 (10.4)	38 (20.8)	7 (3.8)	100 (54.6)
Health schemes	2 (1.1)	16 (8.7)	30 (16.4)	17 (9.3)	4 (2.2)	114 (62.3)
Veterinarians	3 (1.6)	8 (4.4)	19 (10.4)	93 (50.8)	18 (9.8)	42 (23.0)

Table A-12: Number of responses (percentage) for 183 sheep farmers on the usefulness of different channels to provide feedback

Information via	Very undesirable	Undesirable	Neutral	Desirable	Very desirable	Not applicable/ Missing
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Webpage	5 (2.7)	10 (5.5)	55 (30.1)	46 (25.1)	18 (9.8)	49 (26.8)
Email	6 (3.3)	10 (5.5)	34 (18.6)	73 (39.9)	18 (9.8)	42 (23.0)
App	9 (4.9)	24 (13.1)	46 (25.1)	21 (11.5)	12 (6.6)	71 (38.8)
Paper	3 (1.6)	10 (5.5)	44 (24.0)	89 (48.6)	18 (9.8)	19 10.4)

B) Beef farmers: descriptive results from the online questionnaire

The response percentage was lower than the online sheep farmer questionnaire: 32/1000 (0.32%) farmers filled in the online survey to some extent. However, the useable response percentage was only 0.20% (20/1000). Respondents from 14 English ceremonial counties contributed. Six (6/20 or 30.0%) respondents kept beef cattle and sheep. On 2/20 (10.0%) farms, sheep, beef and dairy cattle were kept. Nine (45.0%) respondents were members of a health scheme, whereas ten (50.0%) farmers were members of the BRP in 2017. Median herd size is presented in Table B-1.

Table B-1: Herd size (online questionnaire)

	Sucklers (n)	Finishers (n)	Dairy (n)	Bulls (n)	Calves (n)	Total (n)
Median	50	42.5	87.5	5	40	134
Range	3 - 400	3 - 250	45 - 130	1 – 80	3 - 360	9 - 1025
Respondents n (%)	17 (85.0%)	16 (80.0%)	2 (10.0%)	15 (75.0%)	19 (95.0%)	20 (100%)

Eighteen (90.0%) online respondents said they recorded data on their cattle in 2017 (Table B-2). All 18 respondents used the data recorded for decision-making on their farm and 12 (66.7%) of them recorded electronically to some extent. Ten (55.6%) farmers shared their herd data with others.

Table B-2: Recording of cattle health and production data by 20 respondents to the online questionnaire

Specifics on data recording in 2017	Respondents	
	n	%
Type of data recorded (total n = 18):		
Clinical signs	9	50.0
Diseases diagnosed	11	61.1
Production data	16	88.9
Other	3	16.7
Frequency of electronic data recording on-farm (total n = 12):		
Weekly	4	33.3
Monthly	4	33.3
Annually	1	8.3
Other	3	25.0
Data shared with third parties (total n = 10):		
Other farmers	3	30.0
Veterinarian	9	90.0
AHDB Beef & Lamb	1	10.0
Breed societies	3	30.0
Health scheme	4	40.0
Other	4	40.0

Table B-3: Number of responses (percentage) on whether farmers agreed surveillance of clinical signs in beef cattle would be useful for decision-making, the cattle industry, regional or national benchmarking

Purpose	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable/ Missing
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
			Online respondents (n = 20)			
Decision-making	0 (0.0)	1 (5.0)	4 (20.0)	11 (55.0)	4 (20.0)	0 (0.0)
Industry	0 (0.0)	0 (0.0)	0 (0.0)	10 (50.0)	10 (50.0)	0 (0.0)
Benchmark (Regional)	0 (0.0)	1 (5.0)	2 (10.0)	12 (60.0)	5 (25.0)	0 (0.0)
Benchmark (National)	0 (0.0)	3 (15.0)	1 (5.0)	13 (65.0)	3 (15.0)	0 (0.0)
			Postal respondents (n = 139)			
Decision-making	3 (2.2)	11 (7.9)	53 (38.1)	60 (43.2)	7 (5.0)	5 (3.6)
Industry	2 (1.4)	9 (6.5)	28 (20.1)	86 (61.9)	11 (7.9)	3 (2.2)
Benchmark (Regional)	4 (2.9)	14 (10.1)	36 (25.9)	69 (49.6)	9 (6.5)	7 (5.0)
Benchmark (National)	3 (2.2)	20 (14.4)	43 (30.9)	63 (45.3)	5 (3.6)	5 (3.6)

