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Abstract

The capability to set baselines and monitor trends of health and welfare conditions is an important requirement for livestock industries in order to maintain economic competiveness and sustainability. Monitoring schemes evaluate the relative importance of conditions so that: appropriate actions can be determined, prioritised and implemented; new and (re)emerging conditions can be promptly detected and the effectiveness of any actions can be measured. In 2011, the national pig levy board published a strategy document highlighting health and welfare conditions of importance to the pig industry that were to be targeted for control. In this study, existing schemes that could be used to monitor or set baselines for these conditions in pigs were reviewed, in order to evaluate their suitability for this purpose, using a standardised surveillance evaluation framework (SERVAL). The schemes included: government-funded surveillance of endemic and exotic disease and pig welfare; industry surveillance of endemic diseases; regional schemes for improving pig health; national accreditation schemes; and information collected by retailers, private veterinary practices and private laboratories. The evaluation of each scheme highlights its capability to monitor any of the targeted conditions. This study identifies the biases, strengths and gaps in each scheme and provides discussion of opportunities for future development.

Introduction

The improvement of pig health and welfare is fundamental to securing the sustainability of the pig industry in Great Britain. Disease causes significant cost to pig farmers, limits productivity, and is inextricably linked to pig welfare. Zoonotic diseases also have implications for public health. The costs to the farmer are associated with pig mortality, treatment, control (improved biosecurity, medicine use, cleaning and disinfection, increased labour), reductions in food conversion efficiency and daily live weight gain, and increased carcase condemnation at the abattoir. The full economic impact is usually difficult to estimate, as it is often complicated by multifactorial pathogen involvement and the variety of different disease control measures tailored to each farm. A number of studies have tried to estimate these costs, which can be substantial, for a variety of diseases including swine dysentery and Enzootic Pneumonia (EP) [1-4]. The costs of improvement and maintenance of high welfare standards can also be considerable [5-6].

The implementation of measures to improve pig health and welfare, whilst ensuring the sustainability of the industry, is at the forefront of current initiatives to reduce antimicrobial use [7]. However, to identify where action should be focussed, and to monitor the effectiveness of initiatives, veterinarians, pig

keepers and the pig industry require an effective surveillance system. At national level, industry needs to know the baseline status of animal health and welfare and to monitor changes that occur. This assists in the evaluation of the relative importance of diseases and conditions so that appropriate actions can be determined, prioritised and implemented. In addition, the effectiveness of such actions can then be measured. Industry and Government needs prompt detection of new and (re)emerging threats to pig health and welfare and a robust surveillance system that underpins assurance of notifiable disease freedom and international trade agreements.

Examples of pig health and welfare monitoring programs elsewhere include the Animal Health Surveillance System in the Netherlands, which was designed in 2003 to combine data from multiple sources to meet many surveillance requirements [8]. Another example is the Danish Integrated Antimicrobial Resistance Monitoring and Research Program (DANMAP). This was set up in 1995 to monitor antimicrobial consumption and resistance in bacteria from animals, food and people [9].

In 2011, the national pig levy board, AHDB-Pork (Agriculture and Horticulture Development Board; known as BPEX at the time of this study) launched a strategy for the British pig industry for the coming decade: the BPEX 20:20 Pig Health and Welfare Strategy [10]. Health and welfare conditions of most importance to the pig industry were identified for control. The areas of welfare focus were tail biting, tail docking, teeth clipping, lameness, freedom around farrowing, husbandry of entire males over 80 kg, pre and post weaning mortality. The areas of pig health and food safety focus identified were *Ascaris suum*, *Brachyspira hyodysenteriae* (swine dysentery), *Mycoplasma hyopneumoniae* (enzootic pneumonia), *Actinobacillus pleuropneumoniae* (APP), Porcine Reproductive and Respiratory Syndrome Virus (PRRSv), lesions at slaughter (as recorded by the British Pig Health Scheme), sarcoptic mange, methicillin resistant *Staphylococcus aureus* (MRSA), *Salmonella* in pig meat, condemned pig meat (kg/ pig) and antimicrobial usage. No centralised system for data collection of all of these health and welfare issues existed at the start of the study and the challenge was how could prevalence or occurrence of these pathogens and conditions be monitored to assess control and progress towards the BPEX 20:20 Vision outcomes.

In England and Wales, data collected at different levels (farm, abattoir, laboratory etc) of the pig industry were of variable availability, quality and coverage and their potential use at national level had not been explored. A limited number of English data sources have been previously assessed for general surveillance purposes [11]. In that study, SWOT (strengths, weaknesses, opportunities, threats) analysis was used to assess four monitoring schemes: the British Pig Health Scheme (BPHS), the National Animal Disease Information System (NADIS), the Zoonoses Action Plan (ZAP) for *Salmonella* and APHA's Veterinary Investigation Diagnosis Analysis (VIDA). At the time of this study (2012-2013), two of the four assessed datasets (NADIS and ZAP) were no longer in operation. It was clear that a review with a larger scope was needed, to both determine what data sources existed and which were most appropriate for monitoring pig health and welfare conditions, identified in the BPEX 20:20 Vision outcomes.

Standardised reviews of surveillance systems are rarely published in the literature, especially those relevant to animal health and welfare. Their focus is predominantly on the ability of surveillance schemes to detect new and exotic diseases [12], or on their uses for detecting bioterrorism [13]; an exception being the evaluation of health and production recording of the dairy cattle population in Great Britain [14].

The study described here provides a review of data sources relating predominantly to endemic disease and welfare conditions of importance to the pig industry, as defined by the BPEX 20:20 Vision. It also demonstrates the use of a recently developed standardised evaluation methodology tool [15] to assess

characteristics, such as the proportion and diversity of the pig industry covered by each scheme. The methods, outcomes, highlights and recommendations of the critical evaluation are presented within the context of the requirements of the BPEX 20:20 Vision.

