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Evaluation of the usefulness at national level of the dairy cattle health and production recording systems in Great Britain

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Abstract

The aim of this study was to formally evaluate, qualitatively, the ability of existing recording systems to generate accurate and reliable estimates of the frequency of selected health conditions in the dairy herd of Great Britain (GB). Fifty-nine recording systems were identified of which 36 had their key characteristics defined through a web-based questionnaire. Nineteen of them were further assessed following the SERVAL surveillance evaluation framework against a set of 12 attributes: benefit; bias; communication; coverage; data collection; data

management; data analysis; data completeness; flexibility; multiple utility; representativeness; and stability/sustainability. The evaluated systems showed considerable differences in their coverage, implementation and objectives. There were overlaps in recorded conditions, with Johne's disease, bovine viral diarrhoea, mastitis and lameness being recorded by most of the systems. Selection bias, data ownership and lack of integration of data from different systems appeared to be a key limitation on the future use of existing systems for nationwide monitoring. The results showed that even though the individual systems can provide reliable estimates of dairy health for individual farmers, none of the systems alone could provide accurate and reliable estimates for any of the conditions of interest at national level.

Keywords: evaluation, surveillance, health and production, monitoring, dairy cattle

Introduction

Animal health surveillance has become a keystone of veterinary disease control (Doherr and Audige 2001; O'Neill and others 2014). It can be defined as "the systematic, continuous or repeated measurement, collection, collation, analysis, interpretation and timely dissemination of animal health and welfare related data from defined populations" (Hoinville and others 2013; Drewe and others 2015). To protect animal and human health, good surveillance needs to be in place to allow appropriate actions to be taken to control any potential risks quickly and effectively (Drewe and others 2015).

In Great Britain (GB), dairy farming is well established and dairy production significantly contributes to overall agricultural production. Good quality data at national level are therefore needed to support and inform continuous improvements in dairy cattle health and production. In GB, currently there is no centralised recording system for cattle health and production. Several systems are being used, both private and public, but they are not integrated (Drewe and others 2014). For these systems to be effective at national level, the data need to be reliable and accurate; reliability can be defined as the ability to function without failure and accuracy in terms of completeness and correctness (Drewe and others 2015). For this, the denominator population at risk needs to be well defined; disease diagnosis needs to be valid and recording systems need to be sustainable. Limitations to any of these criteria introduce bias and variability in data making them unreliable and unsuitable for general application (Doherr and Audige 2001; O'Neill and others 2014). Bias can be defined as "the extent to which the prevalence estimate produced by the surveillance system deviates from the value of the true prevalence" (Drewe and others 2015) and most commonly include selection bias, information bias and confounding.

In GB, there has been lot of effort made to improve recording of dairy cattle health and production information. This is exemplified by the implementation of herd health plans by individual farmers (Main and Cartledge 2000; Sibley 2000) and more recently through the implementation of strategies for effective surveillance and recording at national level, driven by the government and dairy industry (DEFRA 2011; NFU 2011; AHVLA 2013). Despite these efforts, most of the databases holding information on cattle health are currently not designed for multiple uses by different organisations and lack of integration of the systems can result in the same information being collected several times increasing the cost of surveillance or research (Drewe and others 2014). Inconsistent standards in recording and limited information on the type and quality of data preclude integration and comparison between data sources (Stärk and Nevel 2009; Drewe and others 2014).

Usefulness of the existing health and production data for veterinary surveillance, research and advisory work is well recognised (Espetvedt and others 2013). In contrast, the attention given to the assessment of the recording systems is modest. To maximise the use of existing data, aspects of the recording system such as data quality, system processes (i.e. data collection, data management, data analysis) and function (i.e. stability and sustainability, flexibility) need to be understood, making the evaluation of the systems crucial (Salman and others 2003; Stärk and Nevel 2009; Mörk and others 2010; Drewe and others 2012; Hoinville and others 2013). Formal evaluation of data quality of Nordic cattle databases has recently been carried out (Mörk and others 2010; Espetvedt and others 2012; Lind and others 2012a; Lind and others 2012b; Rintakoski and others 2012; Wolff and others 2012; Espetvedt and others 2013). Data quality has been assessed in terms of completeness and correctness. Further examples of such studies include, investigation of the quality of the Cattle Tracing System data in GB in terms of known errors, omissions and their distribution (Green and Kao 2007), and completeness and correctness of the Swiss dairy cattle database (Menendez and others 2008).

Different procedures have been proposed for the evaluation of surveillance systems in human and animal health (CDC 2001; Hendrikx and others 2011; Drewe and others 2015). For the latter, a comprehensive evaluation framework called SERVAL was recently developed. Such framework allows evaluation of various surveillance objectives against a set of attributes (Drewe and others 2015). The aim of this study was to formally evaluate, qualitatively, the usefulness of existing dairy health and production recording systems as a national data resource to generate accurate and reliable nationwide estimates of the frequency of diseases/health conditions deemed to be important to farmers and the industry.