Table B-4: Number of responses (percentage) for 20 beef cattle farmers for the statement 'Please indicate the extent to which you agree that a national/regional benchmark on the clinical signs in cattle listed below would be useful to you as a cattle farmer' (Online questionnaire)

Clinical sign	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
			National benchmark			
Abortion	2 (10.0)	1 (5.0)	6 (30.0)	6 (30.0)	4 (20.0)	1 (5.0)
Pneumonia	0 (0.0)	2 (10.0)	6 (30.0)	8 (40.0)	3 (15.0)	1 (5.0)
Mastitis	2 (10.0)	3 (15.0)	6 (30.0)	6 (30.0)	2 (10.0)	1 (5.0)
Deaths	2 (10.0)	1 (5.0)	5 (25.0)	7 (35.0)	5 (25.0)	0 (0.0)
Culls	2 (10.0)	1 (5.0)	6 (30.0)	8 (40.0)	2 (10.0)	1 (5.0)
			Regional benchmark			
Abortion	1 (5.0)	0 (0.0)	7 (35.0)	7 (35.0)	4 (20.0)	1 (5.0)
Pneumonia	2 (10.0)	0 (0.0)	5 (25.0)	8 (40.0)	4 (20.0)	1 (5.0)
Mastitis	2 (10.0)	3 (15.0)	5 (25.0)	6 (30.0)	3 (15.0)	1 (5.0)
Deaths	2 (10.0)	1 (5.0)	7 (35.0)	5 (25.0)	5 (25.0)	0 (0.0)
Culls	2 (10.0)	0 (0.0)	6 (30.0)	8 (40.0)	3 (15.0)	1 (5.0)

Table B-5: Number of responses (percentage) for 139 beef cattle farmers for the statement 'Please indicate the extent to which you agree that a national/regional benchmark on the clinical signs in cattle listed below would be useful to you as a cattle farmer' (Postal questionnaire)

Clinical sign	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable/ Missing
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
			National benchmark			
Abortion	5 (3.6)	10 (7.2)	26 (18.7)	57 (41.0)	9 (6.5)	32 (23.0)
Pneumonia	5 (3.6)	10 (7.2)	19 (13.7)	78 (56.1)	19 (13.7)	8 (5.8)
Mastitis	3 (2.2)	9 (6.5)	42 (30.2)	38 (27.3)	8 (5.8)	39 (28.1)
Deaths	4 (2.9)	9 (6.5)	42 (30.2)	64 (46.00	7 (5.0)	13 (9.4)
Culls	5 (3.6)	12 (8.6)	36 (25.9)	54 (38.8)	6 (4.3)	26 (18.7)
			Regional benchmark			
Abortion	4 (2.9)	6 (4.3)	28 (20.1)	54 (38.8)	12 (8.6)	35 (25.2)
Pneumonia	3 (2.2)	7 (5.0)	24 (17.3)	75 (54.0)	18 (12.9)	12 (8.6)
Mastitis	2 (1.4)	9 (6.5)	40 (28.8)	35 (25.2)	9 (6.5)	44 (31.7)
Deaths	4 (2.9)	6 (4.3)	45 (32.4)	57 (41.0)	10 (7.2)	17 (12.2)
Culls	3 (2.2)	8 (5.8)	39 (28.1)	51 (36.7	8 (5.8)	30 (21.6)

Table B-6: Number of responses (percentage) on whether farmers agreed surveillance of cattle diseases would be useful for decision-making, the cattle industry, regional or national benchmarking