Materials and Methods

Information Gathering Framework (IGF)

Potential sources of pig health or welfare data were identified that met the criteria of being from sources no older than 2004 which included pigs. Potentially useful sources were identified through a literature review and by contacting industry experts, academic colleagues and contacts within the Animal and Plant Health Agency (APHA), AHDB, Food Standards Authority (FSA), and the Pig Health and Welfare Council Surveillance Subgroup. The data sources did not have to be originally designed for monitoring or surveillance purposes.

A set of headings was agreed under which information would be collated for each identified data source. These included: population coverage, what health and welfare data were collected, how the data were currently used and factors relating to the usefulness and suitability of the scheme for analysis (e.g. how were farms identified in the scheme, issues with accessibility). Collecting this information involved either contacting staff responsible for the schemes, or collecting information from reports and/or websites. Where possible, it also included the collection of data summaries, or example sets of raw data, to enable preliminary assessment. There was little recorded information about the data collected by private veterinarians and so a web-based questionnaire (SurveyMonkey Inc., Palo Alto, California, USA) was sent to veterinary practitioner members of the Pig Veterinary Society, from which 20 responses were received. Each data source was assessed to determine the likely usefulness of the data and whether more detailed SERVAL evaluation was merited.

Critical assessment of the data sources

The SERVAL evaluation framework [16] was used for those data sources that justified full evaluation. The framework guides the collection of key information on each data source including the processes of data generation, collection and management, system design and management and the wider context within which the systems operate. The SERVAL framework is flexible enough to allow the evaluation of a large range of surveillance schemes for various different outcomes.

The master list of 22 defined SERVAL attributes was reviewed to select those that were essential to the planned evaluation, and a final list of 13 was selected (Table 1). These attributes were assessed for each data source by the authors and given a score of 1 (excellent) to 3 (poor) [15].

Additionally, comprehensive information was collected on each data source to define the type of surveillance, the target population, potential threats that might affect use and the key strengths and weaknesses defined by the assessment of the attributes. A ‘strong’ system, for our purposes, would include those that had: a clearly defined aim and purpose; good coverage; standardised, validated measurements; simple and easy data capture; centralised electronic data management and storage; accessible data with appropriate analysis; timely reporting; clear identifiers to assist linkage to other data sets; documented biases (if present) and which had been established for a number of years. Also, a strong system would document and minimize changes to the surveillance methods. The information was collated from the IGF and/or through additional communication with the data source contacts as well as by additional analysis of any data that were obtained.

Table 1: Description of the 13 selected attributes used to review surveillance data sources (for further description please see the SERVAL framework: [16].

Attribute	Description
Benefit	Direct and indirect advantages of the system.
Bias	Ability of the scheme to reflect the true prevalence of a condition in the entire pig industry.
Communication	Evaluation of the information produced and accessibility to such information.
Coverage	Proportion of the population of interest covered.
Data analysis	Whether the scheme uses, or could use, appropriate analysis methods
Data collection	This covers evaluations of the methods of data collection e.g. use of case definition, effective sample size, standard approaches to collection of data.
Data completeness and correctness	Proportion of intended data that is collected.
Historic data	Quality, quantity and availability of historical data
Impact	Use of scheme e.g. ability to use data to drive action.
Representativeness	Sectors of the pig industry covered by the scheme (e.g. breeding pigs).
Sensitivity	Sensitivity of detection of health and welfare conditions e.g. laboratory test sensitivity or evaluation of ability of assessors to detect abattoir lesions.
Specificity	Specificity of detection of health and welfare conditions
Stability/ sustainability	Whether system has been stable over time and whether it will remain in the current format in the future.

Results

Identification of data sources

A total of 45 data sources were identified that could potentially be used for health and welfare monitoring of trends (Final Report to AHDB, Annex 6, 2013, details available from the corresponding author). These included government sources of endemic and exotic disease and welfare surveillance (e.g. VIDA); industry surveillance of endemic diseases (e.g. BPHS, Wholesome Pig Scheme, Qbox); schemes for improving regional pig health (Pig Health Improvement Project (PHIP)); accreditation schemes (e.g. Quality Assurance, organic accreditation, Freedom Foods); health and welfare research studies; retailer, private vet, company or pig farm data sources; sample testing by private laboratories; fallen stock data; and antimicrobial sales data. Reasons that data sources did not progress to a full evaluation included the source only covering Scottish farms; covering too few farms; or collecting data on conditions outside of the BPEX 20:20 Vision.

SERVAL assessments

Of the pig health and welfare data sources identified, 11 were selected for appraisal using the SERVAL framework (Table 2). The evaluations are presented in Table 3, with information provided on which BPEX 20:20 conditions could be monitored by these sources in Table 4. All data sources for England and Wales differed in relation to their surveillance objectives, structure and operation and their attributes scores were diverse. All but the Red Tractor scheme, data from private laboratories and veterinarians were highly scored against the 'Benefit' attribute (Table 1) indicating the advantage of the current use of the data collected by these schemes. All of the data sources reported biases and potential issues. Each SERVAL assessment is discussed (as it existed at the time of this review in 2012-13) in detail below.

170 **Table 2**. Description of each data source, assessed as a potential source of pig health and welfare
171 surveillance, using SERVAL.