Materials and Methods

Identification of relevant health issues

Specific health issues deemed to be important to farmers and the industry where identified, discussed and ranked in a workshop held at the Royal Veterinary College in London on 26 April 2012. The attendees (15 participants) were representatives from the dairy industry, academia and cattle health experts and were selected because of their knowledge of the dairy industry, cattle health or disease surveillance. More detailed information on constituencies represented, including the number of participants and their specialism is provided in Table 1. During the workshop the participants were asked, first, to identify relevant "dairy cattle health issues" within four broad areas: 1) infectious and parasitic diseases, 2) production, metabolic or nutrition related conditions, 3) fertility related conditions, 4) other issues (e.g. public health related); and, second, to identify important health issues for which having accurate up to date estimates would be of value for the industry as a whole and for individual farmers. A "health issue" was considered a "priority" when two thirds or more of participants considered it to be

104 "important". Other health issues that were considered to be important by at least one third of
105 participants were identified as "relevant".

106 **Identification of relevant recording systems**

107 "Relevant recording systems" were defined as systems (private or public) which potentially
108 hold data repositories used for ongoing collection and storage of dairy health and production
109 data in relation to health issues deemed to be "important". Relevant systems were identified
110 through the workshop and subsequent discussions and meetings with industry and cattle health
111 experts.

112 **Evaluation framework**

113 Individual recording systems identified were evaluated using a framework (Figure 1), which is
114 an adaptation of the SERVAL surveillance evaluation framework (Drewe and others 2015)
115 against a set of 12 attributes: benefit, bias, communication, coverage, data collection, data
116 management, data analysis, data completeness, flexibility, multiple utility, representativeness,
117 and stability/sustainability. The attributes were grouped according to the aspect of the systems
118 they evaluated (Hoinville and others 2013). A more detailed description of the attributes and
119 the type of information collected for their evaluation is presented in Table 2.
120
121 The first stage of the evaluation was carried out for all identified recording systems by means
122 of a web-based questionnaire administered to data holders with knowledge of the recording
123 system in order to assess: i) whether a specific condition/disease of interest was currently
124 recorded; ii) how frequently; iii) at what level (individual cow versus herd); iv) the number of
125 farms/animals included in the database; v) the geographic coverage; and vi) whether the data
126 were primary or secondary. Primary data were considered as data collected by individual
127 systems themselves or people working with them (i.e. farmers, veterinarians, technicians) and

can include for example: farm records, laboratory results, or post-mortem results; and secondary data: data received or imported from other existing recording system(s) with no control over original data collection and used for other purposes than originally collected. The second stage of the evaluation of the recording systems, which was based on data gathered during telephone interviews with data administrators, was carried out only for those systems that: i) record one or more conditions of interest; ii) involve regular (as opposed to one-off) recording; and iii) include at least some primary data (as opposed to secondary data only). For the telephone interviews a questionnaire was developed that allowed for the administrators to be interviewed in a standardised manner. Both, telephone interviews and web-based questionnaires were preceded by extensive interaction with those involve in the system to ensure the objectives were clear and the appropriate individuals were identified. For data holders who were no longer willing to participate in the telephone interview, publicly available information (found on their respective websites) and information from colleagues who had some knowledge on respective systems was used.

Data analysis and attribute assessment

Information on individual attributes was summarised qualitatively and the attributes were assessed using a coloured "traffic light" system as: a) green - excellent or very good; b) orange - good, though room for improvement; c) red - poor, in need of attention (Drewe and others 2015). Each of the categories was defined to facilitate more consistent assessment of attributes such as data collection, data management and data analysis (Table 3). All the attributes were assessed by a single assessor (the first author). Therefore for purpose of validation, a second assessor evaluated independently five attributes for three different systems.

Usefulness of recorded data for use at national level

The usefulness of the recorded data at national level was assessed in terms of the ability of the system to provide both accurate and reliable estimates of health conditions deemed to be important, rather than in terms of internal data quality. Reliability can be defined as the ability to function without failure and accuracy in terms of completeness and correctness (Table 2). The aspects (and respective attributes) of the recording systems used for the assessment of the reliability included: system processes, system performance and system function and for the assessment of accuracy: system processes, inclusion and evidence quality (Table 2). Recorded data were considered reliable and accurate as a national data resource if the individual systems had data collection processes clearly defined and stable to ensure consistency over time, reflected any changes in performance, data were recorded in sufficient detail (include information such as production type, and herd size to avoid duplications and to allow representativeness to be assessed) and were without bias. The outcome of the assessment of individual attributes was used to evaluate system reliability and accuracy. The recorded data were categorised as very reliable and very accurate – green colour (attributes were assessed as green), reliable and accurate – orange colour (attributes were assessed as green and orange or orange only) or not reliable and not accurate – red colour (attributes were assessed as red and orange or red only). Due to the commercial value of some of the systems and confidentiality agreements with the clients, no access to the original data was obtained. To preserve anonymity of individual systems, the results of the assessments were combined according to the type of the recording system. For example all consulting companies were assessed together.