Purpose	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable/ Missing
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
			Online respondents (n = 20)			
Decision-making	0 (0.0)	2 (10.0)	4 (20.0)	9 (45.0)	5 (25.0)	0 (0.0)
Industry	0 (0.0)	0 (0.0)	1 (5.0)	12 (60.0)	7 (35.0)	0 (0.0)
Benchmark (Regional)	0 (0.0)	1 (5.0)	0 (0.0)	13 (65.0)	6 (30.0)	0 (0.0)
Benchmark (National)	0 (0.0)	1 (5.0)	1 (5.0)	14 (70.0)	3 (15.0)	1 (5.0)
			Postal respondents (n = 139)			
Decision-making	4 (2.9)	18 (12.9)	44 (31.7)	62 (44.6)	2 (1.4)	9 (6.5)
Industry	3 (2.2)	7 (5.0)	28 (20.1)	90 (64.7)	5 (3.6)	6 (4.3)
Benchmark (Regional)	3 (2.2)	19 (13.7)	33 (23.7)	68 (48.9)	8 (5.8)	8 (5.8)
Benchmark (National)	3 (2.2)	23 (16.5)	40 (28.8)	59 (42.4)	5 (3.6)	9 (6.5)

Table B-7: Number of responses (percentage) for 20 cattle farmers on the question 'Please indicate the extent to which you agree that a national/regional benchmark on the cattle diseases listed below would be useful for you as a cattle farmer' (Online questionnaire)

Cattle disease	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
			National surveillance			
Johne's disease	1 (5.0)	1 (5.0)	2 (10.0)	8 (40.0)	7 (35.0)	1 (5.0)
bTB	1 (5.0)	1 (5.0)	5 (25.0)	5 (25.0)	8 (40.0)	0 (0.0)
Leptospirosis	1 (5.0)	1 (5.0)	3 (15.0)	8 (40.0)	6 (30.0)	1 (5.0)
BVD	1 (5.0)	1 (5.0)	0 (0.0)	11 (55.0)	7 (35.0)	0 (0.0)
Fasciolosis	1 (5.0)	0 (0.0)	5 (25.0)	8 (40.0)	6 (30.0)	0 (0.0)
			Regional surveillance			
Johne's disease	0 (0.0)	2 (10.0)	2 (10.0)	8 (40.0)	7 (35.0)	1 (5.0)
bTB	0 (0.0)	1 (5.0)	2 (10.0)	7 (35.0)	10 (50.0)	0 (0.0)
Leptospirosis	0 (0.0)	2 (10.0)	4 (20.0)	5 (25.0)	8 (40.0)	1 (5.0)
BVD	0 (0.0)	2 (10.0)	0 (0.0)	9 (45.0)	9 (45.0)	0 (0.0)
Fasciolosis	0 (0.0)	2 (10.0)	3 (15.0)	6 (30.0)	9 (45.0)	0 (0.0)

Table B-8: Number of responses (percentage) for 139 cattle farmers on the question 'Please indicate the extent to which you agree that a national/regional benchmark on the cattle diseases listed below would be useful for you as a cattle farmer' (Postal questionnaire)

Cattle disease	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
			National surveillance			
Johne's disease	2 (1.4)	11 (7.9)	33 (23.7)	60 (43.2)	20 (14.4)	13 (9.4)
bTB	5 (3.6)	9 (6.5)	29 (20.9)	56 (40.3)	32 (23.0)	8 (5.8)
Leptospirosis	3 (2.2)	9 (6.5)	44 (31.7)	54 (38.8)	14 (10.1)	15 (10.8)
BVD	2 (1.4)	7 (5.0)	30 (21.6)	66 (47.5)	21 (15.1)	13 (9.4)
Fasciolosis	2 (1.4)	8 (5.8)	32 (23.0)	68 (48.9)	18 (12.9)	11 (7.9)
			Regional surveillance			
Johne's disease	3 (2.2)	6 (4.3)	24 (17.3)	69 (49.6)	21 (15.1)	16 (11.5)
bTB	3 (2.2)	4 (2.9)	19 (13.7)	66 (47.5)	34 (24.5)	13 (9.4)
Leptospirosis	3 (2.2)	7 (5.0)	32 (23.0)	63 (45.3)	17 (12.2)	17 (12.2)
BVD	3 (2.2)	5 (3.6)	23 (16.5)	72 (51.8)	21 (15.1)	15 (10.8)
Fasciolosis	3 (2.2)	5 (3.6)	22 (15.8)	72 (51.8)	22 (15.8)	15 (10.8)