Data source	Source Type	Target population	Inspection type	Inspection performed/ Data provided by
Antimicrobial sales	Government	All pharmaceutical companies supplying UK food and non-food animals	Data collection	Pharmaceutical companies
APHA cross-compliance welfare	Government	Subset of pig premises in GB	Visual inspection	Govt veterinary and animal health inspectors
BPHS	Industry	Selected batches of slaughtered pigs from members in England and Wales	Visual inspection	Veterinary practitioners
FSA Ante-mortem/ Post-mortem inspections	Government	All slaughtered pigs for human consumption in England and Wales	Visual inspection	Meat inspectors
PHIP	Industry	All commercial pig farms in England	Data collection	Veterinary practitioners
Private laboratories	Industry	All pig premises in GB	Various sample types	Private laboratory staff
Private veterinary practices	Industry	All commercial pig units in GB	Data collection/ visual Inspection/ sample collection/ post mortems	Veterinary practitioners
Red Tractor	Accreditation scheme	All commercial pig farms in GB	Data collection/ visual Inspection	Veterinary practitioners, scheme inspectors
Real Welfare	Industry	All pigs on commercial units in England and Wales	Visual Inspection	Veterinary practitioners
Retailers	Industry	All pig units supplying the relevant retailers in GB	Data collection/ visual inspection	Meat inspectors, farm inspectors
VIDA	Government	All farms with livestock attended by veterinarians in GB	Various sample types and post-mortems	Veterinary practitioners and Veterinary Investigation Officers

172 UK: United Kingdom; GB: Great Britain.

Table 3. The summary of evaluation of each animal health surveillance system against 13 selected attributes and health and welfare factors from the BPEX 20:20 Vision using the SERVAL framework.

	Attributes												
Data source	*Benefit*	*Bias*	*Communication*	*Coverage*	*Data analysis*	*Data collection*	*completeness and correctness*	*Historic data*	*Impact*	*Representativeness*	*Sensitivity*	*Specificity*	*Stability/ sustainability*
Antimicrobial sales	1	2	1	1	2	2	2	1	2	3	N/A	N/A	1
APHA cross-compliance welfare	1	2	2	3	2	2	1	2	2	1	2	1	2
BPHS	1	2	2	1	1	1	2	1	2	2	2	1	1
FSA Ante-mortem/ Post-mortem inspections	1	2	2	1	1	1	2	2	1	2	2	1	3
PHIP	1	3	2	2	3	2	3	3	2	2	2	2	2
Private laboratories	2	3	3	2	3	3	3	2	3	3	2	2	3
Private veterinary practices	2	2	3	1	N/A	2	2	2	1	1	2	2	2
Red Tractor	2	2	3	1	1	1	2	2	2	2	2	2	2
Real Welfare	1	2	2	1	2	1	1	2	2	2	1	1	2
Retailers	1	2	3	2	3	1	3	2	2	2	2	2	1
VIDA	1	3	1	2	2	2	2	1	1	3	2	2	2

Key to surveillance system performance against each attribute: (1) Excellent or very good; (2) Good, although with some room for improvement; (3) Poor, in need of attention. [15]. N/A – not evaluated.

Table 4. Summary of whether each animal health surveillance system can be used for monitoring (marked with an x) for 20 key health and welfare factors identified in the BPEX 20:20 Vision.

BPEX 20:20 Vision: areas of health and welfare focus	Antimicrobial sales	APHA cross-compliance welfare	BPHS	FSA Ante-mortem/ Post-mortem inspections	PHIP	Private laboratories	Private veterinary practices	Red Tractor	Real Welfare	Retailers	VIDA
(a) tail biting		x	x	x				x	x	x	
(b) tail docking		x						x	x		
(c) teeth clipping								x			
(d) freedom around farrowing		x						x			
(e) lameness				x			x		x	x	
(f) husbandry of entire males> 80kg											
(g) pre-weaning mortality							x				
(h) post-weaning mortality							x				
(i) swine dysentery (*Brachyspira hyodysenteriae*)					x		x	x			x
(j) Sarcoptic mange			x		x		x				x
(k) *Mycoplasma hyopneumoniae*			x	x	x	x	x	x			x
(l) *Actinobacillus pleuropneumoniae*			x	x		x	x				x
(m) PRRS					x	x	x	x			x
(n) *Ascaris suum*			x	x			x				x
(o) post-mortem lesions			x	x						x	x
(p) condemned pig meat kg/pig in abattoirs										x	
(q) antimicrobial usage as mg active/kg pig meat	x										
(r) Methicillin-resistant *Staph.aureus*											
(s) *Salmonella* in pig meat (re: EU reduction targets)											

Government schemes (details accurate at time of study 2012-13):

1. VIDA: The VIDA database records disease diagnoses and surveillance data generated by diagnostic submissions to the Government-funded scanning surveillance network. Diagnostic samples (e.g. serum, blood, nasal swabs, faeces) including live or dead pigs for post-mortem examination, are submitted to APHA and SAC veterinary investigation centres by private veterinary surgeons from any type of pig holding, including pet and smallholder pigs. However, the representativeness of the whole pig population is low (score 3) with most submissions being from commercial growing pigs and fewer submissions are received from small or 'breeding-only' holdings or areas of low pig farm density [17]. Data captured includes the farm and submitting veterinary practice details, purpose of the livestock holding, age, sex, accommodation of the pigs, nature and duration of clinical signs, samples submitted, tests performed, clinical syndrome involved and diagnoses made. Quarterly reports are published online [18]. VIDA includes several diseases caused by pathogens specified in the 20:20 Vision (Table 4), and is thus of importance for contributing to monitoring trends in the diagnostic rate of these diseases. It is recognised that for certain diseases, like mange and "milk spot" caused by *Ascaris suum*, few VIDA diagnoses are made as this is often diagnosed in veterinary practices, at slaughter, or at private laboratories without need for samples to be sent to VIDA. *Salmonella* infection is recorded in VIDA only when it is causing disease, and isolations are also reported to Defra as part of the Zoonoses Order 1989 requirements. However, there is no routine screening for *Salmonella* infection from diagnostic submissions and these are from diseased pigs of any age. In addition, they are not representative of healthy finisher pigs at slaughter, thus VIDA does not contribute to monitoring *Salmonella* in pig carcases which is delivered to meet EU legislation by food business operators at slaughter. VIDA diagnoses are allocated according to strict diagnostic criteria agreed nationally (specificity score 1) and only from disease-associated incidents, thus for example, the isolation of *Salmonella* or detection of PRRS virus in the absence of relevant clinical signs or pathology is not recorded as a diagnosis. Data from samples sent from healthy pigs for monitoring purposes are not included. VIDA data is from a biased population as submissions are likely to come from pigs with more unusual, severe or unresponsive disease presentations, thus the data can be used to assess trends in diagnostic rate, but not directly for disease prevalence (bias score 3). In addition, veterinarians are not obliged to submit samples or pigs to VIDA and can use commercial laboratories which do not, at present, provide data to VIDA. VIDA data can be viewed as having high accuracy of diagnosis but the scheme scored 2 for sensitivity due to the variability of detection for some of the wide variety of pathogens covered by the scheme. The stability of the scheme is good with reference to the diagnostic criteria and training of staff and the scheme has been operating since 1975 (historical data score 1). However, the number and type of submissions are influenced by several variable factors including: disease occurrence, awareness of disease threats, and the economic prosperity of pig production, which is itself particularly affected by feed and pig prices, with the effect of some of these factors hard to quantify [19].