The project was approved by the Ethics and Welfare committee at the Royal Veterinary College (approval number URN 2013 0097H).

Results

Thirty-nine health conditions were considered during the workshop of which 29 (nine infectious, 10 production, metabolic or nutrition-related and 10 fertility-related conditions) were identified as priorities or relevant either to the industry or farmers (Table 4). Fifty-nine relevant systems were identified of which data were collected from 36 via web-based questionnaires (61 per cent). Nineteen of them regularly recorded all or some primary data on at least one condition of interest and were therefore selected for telephone interviews and subsequent evaluation (3/3 milk recording companies, 2/2 government and private laboratories, 4/4 accredited health schemes, 5/7 consulting companies, 1/4 genetic companies, 2/4 retailers, 0/1 farm assurance scheme, 0/4 dairy industry and 2/7 other data sources). Two data holders chose not to participate in the telephone interview and therefore only publicly available information was used for their evaluation.

Characteristics of the evaluated recording systems

All 19 evaluated systems indicated recording health data, 11 (58 per cent) reproduction and fertility and nine (47 per cent) milk production data. The majority of the systems (11/19) recorded data at both individual animal and herd level, four at animal level only and four at herd level only. Farm and/or laboratory records were the main source of data for 16 of them. Fourteen of the systems held only primary health and production data and five held both primary and secondary data. Seventeen systems collected data from all GB regions although three of them indicated that some regions might be more represented than others; only two collected data exclusively from specific region(s). The main characteristics of the systems evaluated are presented in Figure 2. Table 5 summarises the recording of the important health condition by the type of the recording system.

Health data recorded

198 Health conditions such as Johne's disease, bovine viral diarrhoea - BVD, mastitis and lameness
199 were directly recorded by most of the evaluated systems (14, 13, 13 and 13 respectively), Fig
200 2. There was also a strong focus on fertility conditions such as calving problems and metabolic
201 conditions such as ketosis and milk fever. The least commonly recorded conditions included
202 salmonellosis (4 recording systems), and ectoparasites (5 recording systems), Fig 2.

203 **Evaluation of the recording systems at national level**

204 The results of the qualitative assessment of reliability and accuracy of the systems are presented
205 in Table 6. The results showed that none of the systems alone could provide accurate and
206 reliable estimates for any of the conditions of interest at national level. The systems varied
207 considerably in terms of level of recording, design and implementation. Apart from one system
208 focusing on the eradication of BVD in Scotland, all the systems obtained the health information
209 on a voluntary basis. All the recording systems were fully electronic with data quality control
210 in place and standard procedures for data collection. Voluntary participation, lack of
211 completeness, coverage and standardisation were common weaknesses of the systems. More
212 information on the recording systems is provided below.

213 **Milk recording companies**

214 Health and production information was recorded at the level of individual cow and herd.
215 Completeness of the health records varied between different herds depending on farmers'
216 requirements with recording of mastitis being the most complete. The recorded data were an
217 aggregation of data captured on farms either by trained field technicians or farmers themselves
218 combined with the laboratory data. High specificity was assured by laboratory testing, for
219 example for mastitis, Johne's disease and BVD within each of them. Variation in recording by
220 individual producers for health conditions for which no laboratory confirmation is obtained
221 was likely.

Laboratory data

One government and one private laboratory provided a well-established service based on laboratory testing to their customers. Records mainly included the presenting signs and diagnosis of disease. The weakness is that the sample submission was customer-dependent and therefore likely to under-represent the number of cases. Due to under-reporting and unknown representativeness of the dairy cattle population, the use of these data to make inferences at national level would be limited. On the other hand, an advantage of these systems was that agreed criteria must be met for any diagnosis to be recorded.

Herd health schemes

The main aim of these schemes was to control major endemic disease of dairy cattle including; Johne's disease, BVD, leptospirosis and infectious bovine rhinotracheitis (IBR). Frequency and type of testing was customer dependent therefore completeness of the records varied. Integration of these data would increase the coverage of the dairy cattle population and could be used to supplement passive disease surveillance data. Participation in the schemes was voluntary except for Scottish Government BVD eradication scheme which was mandatory for all cattle producers in Scotland providing reliable estimates of BVD at regional level.

Consulting and genetic companies

Five consulting companies were evaluated. Three of them recorded data at both individual animal and herd level and two at herd level only. Recorded health and production data were an aggregation of mostly farm, laboratory and milk recording data. Strong focus was on recording production, nutrition and fertility related conditions including culling, mastitis and lameness. The genetic company recorded primary health and fertility data at both individual animal and herd level. Various degree of quality control was operated by both consulting and genetic

companies. The main challenges included commercial value of their data and therefore limited or no access to the individual data; limited analysis of aggregated data and completeness of recordings.