Table B-9: Number of responses (percentage) for 139 cattle farmers on how they would use feedback from a surveillance system for cattle health

'I would use feedback from a surveillance system to…'	Strongly disagree n (%)	Disagree n (%)	Neither agree nor disagree n (%)	Agree n (%)	Strongly agree n (%)	Missing n (%)
Help recognise diseases	2 (1.4)	10 (7.2)	27 (19.4)	81 (58.3)	12 (8.6)	7 (5.0)
Track diseases in my area	2 (1.4)	8 (5.8)	30 (21.6)	75 (54.50)	13 (9.4)	11 (7.9)
Increase my understanding of diseases	3 (2.2)	6 (4.3)	19 (13.7)	85 (61.2)	19 (13.7)	7 (5.0)
Help demonstrate freedom from disease	3 (2.2)	15 (10.8)	35 (25.2)	54 (38.8)	14 (10.1)	18 (12.9)
Reduce the risk of buying in diseased animals	3 (2.2)	10 (7.2)	17 (12.2)	68 (48.9)	20 (14.4)	21 (15.1)
Reduce economic losses	2 (1.4)	10 (7.2)	31 (22.3)	72 (51.8)	16 (11.5)	8 (5.8)
Increase production	3 (2.2)	19 (13.7)	34 (24.5)	58 (41.7)	12 (8.6)	13 (9.4)
New threats	2 (1.4)	4 (2.9)	12 (8.6)	94 (67.6)	21 (15.1)	6 (4.3)
Receive advice	2 (1.4)	6 (4.3)	22 (15.8)	80 (57.6)	21 (15.1)	8 (5.8)

Table B-10: Number of responses (percentage) for 139 beef cattle farmers on whether they agree the data sources listed have useful data for cattle health surveillance

Data source	Strongly disagree n (%)	Disagree n (%)	Neither agree nor disagree n (%)	Agree n (%)	Strongly agree n (%)	Not applicable /Missing n (%)
Abattoir	1 (0.7)	2 (1.4)	15 (10.8)	90 (64.7)	23 (16.5)	8 (5.8)
Post mortem examiners	0 (0.0)	1 (0.7)	17 (12.2)	88 (63.3)	22 (15.8)	11 (7.9)
Laboratories	1 (0.7)	1 (0.7)	29 (20.9)	81 (58.3)	18 (12.9)	9 (6.5)
Health schemes	0 (0.0)	7 (5.0)	37 (26.6)	72 (51.8)	14 (10.1)	9 (6.5)
Veterinarians	0 (0.0)	2 (1.4)	21 (15.1)	85 (61.2)	24 (17.3)	7 (5.0)

Table B-11: Number of responses (percentage) for 139 beef cattle farmers on where farmers had received useful feedback from in 2017

Feedback from	Strongly disagree n (%)	Disagree n (%)	Neither agree nor disagree n (%)	Agree n (%)	Strongly agree n (%)	Not applicable/ Missing n (%)
Abattoir	1 (0.7)	14 (10.1)	23 (16.5)	48 (34.5)	13 (9.4)	40 (28.8)
Post mortem examiners	0 (0.0)	9 (6.5)	21 (15.1)	21 (15.1)	6 (4.3)	82 (59.0)
Laboratories	0 (0.0)	7 (5.0)	20 (14.4)	30 (21.6)	13 (9.4)	69 (49.6)
Health schemes	1 (0.7)	11 (7.9)	30 (21.6)	18 (12.9)	7 (5.0)	72 (51.8)
Veterinarians	0 (0.0)	4 (2.9)	17 (12.2)	77 (55.4)	21 (15.1)	20 (14.4)