2. FSA ante-mortem and post-mortem inspections: This scheme provides surveillance for conditions of public or animal health significance and the monitoring of animal welfare. This is achieved through ante-mortem and post-mortem inspection at abattoirs. The recording of specified conditions is a statutory requirement at each slaughterhouse [20]. Although this scheme mostly records data from finisher pigs, a strength is that all slaughtered pigs are assessed (coverage score 1). At the time of assessment by this study, the list of relevant conditions covered by this scheme included tail bite, lameness (inferred from foot lesions, joint-leg lesions and others not defined), milk spot (localised and generalised), and post-mortem lesions of the heart, liver and kidney. The scheme also reports pneumonia with or without abscessation and with or without pleurisy, which could be indicators of *M. hyopneumoniae* and APP infection, but are not specific for either. Although the scheme has been in place for many years, the electronic recording of findings is relatively recent and the list of conditions recorded has changed many times. This affects the stability of the scheme (score 3). The scheme scored 3 for completeness and correctness due to issues with identifying pigs from the same batch and lack of routine data cleaning and checking. Although there are details of diagnostic criteria for some conditions, there is little evaluation of the ability of inspectors to detect and identify specific conditions. It is believed that severe cases may be detected, but that less severe cases may be missed, especially in a busy slaughterhouse.

3. APHA cross-compliance welfare inspections: The surveillance of welfare standards on pig farms is completed via a system of regular visits to farms by trained APHA inspectors (either veterinary staff or animal health officers). Cross-compliance is the set of conditions which must be met by farmers who claim payments under the Common Agricultural Policy (CAP) (such as the Single Payment Scheme). This would indicate a high representativeness of farms in England and Wales (score 1). As the inspections are statutory, they include farms that might not contribute data to other schemes or projects. Each year a minimum of 1% of pig farmers subject to cross-compliance are inspected indicating poor coverage (score 3). The selection of farms to visit is 80% risk-based (based on risk factors, such as those farms infrequently visited by APHA inspectors for other reasons) and 20% randomised, indicating potential for sampling bias. Additional reactive visits also take place but are not covered here due to differences in data collection. On-farm assessments are made of staffing, staff inspection of animals, disease treatment, records, housing, environment, freedom of movement, feed and water, breeding procedures, space, and implementation of specified interventions e.g. tail docking. Each are scored from A, indicating compliance with legislation and code of recommendations, to D, indicating non-compliance with legislation with unnecessary suffering. Information is also collected on actions and bans, which are recorded in a central database (data completeness score 1). Although this scheme could in theory be useful to collect some of the welfare conditions detailed by the 20:20 Vision, a score of non-compliance does not provide information on which specific problems were detected.

4. Antimicrobial sales: The Veterinary Medicines Directorate (VMD) collects and publishes annual figures on the volume of UK sales of antibiotics authorised for use in animals. Antimicrobial sales other than antibiotics are also reported (e.g. anti-fungus, coccidiostats, anti-protozoals). The annual report published online [21] is based on sales data provided by the veterinary pharmaceutical companies under a statutory requirement since 2005 and therefore the coverage of data collection is assumed to be very good (historical data and coverage scores of 1). Sales of antibiotics are shown: per chemical group (active ingredient); by route of administration (medicated foodstuff, oral/water, injectables, intra-mammaries, others) and as overall sales by animal species for which the antibiotics are licenced. Data on pig demographics from Defra's June Census and the average weight at time of treatment per species provided by the European Medicine Agency (EMA) are used to calculate what is known as the Population Correction Unit (PCU): the total tonnes of animal for each species at time of treatment. The total quantity of antibiotic sold divided by the PCU provides a value enabling a year-on-year comparison between countries using the same methodology: quantity of antibiotics used (in mg) by weight of animals at time of treatment (in kg). The results may not provide an accurate indicator of clinical disease as some sales may be used prophylactically to prevent the establishment of disease, which is reflected in the poor representativeness score. This scheme could support the collection of data on the use of antimicrobials; an identified goal in the 20:20 Vision. However, a key weakness of the data is that it cannot identify the target species for which the antimicrobials were used, as many products are authorised for use in more than one animal species with a substantial number of products licensed for use in both pigs and poultry.