Retailers

Two evaluated retailers recorded health and production data as an aggregation of mostly farm, laboratory and milk recording data. For a farm to become a member of the recording system, it had to comply with certain standards set by the retailers. Although this was on a voluntary basis, once the farm becomes a member, recording of health and production data becomes compulsory. A confidentiality agreement with member farms limited the access to the recorded data.

Discussion

To continue improving production efficiency, guide disease control efforts, and protect public health through production of safe food, accurate and reliable information on cattle health and production on a national basis is needed. Different procedures and sets of criteria have been proposed for the evaluation of surveillance systems (CDC 2001; Hendrikx and others 2011; Drewe and others 2015). Here we used an adaptation of the SERVAL system, which was originally proposed for the evaluation of animal health surveillance to ascertain whether a surveillance system is meeting its objectives. In our evaluation we prioritised attributes in order to identify recording systems that can produce reliable and accurate estimates of important health conditions at national level and the same attributes were assessed for all the systems as opposed to the attribute selection based on the objectives of the individual recording systems as it is described in the SERVAL framework (Drewe and others 2015). This evaluation revealed that even though the individual systems can provide reliable estimates of dairy health for individual farmers or groups of farmers, the use of this information at national level is

limited due mainly to the voluntary or selective nature of data recording and an unknown but potentially high level of bias. The voluntary or selective nature of recording compromises coverage, data completeness and representativeness and is likely to introduce bias. Voluntarily recorded data have the potential of being non-representative in terms of factors such as breed, production type or disease statuses, as these factors are likely to influence motivation to participate. Even though some general farm information (e.g., herd size, geographic location) was recorded by some of the systems, without access to the actual data, the level of bias could not be assessed. Additionally, this information was likely to be noted at the beginning of the recording without being regularly updated and thus has the potential to be wrong. Therefore, selection bias seems to be a limitation on the future use of existing systems for nationwide monitoring of dairy health. It is important to note that the performed evaluation focused on non-statutory health conditions of dairy cows, with the exception of BVD surveillance which is mandatory in Scotland. Conditions such as bovine tuberculosis (bTB), even though identified as important health conditions during the workshop, were omitted from the evaluation due to statutory surveillance being in place providing accurate and reliable estimates at a national level.

Recording of health and production events in GB dairy herds is rather complex involving a large number of organizations with considerable variations in the level of recording (animal vs. herd), the implementation (frequency of recording, case definitions) and the outputs derived from the system (counts of animals, proportions, rates). Similar findings were obtained in an evaluation of pig health monitoring in England, which highlighted the diversity of existing systems (Stärk and Nevel 2009). The majority of the evaluated systems were private or industry led, reflecting the high awareness of the value of health recording.

Collection of good quality data by farmers is critical to the overall quality of the recording systems. During the evaluation it became apparent that the majority of the systems rely on farm

294 and or laboratory records which are either directly submitted to the systems by individual
295 farmers or collected by technicians or consultants during farm visits. These data are mostly
296 based on farmers' own records, milk recording data or laboratory results kept on the farm. The
297 results suggest that the recording of the health conditions varies depending on farm's disease
298 situation and production type. Major endemic health conditions such as Johne's disease, BVD,
299 mastitis and lameness were recorded by most of the evaluated systems whereas conditions such
300 as ovarian dysfunction and salmonellosis were recorded by the least of them (Table 6). The
301 latter ones are likely to occur at lower level or are of less concern to individual farmers. The
302 health situation on individual farms and farmer's priorities influences on-farm decision
303 making. This indeed has a big influence on the quality of the farm records and thus on the
304 quality of the systems relying on such data (Gilbert and others 2014). The issue of
305 underreporting or recording with low specificity by individual farmers suggests that the
306 importance of accurate and systematic health recording is not always understood.

307 Collection of primary data allows better control over the type and quality of information
308 gathered and therefore might be easier to validate (O'Neill and others 2014). In this study,
309 systems most likely to capture primary data represent laboratories, accredited health schemes,
310 genetic and milk recording companies. Fourteen out of 19 of the evaluated systems were
311 considered as primary. This indicates limited data sharing between the systems and therefore
312 recording of the same health conditions by multiple systems. This has a great implication for
313 the resources used which could be minimised if better integration of these systems was
314 achieved, highlighting the need for a centralised database at national level. Currently, the main
315 reason for this lack of data sharing seems to be the commercial value of the private systems
316 and data confidentiality agreements with individual producers. As a result, many data
317 administrators were reluctant to share information on their databases. Consequently, full
318 benefits of such systems are limited by data ownership. Similar observations were made during

the study on the expenditure distribution of animal health surveillance in GB (Drewe and others 2014).

In addition to the bias, data ownership, quality of on-farm recordings, the use of case definitions between the systems also need to be considered. Even though each system uses case definitions, and this is particularly strong for conditions detected by means of laboratory testing, we anticipate the variation in those definitions to be high, as some systems might include both clinical and subclinical cases, some only clinical and some definitions of clinical cases might also vary between the systems. Further work would have to be done to assess this. On the other hand, use of data collection protocols is likely to minimise variability of recording within the individual systems.