Table B-12: Number of responses (percentage) for 139 beef cattle farmers on the usefulness of different channels to provide feedback

Information via	Very undesirable n (%)	Undesirable n (%)	Neutral n (%)	Desirable n (%)	Very desirable n (%)	Not applicable/ Missing n (%)
Webpage	5 (3.6)	8 (5.8)	38 (27.3)	47 (33.8)	7 (5.0)	34 (24.5)
Email	4 (2.9)	8 (5.8)	28 (20.1)	52 (37.4)	18 (12.9)	29 (20.9)
App	10 (7.2)	27 (19.4)	30 (21.6)	24 (17.3)	6 (4.3)	42 (30.2)
Paper	5 (3.6)	18 (12.9)	37 (26.6)	49 (35.3)	14 (10.1)	16 (11.5)

Appendix 5-8: Sheep farmers: individual Likert item loadings onto components

Likert-item	Component			
	PC1	PC2	PC3	PC4
MV (Nat)	0.907			
CLA (Reg)	0.888			
MV (Reg)	0.886			
JD (Nat)	0.839			
JD (Reg)	0.834			
EAE (Reg)	0.816			
CLA (Nat)	0.812			
EAE (Nat)	0.766			
Sheep scab (Reg)	0.674			
Sheep scab (Nat)	0.626		*(0.318)*	
Lameness (Reg)		0.920		
Deaths (Reg)		0.916		
Mastitis (Reg)		0.846		
Lameness (Nat)		0.828		
Culls (Reg)		0.813		
Abortion (Reg)		0.741		
Deaths (Nat)		0.728		
Mastitis (Nat)		0.672		
Culls (Nat)		0.638		*(0.320)*
Abortion (Nat)		0.609		
Increase understanding			0.922	
New threats			0.850	
Reduce risk buying diseases			0.822	
Advice			0.816	
Reduce economic losses			0.796	
Increase production			0.777	
Recognise diseases			0.761	
Track diseases			0.732	
Freedom from disease			0.627	
Dx Industry				0.848
Dx Decision-making				0.798
CS Industry				0.769
CS Benchmark (Nat)				0.719
CS Decision-making				0.706
Dx Benchmark (Nat)				0.700
CS Benchmark (Reg)				0.561
Dx Benchmark (Reg)				0.555

'Nat' = national; 'Reg' = regional; 'Dx' = diseases diagnosed; 'CS' = clinical signs

Appendix 5-9: Beef farmers: individual Likert item loadings onto components

Likert-item	Component			
	PC1	PC2	PC3	PC4
JD (Nat)	0.900			*(0.308)*
JD (Reg)	0.897			
Leptospirosis (Nat)	0.875			
Leptospirosis (Reg)	0.872			
BVD (Reg)	0.866			
BVD (Nat)	0.862			
bTB (Reg)	0.837			
bTB (Nat)	0.720			
Fluke (Reg)	0.530			
Dx Benchmark (Reg)	0.341			
Reduce economic losses		0.916		
Track diseases		0.896		
Freedom from disease		0.774		
Reduce risk buying diseases		0.749		
Advice		0.728		
Increase understanding		0.724		
New threats		0.712		
Recognise diseases		0.674		
Mastitis (Reg)			1.004	
Culls (Reg)			0.982	
Deaths (Reg)			0.971	
Pneumonia (Reg)			0.742	
Culls (Nat)			0.720	
Abortion (Reg)			0.634	
CS Decision-making				0.861
Dx Decision-making				0.780
CS Industry				0.681
Dx Benchmark (Nat)	*(0.380)*			0.581
CS Benchmark (Nat)				0.517
CS Benchmark (Reg)				0.484

'Nat' = national; 'Reg' = regional; 'Dx' = diseases diagnosed; 'CS' = clinical signs