<u>Farm accreditation schemes (details accurate at time of study 2012-13:</u>

1. The Red Tractor Quality Assurance (QA) scheme: Data are collected from member pig farms to ensure required quality standards are maintained. It was estimated that 85% of pigs were covered by the scheme in 2012-13, as most commercial producers raising pig for slaughter require membership to access accredited slaughterhouses. The sampled population is unlikely to include non-commercial and specialist breeder pig farms, but would provide very good coverage of commercial pigs destined for slaughter (score 1). Information is gathered during quarterly veterinary visits and annual visits carried out by a QA auditor. Data are entered onto a central database, with simple descriptive analyses carried out for reporting purposes (data analysis and collection scores of 1). Within data relating to farm management, some procedures of relevance to the BPEX Vision outcomes are included such as teeth clipping, tail docking, ear notching and tattooing. The recording system registers the estimated number of pigs affected by these four conditions under five categories (0, 0-10, 10-50, 50-90, >90%) and describes the portion of tail removed if docking is performed. Information on the use of farrowing crates is also included. Information on EP, PRRS and swine

dysentery is restricted to recording farm-level presence or absence of infection. However, there are issues related to data completeness and variability in recording of information from each visit, although systems to improve data checking have been added (score 2).

Industry schemes (details accurate at time of study 2012-13):

1. Pig Health Improvement Project (PHIP): This AHDB project was phased out in 2012 but at the start of the study the scheme aimed to promote sharing of pig farm health status data for specified pathogens in England and Wales alongside a regional mapping system. The idea was to assist farms in the same geographic region to share information and understand and tackle disease risks at a local level. The focus was on four causes of disease: *Mycoplasma hyopneumoniae*, PRRSv, *Brachyspira hyodysenteriae* and *Sarcoptes* species (mange mites), with the scheme monitoring disease presence rather than identifying the pathogens. Data on each pig farm's infection status was recorded by vets, if the farm owner gave permission. They were only accessible to those working on the project, the farmers themselves and their veterinarians, unless farmers agreed to share their information with others within their regional cluster. The disease classifications were based on the attending veterinarian's opinion supported by guidance documents to help standardise responses, as a pilot study showed that the veterinary opinions showed good correlation with diagnostic results. The scheme was voluntary and, although open to anyone, mainly represented commercial farms within the main pig-producing regions of England, thus biasing data at national level. The scheme was only in existence for a short period and so there was little historical data to allow temporal analysis. Furthermore, the completeness of the data was reported to be suboptimal with initial engagement waning in part due to pathogen mapping not being fully developed (historical data and data completeness scores of 3). Although the scheme was phased out, aspects were incorporated into the broader disease prevention and control within AHDB [22].

2. British Pig Health Scheme (BPHS): This slaughterhouse surveillance scheme provided pig health and welfare information inferred from abattoir lesions. It has helped farmers and vets monitor conditions to inform management decisions. This is a voluntary scheme, led by AHDB, collecting post-mortem lesion data on thirteen gross lesions observed in slaughtered finisher pigs: peritonitis, pericarditis, hepatic scarring, papular dermatitis, tail damage, EP-like lung lesions, viral-like lung lesions, acute pleuropneumonia-like, chronic pleuropneumonia-like, pleurisy, milk spot, abscess and pyaemia [23]. The scheme covers several areas of BPEX 20:20 Health/Disease focus. Assessments are completed quarterly on batches of at least 50 pigs from each member farm, by trained veterinary inspectors. Problems with consistency are possible, due to differences between assessments carried out by different vets and at different abattoirs, although to aid standardisation the scheme includes benchmarking exercises, regular staff training and data analysis to compare assessors. BPHS is a fully electronic scheme with good coverage of the commercial fattening pig production (data collection, data analysis and coverage scores of 1). However, as diseased animals and breeding pigs are not included this limits the representativeness (score 2). Anecdotal evidence suggests that time limitations may impact upon assessment so that not all conditions present are recorded, and difficulties with batch identification may be encountered at some abattoirs; these may cause errors in estimating condition occurrence. The scheme has been running since 2005 providing a stable and useful dataset (historical data and stability scores of 1).However, there is a risk that the scheme could be discontinued if funding from AHDB or industry partners is removed.

3. Real Welfare scheme: This scheme was designed and is managed by AHDB. The scheme provides a standardised and validated method (sensitivity and specificity scores of 1) to collect information on welfare conditions from a representative proportion of growing pigs over 50kg and sows on participating farms [24]. Real Welfare involves on-farm assessment of pig welfare using a set of five objective and repeatable measures involving the observation of pigs. These data allow benchmarking and comparison between units. Data are collected by vets during routine visits two to four times a year, depending on the operation of the farm. The number of pigs assessed is between 300 and 900 a year, according to the size of the farm. Inspections were designed to be representative across a farm. At the time of the assessment (2012-2013), the scheme was only in its second year with limited coverage thus the lack of historical data would limit its

use for temporal trend analysis, but the scheme was to be rolled out through the Red Tractor scheme to its members as a requirement (which will provide a coverage score of 1). The scheme does not evaluate welfare at boar, piglet or weaner level, limiting how representative it is of the overall pig population. The areas of BPEX 20:20 Vision Welfare outcomes covered by this scheme are tail biting, tail docking and lameness. However, the scheme may underestimate prevalence of tail biting and lameness as the assessment excludes pigs hospitalised, culled or dead due to these conditions.

4. Private veterinary practices (PVP): Data may be collected on pig health and welfare and vaccines and antimicrobial treatments prescribed from routine quarterly, emergency and other visits to pig farms, as well as information from off-farm contact with farmers. These contacts are privately-funded by the farmer, unless the pigs are owned by a company with in-house veterinarians. Information about farm status for certain pathogens, clinical signs and diagnoses are usually recorded. However, accessibility is problematic as there is not currently a common database or template for farm reports etc used by different veterinarians and veterinary practices, nor is there a ready means of extracting relevant data from the diverse methods of data recording (communication score 3). Confidentiality concerns are also present. Coverage and representativeness are high (scores of 1) for commercial pig farms, with quality assured pig farms being visited routinely on a quarterly basis as described above, although less regular visits to non-commercial herds would also be included. The recorded data includes visit reports, laboratory tests (in-house and external), action plans, performance data, post-mortem examination reports, medicine lists and veterinary health plans. Another concern over the use of these data for surveillance is the lack of standardisation of recording between practices with some information well-collated across practice or company but data on diseases diagnosed/ clinical signs are poorly standardised. Data from telephone or e-mail contact is only regularly recorded by approximately 25% of those responding to the web-based survey of specialist pig vets. Electronic recording and storage of the reports and records was reported to occur by most (80%) of survey respondents.