Better integration of data from various recording systems at national level would significantly increase coverage. For example, combining the data from all three milk recording companies, the coverage would be increased to approximately 80% of GB dairy farms. Such integration would provide more reliable and useful information for surveillance than the separate analysis of individual systems. Any discrepancies in terms of recording between these systems would have to become transparent in order for those using such data to make correct interpretations.

Identification of relevant health issues was likely to be influenced by the selection of the workshop participants and their specialism and could therefore introduce a potential source of bias and thus have an impact on the validity of the evaluation performed. The evaluation process used in this study relied entirely on the quality of the information provided by the individual data holders and was therefore limited where no or incomplete information was obtained. To ensure that correct information on individual systems was collected responders to the web-based questionnaire and telephone interviews were selected based on their knowledge of the recording system and responsibilities they had within the system. This was achieved by

343 extensive interaction with those involve in the system to ensure the objectives were clear and
344 the appropriate individuals were identified. However no validation beyond checking for
345 inconsistencies or contradictions by the interviewer of the information received was performed
346 which could have had potential implication for the validity of the results of the evaluation. Of
347 all the data sources originally identified (59), 36 of them (61 per cent) responded; therefore it
348 is possible that our assessment has failed to include some relevant data recording systems.
349 However, given the very inclusive criteria used for the initial identification of recording
350 systems, we think it is unlikely that any major, active, recording system has been excluded.
351 Out of 36 systems, only half of them were considered to be relevant for the evaluation (i.e. they
352 record primary data on relevant conditions in a regular, ongoing fashion), which shows the
353 inclusiveness of our initial search. Qualitative assessment of the individual attributes as green,
354 orange or red has an element of subjectivity and thus the assessment of the attributes by a single
355 person could have introduced some bias. To minimise this bias, the type of information
356 collected for their assessment and criteria used for the colour assessment of each attribute have
357 been described in Tables 2 and 3 respectively. In addition to this, 15% of the systems were
358 evaluated independently by a second evaluator; assignment of red colour to the assessed
359 attributes was in total agreement with the first one. Two attributes, data collection and data
360 management for two of the systems were differently assessed by the two assessors as green and
361 orange. This disagreement had however no implication for the overall assessment of the
362 usefulness of the systems at national level.

363 Despite some limitations, the study results provide important information that could be used to
364 inform and enhance existing dairy cattle disease surveillance and serve as a basis for a potential
365 future integration of relevant systems at national level. Creation of such centralised database
366 would allow for a regular recording of health information from a large population. This would
367 reduce bias and provide valuable information on disease trends and occurrence of new and

emerging diseases as it can be seen in Nordic countries where extensive national-level recording systems are well established (Østerås and others 2007; Mörk and others 2009; Mörk and others 2010a; Wolff and others 2012a).

In conclusion, dairy cattle health and production information in GB is currently recorded by a considerable number of private and public systems demonstrating the interest and perceived value in disease surveillance. The results of the qualitative evaluation highlighted the limited use of such data at national level due to potentially high level of bias resulting from limited geographic coverage and voluntary or selective inclusion of farms. Better integration of the systems could increase coverage and reduce bias, thus providing valuable information at national level. Currently, the complexity of the systems, lack of standardisation and the issue of data ownership represent the main constraints in doing so.

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TABLE 1: Workshop participants (n=15); constituency represented and their specialism

Constituency represented	Number of participants	Specialism
Government Agencies	1	Veterinary epidemiology and animal health surveillance
Government advisory groups	2	Animal (cattle) health and welfare policy including public health
Practicing dairy cattle veterinarians	3	Cattle health and welfare
Dairy farmers organisations	3	Dairy industry, dairy cattle health and welfare
Universities (Veterinary Schools)	6	Veterinary epidemiology, animal health surveillance, cattle health, dairy industry

TABLE 2: Definition of attributes as described in the SERVAL framework (Drewe and others 2015) and the description of the information collected for their assessment via web-based questionnaire and telephone interviews. The attributes are grouped according to the evaluated aspect of the surveillance (Hoinville and others 2013).

Group	Attribute	Definition	Information collected for attribute assessment
System processes	Data collection	The use of appropriate data sources and data collection methods, protocols and the existence of a case definition	• Use of protocols, standard procedures when collecting data • Consistent, continuous collection • Active vs. passive collection • Paper vs. electronic collection • Use of trained personnel • Use of clear definitions for diseases/conditions
	Data recording and management	Appropriate use of data management systems and protocols and quality control of data	• Manual data entry vs. electronic • Central recording • Using bespoke spread sheet/databases • Use of unique identifier for individual animal/farm • Checking for errors, duplicates • Data manipulation/collation
	Data analysis	Use of appropriate methods for analysis and interpretation of results	• At animal/farm level • Prevalence/incidence estimates, descriptive • Who is involved in the analysis • How often data are analysed
	Communication	Assessment of methods and ease of reporting, including type of outputs reported	• To individual farmer, producers, industry, government, veterinarian, consumer • Use of standard format of reporting • Regular reports