5. Private (commercial) veterinary laboratories: these may be used by veterinarians attending pig premises for a range of diagnostic tests on samples they submit. The number and type of pig samples (blood, post-mortem tissue, nasal swabs, faeces) received by private laboratories varies, as do the range of tests for pig pathogens offered (stability score 3). Most of the tests offered relate to the more common endemic pathogens and several are included in the BPEX 20:20 Vision, namely: *Ascaris suum*, *Mycoplasma hyopneumoniae*, APP, PRRS and mange, but not *Brachyspira hyodysenteriae*. Bacteriological culture is offered by some and in theory could be used for detection of *Salmonella* in slaughter pigs, although it is unlikely to be used. There is generally a smaller dataset of information collected from each submission compared with VIDA, with submitting veterinary practice and farm details recorded, but the latter probably not with sufficient detail to localise farm premises. There may be no surveillance information beyond knowing the testing required, while detection of pathogens in a laboratory report does not necessarily equate with diagnosis of disease. There is no standardised system used by all the different laboratories to collate sample and background information (data collection score 3). Similarly the provision of results is also not standardised across laboratories i.e. whether an interpretation of the test results is provided. In general, the laboratories only use the data generated to compile summaries for internal logistical and supply purposes (data analysis score 3). Identifying the number of samples from, and results for, different farms may be problematic from these summaries as a single sample from 100 farms would not be distinguished from 100 samples from the same farm, making it difficult to calculate prevalence. Submissions to laboratories is voluntary and influenced by various factors including quality, price, speed of reporting and tests offered and biases in the sample set are likely, making the dataset unlikely to be representative (score 3).

6. Retailers: A number of retailers collect health and welfare data alongside performance data from farms supplying pigs to them. They mostly collect data from their supply chain (from farm and/or slaughterhouse records), linking them with reports from BPHS and other schemes, rather than having their own active surveillance systems (data collection score 1). However, specific retailer surveillance schemes related to offal condemnations and visual inspection of carcasses were identified and retailers also inspect producers

to ensure they are meeting the agreed standards of production. Parameters specified in the 20:20 Vision, covering lameness, tail biting and tail docking, are collected from inspectors at the abattoir lairage and slaughter line, as well as factors on meat quality, including condemnations. The schemes ensure producers meet the required retailer standards and allows retailers to make management decisions when slaughter pigs are not compliant, such as to prioritise farm investigations. There is no known detailed analysis completed on the health and welfare data and currently no external access to the information (data analysis and communication scores of 3), but the results could be used to examine trends. A weakness of this source is the lack of standardisation between retailers, meaning that the analysis could only be conducted on a subset of the pig population or by assessing each retailer's information in tandem (data completeness score 3).

Summary of BPEX 20:20 Vision welfare outcome coverage

Of the welfare conditions identified by AHDB as being of importance to the pig industry, suitable useful data were only currently available for monitoring tail biting through the BPHS and FSA slaughterhouse schemes. These provide standardised protocols to detect the condition and good coverage of the pig industry, although they are biased towards healthy finisher pigs. Trends in on-farm tail damage assessed in Real Welfare inspections can help monitor the condition but underrepresent the true prevalence. Data on tail biting held by retailers, are likely to replicate information gathered by other schemes.

APHA welfare inspections and the Red Tractor/ Real Welfare schemes could provide useful baseline estimates of the prevalence of tail docking, non-compliances and information on the length of pig tails. Indeed the first Real Welfare report published provides an overall figure for the number of farms tail docking [24]. However, the APHA welfare surveillance would not provide a large enough population each year for monitoring, whereas the other schemes would be useful for monitoring but would be biased towards commercial finisher farms. Lameness detected ante-mortem, recorded by the FSA scheme, provides good coverage of slaughtered pigs. However, the incidence detected at abattoir may indicate problems with transport rather than reflect welfare standards on the farm. Real Welfare scored as excellent for coverage, data collection, completeness and correctness, sensitivity and specificity with all other factors categorised as good. Due to the use of veterinary assessors and standardised procedures, the scheme could be used to provide robust and reliable quarterly monitoring of trends of tail docking and lameness [25-26], which would allow trends to be monitored over time. However, as the scheme does not collect data on lameness in culled pigs, the results may not provide an accurate reflection of prevalence in the full pig population. Lameness incidents may be recorded in PVP reports, but accessing this information in a standardised manner from these is not currently feasible.

Teeth clipping of piglets was only recorded by the Red Tractor scheme. This could provide quarterly estimates of the use of this practice in assured commercial breeding farms only, as non-assured pig premises with breeding pigs, which includes many small holders and pedigree breeders, are not included. Red Tractor scored highly for coverage and data collection, but issues were raised over completeness and accuracy of the data. During previous assessments of Red Tractor data [27] inconsistencies and missing values in the assessments were highlighted, although recent initiatives to improve these issues meant that these factors were not scored as poor. The recording of categorised proportions of pigs with clipped teeth was introduced relatively recently and so historical data was lacking, although a binary (yes, no) response to teeth clipping had been recorded previously up to 2002.

Welfare problems related to freedom around farrowing would be included under APHA welfare surveillance, which covers all pig farms. However, the data held electronically would not identify the nature of any non-compliance. The Red Tractor scheme records the use of farrowing crates by member farms but does not record how prevalent it is on a farm or the specifics of the type and size of crate used. The schemes did not provide a suitable dataset for estimating a baseline or for monitoring of freedom around farrowing.

From our assessments, none of the schemes collected specific details on the husbandry of entire males over 80 kg. However, the 20:20 Vision objective does not indicate what parameters are considered relevant and necessary for assessment of this issue. Details of pre- and post-weaning mortality are only collected by PVP in the schemes assessed. The issues relating to PVP data have been outlined above and the provision of estimates would also be hampered by the lack of standardisation in how these mortality measurements are calculated, with some including culled pigs while others do not.

Summary of BPEX 20:20 Vision health outcome coverage

VIDA provides an accurate source of data for ongoing monitoring of temporal and regional disease trends due to *Brachyspira hyodysenteriae,* PRRSv, *M. hyopneumoniae* and APP. To provide the greatest detail, coverage and representativeness VIDA would need to be complemented by data for these diseases from PVPs or Red Tractor. VIDA data would complement those from Red Tractor as VIDA scored highly for historical data, with the system starting in 1975, but poorly for bias and representativeness. The surveillance is continuous whereas Red Tractor covers a very high proportion of commercial farms, but only assesses the farms every quarter. Red Tractor data would only record whether PRRS or swine dysentery was present and not the severity. VIDA data are currently used for monitoring the diagnostic rate, rather than prevalence of disease, and the relatively low frequency of diagnosis of some of the health conditions may limit the ability to identify significant changes over time. Data held by PHIP would have been limited by the number of holdings sharing that information within the scheme.

Mange is recorded by VIDA, PVP and PHIP, while BPHS records papular dermatitis as a proxy for mange. It is unlikely that VIDA would provide a useful estimate of mange as it is infrequently recorded. Although identifying herds with a mange problem to provide a baseline or for monitoring could be achieved through PVP and PHIP, issues with standardisation of PVP recording and access to data, and PHIP's lack of coverage and sustainability, would limit their usefulness. The findings of the review suggest that BPHS would provide the best platform for standardised monitoring of mange lesions, although severe cases are unlikely to present at slaughterhouses. A drawback is that smaller herds will be under-represented and these may have a higher incidence of mange than commercial herds, especially now that many commercial herds are free of mange [28].

The presence of *M. hyopneumoniae* (the causative agent of EP) and APP was recorded by many schemes. The BPHS slaughterhouse scheme can provide a robust estimate of prevalence for monitoring, although this would only represent member farms and healthy finisher pigs. Private laboratory and VIDA disease data would provide large 'on-farm' coverage but submissions would only be likely to be sent when the prevalence amongst the herd increased or became problematic. Analysing these datasets in tandem would provide a more effective monitoring of these conditions. PVP are likely to record EP and APP in the clients' herds but the data are not currently in an accessible or standardised form suitable for analysis. The Red Tractor scheme records farm infection status for *M. hyopneumoniae*, and although this would cover most commercial farms, quarterly updates of these statuses would not be suitable for real-time monitoring and temporal analysis. The FSA slaughterhouse inspections only record pneumonia and so could only provide a basic proxy, whereas PHIP would not have provided countrywide coverage and did not assess APP.

Ascaris suum (which results in milk spot lesions) is recorded by four schemes. PVP data would have the same issues as those described above, while VIDA diagnoses are few and do not provide a robust scheme for monitoring, leaving BPHS and FSA as the most effective sources of information. It is acknowledged that milk spot may be absent when *A. suum* worms are present and vice versa, and milk spot lesions do not always correlate with presence of *A. suum* worms in the intestine.

The collection of data on post-mortem lesions was recorded by BPHS, FSA slaughter inspections and by retailers. The BPHS scheme would be the best source of these data as the lesions identified in the 20:20 Vision were aligned to those within this scheme. The BPHS scheme was scored excellent for coverage, stability, historical data and specificity and good for bias, completeness and correctness, representativeness

and sensitivity. However, the assessments are only collected every quarter for each member meaning that analysis could only be used to compare quarters rather than assess true temporal trends. The FSA data may provide greater coverage and timeliness of data collection for the lesion conditions. Concerns over the sensitivity of FSA inspections for the monitoring of conditions and standardisation between assessors indicate that the system, as assessed at this time point, may not currently be as useful as BPHS for this purpose. This has been demonstrated in a study of the correlation of results between the two schemes [29]. The retailer data also covered the recording of carcass lesion inspections and would have good coverage from commercial farms but the lack of standardisation between retailers, and potential difficulties with accessing the data, limit the usefulness of the data. Retailer data provided the only source of data for condemned pig meat and analysing the data from the different retailers in tandem may provide a basic monitoring scheme for this factor.

Antimicrobial usage, as determined by the BPEX 20:20 Vision (mg of active ingredient/ kg of pig), was not recorded by any of the assessed data sources. The most useful proxy for this would be the use of the VMD antimicrobial sales data. However, this figure does not directly reflect use on pig farms and the denominator used (PCU) does not accurately indicate milligrams of active ingredient in kilograms of pig, as the values for a specific antibiotic used on adult sows and piglets would vary greatly. Additionally, from 2013 onwards the VMD report concentrated on reporting antibiotic sales and surveillance of resistance, ceasing reports of sales of other antimicrobials (anti-fungals, coccidiostats etc) although these data are still collected [30]. Although pig veterinary practices would record treatments sold and may include details about which pig types were treated, these data would be difficult to extract from each practice in a standardised format to provide suitable coverage. None of the schemes reported data on detection or prevalence of MRSA or *Salmonella* in pig meat.