			• Ways of reporting - use of website, over the phone, etc.
Inclusion	Representativeness	Extent to which features of the population of the interest are reflected in the surveillance data that are collected	• Information on geographic location, herd size, production type, age, sex
	Coverage	Proportion of the population of interest that is included in the surveillance activity	• Number and geographic coverage of farms/animals included in the database
	Multiple utility	The ability of a surveillance system to capture information on several diseases or health conditions; measure of how generic the system is	• Type of data recorded in the system • Specific health conditions recorded in the system
System performance	Benefit	Direct and indirect advantages produced by the surveillance system	• Reason for recording: legal requirement, reduction in disease occurrence, improved animal health on farm, identification of research needs, improved genetics, providing advice • Who benefits: individual farmers, producers, government, consumer, industry
System function	Flexibility	Ability of the system to adapt to changes and to continue working in long term	• How easily can it adapt to changes in case definition, variation in funding, staff availability, etc.
	Stability and Sustainability	The ability to function without failure (reliability), the ability to be operational when needed (availability) and the robustness, and the ability of the system to be ongoing in the long term (sustainability)	• Use of protocols, standard procedures when collecting data • Consistent, continuous collection • Quality control • Staff availability, funding
Evidence quality	Bias	The extent to which prevalence estimate produced by the surveillance system deviates from the true	Assessed in terms of methodological flaws: • Selection of farms (implication for selection bias) • Data collection (implication for information bias)

		prevalence value. One way to reduce bias would be to increase representativeness	• Use of case definitions, laboratory testing (implication for misclassification bias)
Data quality	Data completeness and correctness	Proportion of the data that was intended to be collected that actually was (data completeness), and the proportion of data entries that correctly reflect the true value of the data collected (data correctness)	• Number of individual animals/herds recorded in the database (information for data completeness) • Check on the completeness of disease recording (i.e. whether particular health conditions are recorded for all of the animals or herds in the database).

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TABLE 3: Traffic light system for the assessment of selected attributes such as data collection, data recording, data management, data analysis and quality control. Each category is defined to ensure consistent coloured assessment of the attributes.

Category	Selected attribute
Excellent or very good	Is clearly defined, robust, and consistent, applied regularly to all recorded conditions, use of standard protocol, and trained personnel.
Good, though room for improvement	Is reasonably clearly defined, robust, applied regularly for most of recorded conditions, with some minor deficiencies.
Poor, in need of attention	No clear definition in place, no robust application, major deficiencies in selected attributes.

480 **TABLE 4:** Disease/conditions identified during a cattle health workshop held in 2012, for which having accurate and reliable estimates would be
481 of value for the industry, farmers or both (conditions in bold). Within each of the three listed categories conditions were ranked as priority or
482 relevant.

Category	Importance	Industry	Farmers
Infectious and parasitic diseases	Priority	**Johne's disease, Bovine Viral Diarrhoea, Calf Diarrhoea, Calf Pneumonia**,	**Johne's disease, Bovine Viral Diarrhoea, Calf Diarrhoea, Calf Pneumonia**
	Relevant	**Liver Fluke, Salmonella, Parasitic Gastroenteritis**, Ectoparasites	**Liver Fluke, Salmonella, Parasitic Gastroenteritis**, Lungworms
Production, metabolic and nutrition-related conditions	Priority	**Ketosis/Negative Energy Balance/Fatty Liver Disease, Lameness, Mastitis, Sub-Acute Ruminant Acidosis/Rumen Health/Acidosis, Longevity, Culls/wastage**	**Ketosis/Negative Energy Balance/Fatty Liver Disease, Lameness, Mastitis, Sub-Acute Ruminant Acidosis/Rumen Health/Acidosis, Longevity, Culls/wastage**, Young Stock Nutrition/Growth, Down/Injury
	Relevant	**Milk Fever/Hypomagnesaemia/Minerals**, **Displaced Abomasum,** Young Stock Nutrition/Growth, Down/Injury,	**Milk Fever/Hypomagnesaemia/Minerals, Displaced Abomasum**
Fertility-related conditions	Priority	**Failure to Conceive**, Dystocia, Abortion, Endometritis, Ovarian Dysfunction, AI Factors, Heat/Submission Rates	**Failure to Conceive**
	Relevant	**Retained Foetal Membrane, Bull Infertility, Early Embryonic Death**	**Retained Foetal Membrane**, **Bull Infertility**, **Early Embryonic Death,** Dystocia, Abortion, Endometritis, Ovarian Dysfunction, AI Factors, Heat/Submission Rates

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484 TABLE 5 Relationship between the type of the evaluated recording system and the individual important health condition identified during the
485 workshop represented by the shaded area.
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	Milk recording company	Laboratory data	Herd health scheme	Consulting company	Genetic company	Retailer	Other
1 Infectious and parasitic diseases							
Johne's disease							
Bovine Viral Diarrhoea (BVD)							
Liver fluke							
Calf pneumonia							
Calf diarrhoea							
Parasitic Gastroenteritis (PGE) and Lungworm							
Ectoparasites							
Salmonellosis							
2 Production, metabolic and nutrition related							
Mastitis (clinical and/or subclinical)							
Lameness							
Ketosis/Negative energy balance							
Milk fever/Minerals							
Displaced abomasum							
Rumen health /Sub-acute ruminant acidosis/ Acidosis							
Cull/wastage							
3 Fertility related conditions							

Calving problems/ dystocia/assisted calving/stillbirth							
Endometritis							
Abortions							
Retained foetal membrane							
Failure to conceive							
Early embryonic death							
Ovarian dysfunction							
Bull infertility/AI factors							

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489 **TABLE 6:** Results of the evaluation of the potential 19 dairy cattle health and production recording systems to provide accurate and reliable
490 estimates of important health conditions at national level. Within each health category, individual conditions are listed in descending order based
491 on the number of systems that record data on them (number of primary systems in brackets). The assessment of the ability of the systems to provide
492 accurate and reliable estimates at national level is presented (green: very reliable and very accurate, orange: reliable and accurate, red: not accurate
493 and reliable) together with the strengths and weaknesses of each system.

Conditions	Number of systems (Number of primary systems)	Assessment of reliability and accuracy of recording for use at national level	Strengths	Weaknesses
1. Infectious and parasitic disease				
Johne's disease	14 (11)	Not reliable and not accurate	Data quality control in place Fully electronic/centralised database High specificity of case definition Flexibility BVD surveillance compulsory in Scotland Johne's disease and BVD recorded by 12 same systems	Biased due to voluntary recording, except for BVD surveillance in Scotland Coverage, completeness and frequency of recording is customer-dependent Commercial value – limited or no access to the data
Bovine Viral Diarrhoea (BVD)	13 (10)			
Liver fluke	7 (5)	Not reliable and not accurate	Fully electronic/centralised database Use of data collection protocols High specificity of case definition Flexibility	Biased due to voluntary recording Lack of quality control Unknown coverage and representativeness Under-reporting
Calf pneumonia	7 (5)		Fully electronic/centralised database	Biased due to voluntary recording

Calf diarrhoea	6 (4)	Not reliable and not accurate	Use of data collection protocols Flexibility Both recorded by 6 same systems	Lack of standardisation Under-reporting
Parasitic Gastroenteritis (PGE) and Lungworm	6 (4)	Not reliable and not accurate	Fully electronic/centralised database Use of data collection protocols Recorded by the same systems	Lack of quality control Unknown coverage and representativeness Under-reporting
Ectoparasites	5 (3)	Not reliable and not accurate	Fully electronic/centralised database Use of data collection protocols	Lack of quality control Unknown coverage and representativeness Under-reporting
Salmonellosis	4 (2)	Not reliable and not accurate	Fully electronic/centralised database Use of data collection protocols High specificity of case definition	Biased due to voluntary recording Unknown coverage and representativeness Under-reporting
2. Production, metabolic and nutrition related				
Mastitis (clinical and/or subclinical)	13 (11)	Not reliable and not accurate	Fully electronic/centralised database Quality control in place Use of trained personnel Both recorded by 12 same systems	Coverage, completeness and frequency of recording varies Voluntary recording Under-recording
Lameness	13 (9)	Not reliable and not accurate		
Ketosis/Milk fever/Minerals/Displaced abomasum	11 (7)	Not reliable and not accurate	Fully electronic/centralised database Use of data collection protocols Use of trained personnel for data collection Flexibility	Coverage, completeness and frequency of recording varies Voluntary recording Under-reporting
Rumen health /Sub-acute ruminant acidosis/ Acidosis	7 (5)	Not reliable and not accurate	Fully electronic/centralised database Use of data collection protocols Use of trained personnel for data collection Flexibility	Coverage, completeness and frequency of recording varies Voluntary recording Under-reporting
3. Fertility related conditions				
Calving problems/ dystocia/assisted calving/stillbirth	12 (8)	Not reliable and not accurate	Fully electronic/centralised database Use of data collection protocols Use of trained personnel for data collection	Coverage, completeness and frequency of recording varies Voluntary recording

Endometritis	10 (7)		Both recorded by 9 same systems	Commercial value
Abortions	10 (6)	Not reliable and not accurate	Fully electronic/centralised database Use of data collection protocols Mandatory reporting High specificity	Unknown coverage Unknown representativeness
Retained foetal membrane	9 (7)	Not reliable and not accurate	Fully electronic/centralised database Use of data collection protocols Use of trained personnel for data collection Both recorded by 7 same systems	Voluntary recording Completeness and depth of recording varies
Failure to conceive	9 (6)			
Early embryonic death	6 (4)	Not reliable and not accurate	Fully electronic/centralised database Use of data collection protocols Use of trained personnel/veterinarians All 3 conditions recorded by 4 same systems	Voluntary recording Unknown coverage and representativeness Completeness and depth of recording varies Low specificity
Ovarian dysfunction	5 (4)			
Bull infertility/AI factors	5 (3)			