Discussion

Selected data sources were reviewed in a standardised manner for their ability to assist with the production of baseline values and ongoing monitoring for pig health and welfare conditions determined to be of high importance by the BPEX 20:20 Vision. The appraisal of the identified data sources highlighted a range of health and welfare conditions that could be monitored effectively, but the data sources had diverse characteristics influencing their suitability. The coverage and representativeness of the datasets were key, with schemes such as PHIP suffering poor geographical coverage that would limit the ability to monitor geographical trends, whereas schemes that collected data periodically (e.g. BPHS, Red Tractor) would limit analysis of temporal trends within a year. Slaughterhouse schemes were biased towards healthy finisher pigs; VIDA and PVP reports have data from diseased pigs; while other schemes mostly collect data from finisher pigs. These differences highlight the need to analyse multiple datasets in tandem to enhance monitoring. The findings also highlight the scarcity of data sources currently collecting Vision outcomes from breeding pigs. An important concern is the lack of temporal stability and whether they will continue to be funded in their current forms. The lack of historical data present in some schemes also reduces the ability to compare between periods of data. These identified factors suggest that the use of data sources in their current form to determine national prevalence figures would be problematic, whereas monitoring trends within each data source and in tandem with other data sources is likely to be the best approach [29]. This study highlights the value of BPHS and VIDA as sources for data trend analysis from pigs at different stages of their production cycle. However, the continuation of the former is being challenged and there have been substantial changes in the surveillance network from which VIDA data is derived since 2014 [31, 32]. In addition, submissions to private laboratories and VIDA are influenced by multiple factors as described above and reductions in submissions would affect the robustness of surveillance. The description of all of the strengths and weaknesses and collation of background information for each of the schemes would be vital to interpreting the outputs from any analysis.

The review also highlighted areas where improvements could be made or where additional schemes are required. No suitable sources were found for husbandry of entire males over 80 kgs, pre and post weaning mortality, condemned pig meat, antimicrobial usage, mange, MRSA and *Salmonella* in pig meat. The launch

of the electronic Medicines Book for pigs in April 2016 has enabled collection of antimicrobial usage data direct from pig farms into the AHDB pig-hub. The requirement to enter data on a quarterly basis as part of Red Tractor standards, since October 2017, has provided good coverage of antimicrobial usage in the pig sector [33, 34]. It is now possible to make comparisons between farms, in the form of benchmarking. As more years of data are collected then robust trend analysis may be achievable, dependent on the quality of the data entered.

The review highlights that several surveillance gaps identified could be solved by access to PVP data, if it was appropriately standardised. Additionally, the development of a methodology to collect pig disease incident data from practitioners, via a mobile app, was a recommendation from a recent meeting of Government, pig industry and veterinary stakeholders to discuss syndromic surveillance in pigs [35]. Access to data from private laboratories would also complement the data held in VIDA and provide wider coverage for certain pathogens. However, gaining access to data from commercial entities like private laboratories may be problematic as shown by a previous study [36]. This was due to the commercially sensitive nature of the data plus an unwillingness to standardise data collection and recording, especially where this would not meet a business need. General threats to the use of these private schemes include: the increasing recognition that data have a commercial value whilst funding for disease monitoring is reducing; restrictive access; and limited data checking/ cleaning to ensure data quality is maintained in these schemes. Future initiatives may require incentives such as regular feedback of data for their clients or access to expertise (such as statistical analysis), which might improve data sharing. Methods have been developed for other purposes, such as SAVSNET by Liverpool University [37] and VetCompass designed by the Royal Veterinary College (https://www.rvc.ac.uk/vetcompass). These systems allow data to be collected directly from small animal vet practices and diagnostic laboratories for use in data analyses which could be amended and customised to meet the needs of livestock surveillance. The development of any similar system for livestock surveillance will face a number of fundamental challenges. Not the least of which will be the different nature of the records currently kept for livestock, which is more often focussed on business matters, such as invoicing and billing, rather than electronic health record keeping. Any such development will also require significant funding.

The data sources reported here and others in action can potentially provide estimates for other health and welfare conditions than they were originally designed. There are also further opportunities to develop the datasets for harmonisation or improved data collection. Ongoing Government surveillance schemes for Aujeszky's Disease and Trichinella could extend the coverage of the breeding pig population for monitoring schemes and could be used as a cost-efficient method for collection of samples to be tested for some of the Vision conditions that are not covered suitably elsewhere (such as *Salmonella* in pig meat or MRSA). Recent data sources, such as Real Welfare, also have the potential for monitoring trends if the schemes are sustained and are able to cover a representative population. Data on condemned pig meat could be collected direct from each slaughterhouse as this is referenced to each farm to deduct from the price paid to each producer. Improving the accuracy of welfare data in these areas will allow useful analyses, such as quantifying and determining association between, for example, tail docking, tail biting and other outcomes. These analyses could lead to more evidence-based health and welfare decisions.

The evidence indicated that the SERVAL framework provided an effective template for surveillance scheme comparison and evaluation for specific conditions but a full description of any scheme requires detailed knowledge of how it works in reality. The ability to select from a panel of attributes allowed for the key factors for surveillance to be assessed efficiently without the need to cover every aspect of the schemes. Although the scoring of each attribute was limited to just three options, this made the evaluations simpler while still making it easy to identify the strengths and gaps of each scheme. Surveillance evaluations require a standardised approach, and a defined objective, and the SERVAL framework ensures the scores were easy to compare across schemes while more detailed relevant details could be recorded elsewhere in the evaluation.

This review has provided a useful, standardised assessment of the ability to monitor health and welfare conditions that are important to the pig industry. The findings could be used to help coordinate and provide a framework for the collation and analysis of data from these schemes, and highlights areas of improvements that are required; priority being development of syndromic surveillance (collection of clinical disease incident data) and data from private laboratories testing samples from pigs. Updates to this review, using the same method to assess new data sources would be useful to track developments and encourage progress. Additionally, reviews of similar schemes from other livestock industries would also be beneficial, especially as synergies may be found.

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