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FIG 1: The process used to identify and evaluate the relevant systems holding information on dairy cattle health and production deemed of importance to the dairy industry and farmers in GB. Stage 1 describes a decision tree used to select the systems that were included for the second stage of data collection and subsequent evaluation. A list of attributes on which information was collected and used for the evaluation is also included. *Recording system not included in the next stage. **Telephone interviews conducted only for 17 systems as two chose not to participate in the interviews.

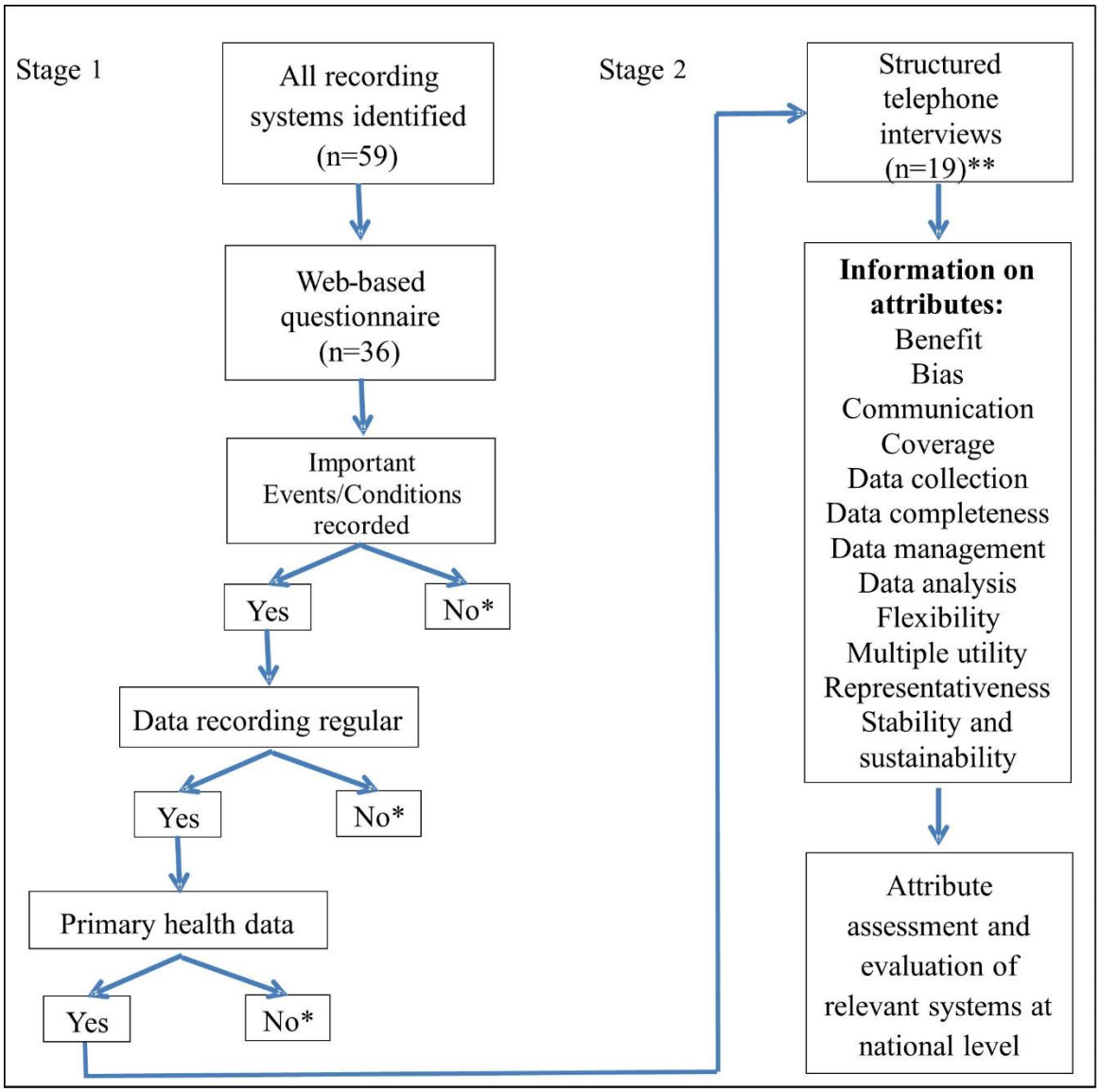

FIG 2: Bar chart shows the number of primary and mixed (primary and secondary) systems recording specific health conditions deemed to be important. Pie charts show the number of systems by a) type of information recorded, b) geographic coverage, c) level of recording.